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# CONTENTS OF VOLUME X.

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# NOTE REGARDING PUBLICATIONS

## OF THE

## NEW YORK ACADEMY OF SCIENCES.

Publication of the **Transactions** of the Academy is discontinued with the issue of Volume XVI, 1898. The matter heretofore printed in the Transactions will be incorporated in the Annals.

The **Annals** (8vo), beginning with Volume XVI, will appear with new forms of typography and arrangement of matter; many changes having been made in the endeavor to facilitate the use of the volume for reference purposes. A volume of the Annals will hereafter coincide with the calendar year and will be issued in three parts. The price per volume is three dollars.

The **Memoirs** in quarto form will be published at irregular intervals. Part I of Volume I has been issued.

ANNALS

OF THE

NEW YORK ACADEMY OF SCIENCES,

VOLUME X.

## I.—*The Nature and Origin of Stipules.*

BY A. A. TYLER, A.M.

Read Feb. 8, 1897.

The investigation which has resulted in the preparation of this dissertation was undertaken with a view to determine the true nature and phylogenetic origin of those appendages of the bases of the petioles of leaves which are known as stipules and which are present in so large a number of the families of flowering plants.

The data have been collected from every available source; the evidences to be gathered from known geological facts have been taken into consideration, observations have been made upon the morphology and anatomy of the foliar organs in a large number of cases, and the gradual modification of leaf-forms in the annual growth of plants from simple scales to adult leaves has been carefully studied. In addition to the data so gathered, the literature dealing with the subject, relatively scanty though it is, has yielded much valuable material both by the record given of the observations of others and by the suggestion of lines of investigation.

With all this material in hand, I have endeavored to ground the theoretical consideration of the problem upon the broadest foundation possible in the present stage of the progress of science, and from a comparative study of the evidence gathered from all the various sources of information, have drawn the conclusions set forth at the close of my paper.

The results of my investigations are herewith given to the public with the conviction that conclusions arrived at in the manner indicated cannot fail of interest to the reader, nor, in some degree at least, of scientific value.

COLUMBIA UNIVERSITY,
NEW YORK, Feb. 8, 1897.

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SYNOPSIS.



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## A Review of Important Literature Pertaining to Stipules.

Owing to the fact that a large part of the literature pertaining to stipules is inaccessible to the majority of botanical students, scattered as it is, for the most part, in the journals of various scientific bodies, it has seemed desirable to preface the consideration of the results of my research on the question of the Nature and Origin of Stipules with a brief summary, in chronological order, of the publications having reference to the general subject of stipules. I have, however, omitted mention of their consideration in systematic works and the general allusions and definitions as they occur in most general works on the Spermatophyta together with their special consideration in individual species and groups except in the most important cases.

Stipules have not received a very large degree of attention from botanists apart from their morphology as used in classification and the publications to be considered are not very numerous, but it is thought that a review of those following will be profitable and of general interest:

**Malpighi, Marcello.**—Opera omnia, 22–39. 1686.

This is one of the earliest works in which stipules are treated. A considerable number are figured and described under the name of *foliola caduca.*

**Linnæus, Carolus.**—Philosophica Botanica, 50. 1751.

A general definition is given of stipules as scales borne at the base of the petiole. Buds are spoken of as formed by stipules, by petioles, or by rudiments of leaves.

**Linnæus, Carolus.**—Prælectiones in ordines naturales plantarum, 520. 1792. (Cited by Hanstein in Abhandl. Akad. Berlin, 77. 1857.)

In speaking of the whorled leaves of the Stellatæ, Linnæus says that only two of these leaves are true leaves, the remainder are stipules which have grown to the same size as the leaves.

**De Candolle, Augustin P.**—Theorie de la Botanique, 364. 1819.

The stipule is defined as a foliaceous appendage or accessory leaf situated at the base of certain leaves. The stipel, first so named by De Candolle, is defined as a stipule placed on the common petiole at the base of the leaflets.

**De Candolle, Augustin P.**—Organographie Végétale, 1 ; 334-341. 1827.

De Candolle's views as here expressed may be outlined as follows: "Stipules do not exist in any monocotyledonous plant,* nor in any dicotyledons in which the petiole has a sheathing base; among dicotyledons with leaves not sheathing, stipules are frequently wanting, especially in plants with opposite leaves. Their existence is intimately connected with the general symmetry of plants, and they occur or are wanting in all the species of a family.

"The only essential character of stipules is their lateral position at the base of the leaves, and it is not impossible that we confound under a common name objects really distinct. Their texture is, in many plants, perfectly foliaceous and in these cases they exhibit so exactly the character of leaves that we can say that they are small accessory leaves.

"In certain verticillate leaves, such as those of *Galium*, it is noticeable that the buds and young branches are not produced in the axils of all the leaves, but only of two among them which are opposite to one another. I presume that these two leaves furnished with buds are the true leaves and that the others should be considered as foliaceous stipules.

"The natural use of stipules seems to be the protection of the leaves during their development, but we must admit that in many cases their smallness or their nature or form make them inappropriate to this use, though we cannot well assign another to them, those which are foliaceous assist in the elaboration of the sap, those which are changed into spines serve for the defense of the plant.

"The tendril in the Cucurbitaceæ is perhaps a modified stipule. The ochrea of Polygonums is a prolongation of the base of the petiole into connate stipules."

In volume 2, pages 213 and 214, De Candolle says in treating of buds, "They have received particular names according as they are formed by different parts of the foliar organs, and according to the degree of their degeneration and adnation.

"1. Buds are called foliar when, the leaves being sessile, the blade itself, reduced to the form of a scale, forms the buds, as in *Daphne mezereum* L.

"2. They are called petiolar when the bases of the petioles dila-

* See also A. Richard. Précis de Bot., 126.

ted into scales form the covering of the young shoot. This occurs in petiolate leaves without stipules, as in the walnut, ash and horse-chestnut.

"3. Buds are stipular when the scales are formed, not by the leaves, but by the stipules which are not united with the petioles. Of these there are two sorts,—those which are formed by a great number of stipules enclosing a young shoot collectively, as in oaks, willows and elms, and those in which the stipules, free or united by their exterior margins, form a peculiar envelope for each leaf, as in *Ficus* and the magnolias.

"4. When the stipules are adherent with the petiole, these two organs united into one form the bud scales, and are named fulcral. This occurs in most of the Rosaceæ, and the scales are frequently three-lobed or three-toothed, indicating the origin of the scale formed by the petiole and the two stipules united together." Plate 21, figure 9, shows the progressive change from scales to foliage-leaves in buds that are fulcral in nature.

**Bischoff, G. W.**—Lehrbuch der Botanik. 177–183. 1834.

The subject is here more fully outlined than in De Candolle's Organographie. Stipules are defined as peculiar leafy expansions at the base of a free middle leaf. They are recognized as belonging to the leaf on the ground of their frequent connection with the petiole, the receiving of their vascular bundles from those of the leaf and the absence of buds from their axils. Various kinds of stipules are described and the ochrea, the ligule, the stipule in the Naiadaceæ and the ochrea of palms are included with stipular formations.

**Lindley, John.**—Introduction to Botany, 99. 1832.

The following statement is of interest: "The exact analogy of stipules is not well made out. I am clearly of opinion that, notwithstanding the difference in their appearance, they are really accessory leaves; because they are occasionally transformed into leaves, as in *Rosa bracteata*, because they are often indistinguishable from leaves of which they obviously perform all the functions, as in *Lathyrus*, and because there are cases in which buds develop in their axilla, as in *Salix*, a property peculiar to leaves and their modifications." The character of stipules is denied to the tendril of the Cucurbitaceæ and the tendrils of *Smilax* (p. 96) are regarded as lateral branches of the petiole.

**Henry, A.**—Recherches sur les bourgeons. Nova Acta Acad. Nat. 18 : 525–540. 1836. (Cited by Clos in Bull. Soc. Bot. Fr. 26 : 193. 1879.)

Henry says that he recognizes in the Betulaceæ and Cupuliferæ that the bud-scales are formed by stipules in an anamorphosed condition, and that in *Platanus* they are formed by the ochrea as he terms the basal foliar appendage in this genus.

**Lestiboudois, Them.**—Etudes sur l'anatomie et la physiologie des vegetaux. 1840. (Cited by himself in Bull. Soc. Bot. Fr. 4 : 746–747. 1857.)

The author states that he has shown that stipules are parts of the leaf, formed by the bundles or lateral fibers of these organs, whether they arise from bundles not yet having left the stem, from anastomosing arcades which unite the leaves as in the Stellatæ, or from the fibres of the petiole, as in the adnate stipules of Rosaceæ, or whether they are in part supplied by bundles directly from the cauline cylinder, as in *Platanus*.

In relation to the tendril in the Cucurbitaceae, he states that its bundles are derived from those which pertain to the axillary bud; that it is therefore not a stipule, but the first foliar appendage of the axillary branch for its fibro-vascular bundles are not disposed like those of stems, but are analogous with those of petioles.

**St. Hilaire, Aug.**—Leçons de Botanique. 170, 1840. (Quoted by Colomb in Ann. Sci. Nat. (VII), 6 : 28. 1887.)

It is stated that the tendrils of *Smilax* are to be considered as lateral leaflets of a compound leaf.

**Agardh, J. G.**—Ueber die Nebenblätter der Pflanzen. (Reviewed by Fries and Wahlberg in Flora, 33 : 758–761. 1850.)

Agardh believes that, although stipules have been considered as degenerate appendages of the leaf or modifications of it, they are not at all a part of the leaf because they are formed before it, and must be considered as independent organs. The outer bud-scales and also the protective coverings of the earliest shoots of a plant are a kind of stipule-formation, leading to the conclusion that in the lower part of a shoot or the outer part of a bud the stipule-formation preponderates, and in the upper or inner parts, the leaf-formation, so that often at the lowest nodes the leaf does not develop and at the upper stipules are absent. In *Tussilago* there are special leafy shoots and the flowering shoots are provided with stipules only.

From these considerations Agardh concludes that there are two kinds of appendicular organs instead of one, namely stipules and leaves.

**Astaix.**—Essai sur la Théorie des stipules, thése de l'Ecole de pharmacie de Paris. 1–25. 1841. (Cited by Clos in Bull. Soc. Bot. Fr. 1 : 302. 1854.)

The conclusion is reached that the leaf is not a primitive appendage of the stipule and that the stipule is nothing more than an appendage of the leaf.

**Regel, E.**—Beobachtung über den Ursprung und Zweck der Stipeln. Linnæa, 17: 193–234. 1843.

Regel has studied the development of stipules in seedlings and in the growth of individual leaves. He believes, but does not feel ready to assert, that stipules are present in all Angiosperms in the earliest stages of growth. He therefore includes in stipular formations the ligule, ochrea, sheathing petiole and the supernumerary leaves of the Stellatæ. He concludes from his observations:

1. "That all the leafy organs of phanerogamic plants are divided into two entirely distinct formations, the stipular and leaf-formations.

2. "That the stipular formation arises from the base of the meristem tissue of the leafy axis, covering the summit, but always with a longitudinal cleft or one passing transversely across the apex.

3. "That perfect stipules are formed by the occurrence of two, four or more clefts in the original stipular sheath, giving rise to as many stipular leaflets.

4. "That the stipules receive their vascular bundles directly from the stem, and are usually parallel veined because of their forming originally a completely encircling sheath.

5. "That they serve always for the protection of the growing point and of the true leaves, when these are present, during their development.

6. "In all plants, organs adapted for protection belong not to the leaf-formation but to the stipule-formation.

7. "That stipules are to be regarded as a formation preceding the leaf-formation, since they appear before the leaves.

8. "That they belong primarily to a nodal ring distinct from that producing the leaves and situated either above or below it.

From these relations, as regards the leaf, interior and exterior stipules are distinguished.

9. "Interior stipules protect the formation of the following node and leaves. The leaf at the same node develops somewhat earlier or at about the same time.

10. "Exterior stipules develop before the leaf at the same node and therefore protect their own node with its leaf.

11. "As stipules are limited in the time during which they are functional, they lose their significance as soon as this purpose is fulfilled. They do not produce buds in their axils except in cases where true leaves are not developed."

The following statement (p. 227) should be noted. "In some species of *Thalictrum* the membrane rising above the inner margin of the base of the petiole is the analogue of the ligule."

**Kirschleger, F.**—Flora, 28 : 615. 1845.

The tendril of Cucurbitaceæ is regarded as a normal stipular formation.

**Mercklin, C. E.**—Entwicklungsgeschicte der Blattgestalten. 1846. (Translated into the French in Ann. Sci. Nat. (III), 6 : 215–246. 1846.)

The statements of Mercklin are contrary to those of Regel. He says, "In all cases the stipules of the developing leaf appear as portions of the lamina; it is only later, during the development and elongation of the petiole, that they become sufficiently separated to be considered as distinct organs. In all simple leaves the stipules never appear at the same time with the first rudiments of the lamina; they develop only with the inferior parts of the lamina including the petiole."

"From my observations of stipules I conclude that in common with the leaflets they owe their origin to the common petiole and are formed later than the leaflets."

**Krause, G.**—Einige Bemerke über den Blumenbau der Fumariaceæ und Cruciferæ. B. Cruciferæ. Bot. Zeit. 4 : 137–150. 1846.

Stipules in the Cruciferæ are considered (pp. 142–145) and the homology with stipules of the so-called glands at the base of the leaves is established by a careful series of observations upon their development. The glands of the bracts and floral organs are also included.*

*See also Duchartre, Rev. Bot. 2 : 208. 1845–7 and Norman, Quelques Observ. de Morph. Veg. 1857.

**Jussieu, Adrien.**—Cours d'Histoire Naturelle: Botanique. 108–111. 1852.

Speaking of the leaf-sheath, Jussieu says that "sometimes the vascular bundles converge little by little, and there is a gradual transition from the sheath to the petiole; sometimes the marginal bundles stop after a course varying in length, or are prolonged in another plane than that of the petiole, and then there is a clear distinction of petiole and sheath. Often, however, the parenchyma does not unite the lateral bundles to the central ones which continue in the petiole, and this is the probable origin of many stipules."

**Trécul, A.**—Sur la Formation des Feuilles. Ann. Sci. Nat. (III), 20: 288–299. 1853.

The usual classification of stipules is given with the addition of extra-foliar stipules to include those of *Nelumbium*. The author says, "In all adnate stipules that I have seen, they do not envelop the leaf to which they belong, but that which comes next after them, and their own leaf is protected by the stipules of the leaf preceding. Under these circumstances the stipules play the same rôle as the sheath, from which they differ very little. We see thus clearly that there is the closest analogy between the formation of adnate stipules and that of a sheath; the analogy is such that it is impossible to distinguish between them in principle." All the forms of stipules, the ochrea, the tendrils of *Smilax* and the ligule of grasses are classed together.

Among the conclusions those relating to stipules are as follows: In basifugal leaf-formation all the parts are formed from below upward, the stipules first of all. In leaves with basipetal formation, the stipules have their origin earlier than the lower parts of the blade and sometimes even before the upper.

**Trécul, A.**—Vegetation du Nelumbium codophyllum. Ann. Sci. Nat. (IV), 1: 291–298. 1854.

In the seedling of this plant the leaves are in two ranks on the upper and lower sides of the rhizome and each of them is provided with an axillary stipule. In its later stages the leaves of the lower rank are aborted with the exception of the stipule of every second one and in the upper rank every second leaf is represented by the stipule only. The internodes above the stipules which stand alone remain undeveloped so that three stipules are associated with each leaf, one axillary and two extra-axillary.

One of these last is on the upper side of the rhizome external to the leaf, the other on the lower side.

This paper was presented before the Botanical Society of France, May 24, 1854. M. Ad. Brongniart took part in the discussion which followed. He agreed with Trécul in his conclusions and closed with the statement that "this arrangement recalls that of certain buds in which the scales result from the stipules of leaves of which the petiole and blade are alike aborted." M. F. J. Lestiboudois remarked that "to decide whether stipules are an integral part of the leaf, it is necessary to study them anatomically. In other plants the same fibro-vascular bundles are distributed to the leaf and stipules. Stipules should therefore be regarded as appendages of the leaf."

**Clos, D.**—Considerations sur la Nature du prétendu Calicule ou involucre des Malvacées. Bull. Soc. Bot. Fr. 1: 289–303. 1854.

The stipular nature of the parts of the involucre or exterior calyx in the Malvaceæ is asserted contrary to the views of Aug. St. Hilaire (Leçons de Bot. 372. 1840) and the term *stipulium* is suggested as applicable to it.

**Clos, D.**—Du Stipulium chez les Géraniacées, les Légumeneuses et les Rosacées. Bull. Soc. Bot. Fr. 2: 4. 1855.

The term *stipulium* is applied to the exterior calyx of the Malvaceæ and the involucre of the umbel of some Geraniaceæ. In the Cistaceæ the bractlets of the calyx are wanting in exstipulate species.* In many of the Leguminosæ and Rosaceæ the bracts are evidently formed by stipules.

**Clos, D.**—La Vrille des Cucurbitacées, Organe de Dédoublement de la Feuille. Bull. Soc. Bot. Fr. 3: 545–548. 1856.

The different theories regarding the tendril in the Cucurbitaceæ are briefly stated. They have been considered to be roots; abortive peduncles by Tassi; stipules by De Candolle, Stoks and Aug. St. Hilaire; leaves by Gasparini, Seringe and Braun; degenerate branches by Meneghini; superfluous branches by Link; terminal branches of the axis as in Vitaceæ by Fabre; partly leaf, partly branch by Naudin. Clos concludes that the tendril arises by a division of the leaf, three fibrovascular bundles entering the leaf when there is no tendril and two when the tendril is present and receives the third bundle.

* See also Aug. St. Hilaire. Leçons de Bot. 326 and 371. 1840.

**Clos, D.**—Les Vrilles des Smilax ni Folioles ni Stipules. Bull. Soc. Bot. Fr. 4: 984–987. 1857.

A summary is given of the literature pertaining to the tendrils of *Smilax*. They are considered as representing two lateral leaflets of a compound leaf by von Mohl (Ueber den Bau und das Winden der Rauken und Schlingpflanzen, 41, 1827), Lindley (Introd. to Botany, Ed. 2, 118, 1835), Link (Elem. Phil. Bot. Ed. 2, 1 : 478, 1837), St. Hilaire (Leçons de Bot. 170 and 854, 1840), Le Maout (Atlas de Bot. 23, 1846) and Duchartre (Art. vrille in Dict. Univ. Hist. Nat.).

Mirbel (Élém. de Physiol. et de Bot., 2: 680, 1815), Treviranus (Physiol. der Gewachse. 2: 138, 1838), Seringe (Élém. de Bot. 175, 1841), De Candolle (Theorie Élément. Ed. 3, 321, 1844), Trècul (Ann. Sci. Nat. (III), 20: 295, 1854) and Lestiboudois (Bull. Soc. Bot. Fr. 4: 745, 1857), believe these organs to be stipular tendrils. It is the opinion of Clos that they are neither leaflets nor stipules, but a double lateral prolongation of the cellulo-vascular elements of the petiole.

**Rossman, J.**—Beiträge zur Kentniss der Phyllomorphose. 1857. (Cited by Clos in Bull. Soc. Bot. Fr. 26: 192. 1879.)

Rossman considers the problem of the nature of stipules, and from a study of bud-scales arrived at his conclusions. He figures the passage from bud-scales to leaves in *Ribes sanguineum* Pursh, *Prunus Padus* L., *Spiræa sorbifolia* L., etc. He notes the presence in the bud-scales of three median veins, separated at the base and joining one another at the apex, where the petiole will originate. The lateral parts of the scale outside of these three nerves he believes to represent the stipules which show themselves at the appearance of the blade in two little points at the apex.

**Hanstein, J.**—Ueber gürtleformige Gefässstrang-Verbindung in Stengleknoten dicotyler Gewächse. Abhandl. der Akademie der Wissenschaften zu Berlin, 1857 : 77–98. 1858.

The vascular nodal girdle of the Stellatæ is treated of at length. It is shown that from this girdle arise the bundles that supply those leaves of the whorl which are really stipules, and in some cases also the veins of the lateral parts of the true leaves. Similar nodal girdles are shown to exist in other families of plants, notably in *Sambucus*, *Valeriana*, *Verbena*, *Dipsacus*, *Scabiosa*, *Dahlia* and *Silphium*. In *Sambucus Ebulus* L. the girdle sends off vascular branches to true stipules. In the majority of other cases if branches arise they enter the margins of the petioles or the interfoliar portions of connate leaves. In *Platanus* and *Liriodendron* with alternate leaves, each of which receives seven vascular bundles, a similar girdle is shown to pass around the stem posterior to the leaf, and is there joined by another small leaf-trace bundle. From this girdle arise a part of the stipular veins, the others being branches of the sixth and seventh leaf-trace bundles.

**Clos, D.**—Sépales Stipulaires. Bull. Soc. Bot. Fr. 6: 580–589. 1859.

It is argued from the similarity of the sepals to the divisions of the involucre (stipulium) and also to the stipules of the fully developed foliage leaves which is frequently observed, that they represent stipules. This is held to be true in many Geraniaceæ, Malvaceæ, Begoniaceæ and Cistaceæ. In concluding Clos adds the theoretical consideration that "whether or not stipules are admitted to be organs different from the leaf, analogy seems to demand that in some cases at least they should participate in some degree in floral formation."

**Cosson, E.**—Note sur la Stipule et la Préfeuille dans le Genre Potamogeton. Bull. Soc. Bot. Fr. 7: 715–720. 1860.

"The stipule in *Potamogeton* is very closely like the first leaf of one of the branches. It is homologous with the ligule of the Gramineæ and Cyperaceæ and is constituted by a single organ, not by two united by their margins."

**Eichler, A. W.**—Zur Entwicklungsgeschichte des Blattes. 22–31, 1861 (Cited by Martin Franke in Bot. Zeit. 54 : 45, 1896.)

Stipules are said to arise without exception as a product of the leaf base of the primordial leaf. This mode of origin of the stipules is their chief characteristic. Their form, their more or less foliaceous condition and their persistence are secondary.

In individual leaf development in the Stellatæ, the whorl originates in a uniform ring about the growing point. Then arise two opposite prominences in the ring. These develop into the true leaves. After them appear two smaller prominences on each side of the stem between the first. These are the stipules. According to the species they develop separately, forming six-leaved whorls, or grow together giving origin to four-leaved whorls.*

*With this view Göbel agrees (Schenk's Handbuch der Botanik 3 : 230. 1884), except that he does not distinguish the time of appearance of the different parts of the whorl.

Where a larger number of leaves occurs, an additional prominence for each arises between the original stipular prominences.*

**Cauvet, D.**—Probabilité de la Presence des Stipules dans quelques Monocotyedones. Bull. Soc. Bot. Fr. 12 : 241. 1865.

A number of cases are considered and the conclusion drawn that very probably some Monocotyledones are provided with stipules, but the difference in their form and position has caused them to be considered as another kind of organ.

**Meehan, Thomas.**—On the Stipules of Magnolia and Liriodendron. Proc. Acad. Nat. Sci. Phila. 114–116. 1870.

Mr. Meehan argues for the origin of the stipules of *Magnolia* as lobes of the lamina similar to the auricles which occur in *M. Fraseri* Walt. by a union of the auricles with the upper surface of the petiole, and a subsequent adnation of their margins and separation from the lamina. He says, "It is scarcely possible to avoid the suspicion that the stipules of *Magnolia* are not formed like the stipules of most plants which are perhaps leaf portions which have never been well developed, but rather are the tolerably well developed side pinnules of a trifoliate or deeply auricled leaf."

Speaking of observations upon the flowers of *M. fuscata* Andr., of East India, the following interesting statement is made : "This observation confirms the views of some botanists as I have learned from Professor Asa Gray, that it is by metamorphosis of the petiolar and stipular parts, rather than by modifications of the leaf-blade, that petals are formed."

**Duval-Jouve, J.**—Sur quelques tissues de Joncées, etc. Bull. Soc. Bot. Fr. 18 : 231–239. 1871.

The presence of the ligule in the Juncaceæ is treated of. To quote the author, "If in certain species the ligule is so reduced that it appears to be lacking between the separated auricles at the apex of the sheath, in most others these auricles are united by a true ligule, as pronounced as that of grasses, either entire or cleft at the middle."

**Dutaily, G.**—Sur les variations de structure de la ligule des Graminées. Bull. de la Soc. Linnéene, 170. 1878.

*F. Pax (Allgemeine Morph. der Pflanzen, 100. 1890) says, when there are more than six parts to the whorl, the additional parts must have their origin in a division of the blades of the stipules.

It is argued from the presence of a median vein in the ligule of some of the grasses in which this organ is supplied with vascular support that it cannot be formed of two stipules grown together.

**Hilburg, C.**—Dissertation über den Bau und die Function der Nebenblätter. (Reviewed by F. Hildebrand in Flora, (II), 36 : 161–167. 1878.)

The general neglect of the subject of stipules and the timeliness of this dissertation is referred to by the reviewer.

The functions of stipules as protecting organs are discussed. They are considered under the heads of (1) those protecting the buds in winter, (2) those protecting the growing parts in the spring, (3) those which serve as protection against insects and other animals, (4) those which serve as well the function of assimilation.

The adaptation of most stipules in their form and manner of growth to the special function they are intended to fulfill and the apparent lack of function in others is remarked upon.

**Clos, D.**—Des Stipules et de leur rôle à l'infloresence et dans la Fleur. Mem. Acad. Sci. Toulouse, (VII), 10: 201–317. 1878.

This paper is the first part of an extended consideration of the subject of stipules. It deals with their occurrence in the families of plants and their importance in classification on account of the great variety of their characteristics.

**Clos, D.**—De la part des Stipules a l'infloresence et dans la Fleur. Comptes Rendus, 87: 305–306. 1878.

The stipular nature of the sepals in *Geranium*, *Helianthemum*, *Begonia*, *Oxalis*, *Alchimilla*, *Viola* and many other genera in different families is maintained.

**Dixon, Alex.**—On the stipules of *Spergularia marina*. Journal of Botany (Trimen), 7: 316. 1878.

Attention is called to the anomalous connation of the stipules of *Spergularia marina* Griseb. exterior to the petioles of the opposite leaves.

**Clos, D.**—Des Stipules considérées au point de vue morphologique. Bull. Soc. Bot. Fr. 26: 151–155. 1879.

Under this title a summary of the opinions of botanical authorities as to the true nature of stipules is given and the different theories are briefly discussed.

Various leaves have been considered as stipules, for example the primary leaves of *Asparagus* (Dutrochet), the first leaves of the branches of *Verbena aphylla* Gill & Hook. (Hooker, Bot. Misc. 1: 116. 1830) and of the Piperaceæ ( C. DeCandolle, Mém. sur les Piper. 18–19, 1866), and the first two leaves of the axillary buds of many Solanaceæ.

The appendages sometimes accompanying the leaf in some Convolvulaceæ, as *Ipomea stipulacea* Sweet., have been considered as stipules (Jacquin. Pl. Hort. Schoenbr. Descr. et Ic. 2: 39. 1797).

Many have regarded stipules as leaflets, as for example in *Vibernum* (Baillon, Adans. 1: 372. 1860), and the lower leaflets in many plants have been taken for stipules, as in *Cobœa scandens* Cav. (Blume. Rumphia 3 : 142. 1837), and *Lotus tetraphyllus* Murr. (Linnæus, Trinius, E. Meyer, Fischer.)

In 1844 Wydler declared that stipules belong to the sheath and cites examples of transition between the two kinds of organs in the Rosaceæ, Polygonaceæ, Leguminosæ, etc. Stipules, in connection with the sheath have been ascribed to *Ranunculus*, *Isopyrum* and *Thalictrum* by Lloyd (Fl. de l'Ouest de Fr. Ed. 2, 1868), to *Caltha* by Wydler, Kützing (Grundz. der phil. Bot. 684, 1851–52) and Hooker. They have been recognized in the scales of the stems of the Aroids.

The so-called " decurrences " of leaves do not differ anatomically from stipules and are to be considered as identical with them, as for example in *Crotalaria*.

The tendril of the Cucurbitaceæ has been regarded as a stipule by Seringe (Mém. Soc. Hist. Nat. Genèv. 3 : 1–31. 1825), De Candolle (Organ. Veg. 1 : 336. 1827), Kirschleger (Flora, 28 : 615. 1845), Stoks (Ann. Nat. Hist. 1846), Payer (Elém. de Bot. 53. 1857–58), Parlatore, etc. Those of *Smilax* have been so considered by Cauvet (Bull. Soc. Bot. Fr. 12 : 241. 1865), but are looked on by Clos as " simple prolongations of the fibro-vascular bundles of the petiole without morphological signification."

The spines of the orange are considered as stipules by Du Petit-Thouars (Cours de Phytol. 47. 1820). Clos regards them as branches and those of *Amaranthus spinosus* L. as leaves, though they are considered stipular by Lamarck (Encyc. Meth. 2 : 118. 1786). *Ribes* shows stipular spines in some species. The spines of *Xanthium spinosum* L. mentioned by Sachs as occupying the place of stipules, Clos regards as representing pistillate flowers. He looks with disfavor on the doctrine that the glands at the base of the leaves in Resedaceæ, Cruciferæ, *Epilobium*, *Lyth-*

*rum* and some Euphorbiaceæ and Balsaminaceæ as well as the axillary hairs in some Portulacaceæ are stipules.

**Clos, D.**—Indépendance, developpement, anomalies des stipules; Bourgeons a écailles stipulaires. Bull. Soc. Bot. Fr. 26: 189–193. 1879.

Stipules have been regarded as appendages of the leaf by Du Petit-Thouars (Cours de Phytol. 46, 1820), Aug. St. Hilaire (Leçons de Bot. 189, 1840), G. St. Pierre and F. J. Lestiboudois.

Clos agrees with Agardh in considering stipules as independent organs, giving as his reason that frequently in the Rosaceæ, Leguminosæ, Malvaceæ, Geraniaceæ, etc., the stipules persist alone, the leaves having completely disappeared, whether in the infloresence or at the base of stems and branches.

Under the head of the development of stipules the conflicting opinions of Mercklin and Trécul as to their time of appearance in relation to that of the leaf-blade is referred to. Agreement with Trécul is indicated and the evidence is not considered sufficient as a basis for the theory of the autonomy of stipules on the ground that they appear before the leaf-blade.

In consideration of stipular bud-scales reference is made to their recognition by Linnæus (Phil. Bot. Ed. 3, 52. 1790), Adanson (Familles des Pl. 246, 1763), De Candolle (Ann. Sci. Nat. (III), 5: 321, 1846)* and Lindley (Veg. Kingdom, 283, 1846).

**Göbel, K.**—Beiträge zur Morphologie und Physiologie des Blattes. Pt. I. Die Niederblätter. Bot. Zeit. 38: 753, etc.—845. 1880.

This extended treatise deals with bud-scales and the scales of subterranean parts of plants and their homologies with leaves. Speaking of the primordial leaf Göbel says, "it is divided into two parts, a stationary zone which takes no farther part in the leaf-formation and a part out of which the lamina is developed." He calls these parts respectively the leaf-base and upper-leaf and states that the petiole arises after the formation of the blade and is inserted between the two parts.

Bud-scales are regarded as modified foliage-leaves and divided into those formed from the blade (*Syringa*), those formed by the leaf-base (*Æsculus*, *Prunus*), and those consisting of stipules (*Liriodendron*, *Quercus*). In *Prunus*, etc., the formation of the bud-scales by the union of petiole and stipules is denied on the ground that the continuous separate development of the petiole and stipules can be followed.

* See also Org. Veg. 2: 213. 1827.

The scales of rhizomes are divided into those formed by a development of the leaf-base (*Dentaria*, *Chrysosplenium*) and those formed by a modification of the upper-leaf (Labiatæ, Onagraceæ).

**Colomb, G.**—Note sur l'ochrea des Polygonées. Bull. Soc. Bot. Fr. 33: 506–507, 1886.

"The ochrea of the Polygonums is a complex organ formed of two parts: one opposite the leaf, the leaf-sheath, the other in its axil and detached from the petiole. This is a ligule." "Practically the same conditions prevail in the Gramineæ as in *Polygonum* with the difference that in the former the sheath proper is greatly developed and little prolonged beyond the insertion of the blade, while in the latter, the sheath proper remains short and is much prolonged above the petiole. By union with the ligule it forms an ochrea. So considered the ochrea is not peculiar to the Polygonaceæ. It is found also in *Ficus* and *Magnolia*, establishing the transition between the ochrea and stipules properly so called.

**Vuillemin, P.**—Apropos d'une recent communication de M. Colomb. Bull. Soc. Bot. Fr. 34: 141–142. 1887.

Commenting on the preceding paper, the author says that the leaf is primitively unifasciculate. The concrescence of a verticil of elementary leaves, such as occurs in the fossil *Asterophyllites*, gave a sheath analogous to that of *Equisetum;* the bundle of one of these elementary leaves becoming predominant and functioning as a midvein gave rise to an aggregate leaf, the first stage of a high differentiation. In this way the origin of the leaf-blade in *Polygonum*, *Platanus*, etc. is explained, while the ochrea, the homologue of the sheath of *Equisetum*, remains as a vestige of the primordial state.

**Kronfeld, M.**—Ueber die Beziehung der Nebenblätter zu ihrem Hauptblatte. Verhand. der Kais.-Konig. Zool.-Bot. Gesellschaft Wien. 37. Abhandl. 69–79. 1887.

The author has made investigations experimenting upon a large number of plants, by the removal of the lamina of the leaves at the earliest possible stage of development, in order to observe the effect upon the development of the stipules and so determine their physiological relation to the leaf-blade. Only in exceptional cases was the ultimate size of the stipules increased, and those where the stipules were normally foliaceous.

**Colomb, G.**—Recherches sur les stipules. Ann. Sci. Nat. (VII), 6 : 1–76. 1887.

This paper is the result of an exhaustive anatomical study of stipules and their homologues. The results obtained are of great interest and value. They are admirably summed up at the close of the paper as follows :

"When a leaf is sheathing, the sheath may be prolonged in a ligule situated above the point of insertion of the blade upon the sheath.

"In this organ three regions may be recognized :

"1. The lateral regions into which the marginal bundles of the sheath are merely prolonged. These regions naturally do not exist if all the bundles of the sheath enter into the leaf.

"2. The stipular regions, the bundles of which arise from a doubling of the last bundle of the sheath entering into the leaf.

"3. The axillary region, which unites the two stipular regions, a lamina, usually of parenchyma, but which may receive bundles arising from the internal doubling of those bundles of the sheath which become petiolar.

"The sheath may be reduced even to complete disappearance without a consequent disappearance of the ligule.

"1. If the ligule is complete with its three regions, I give it the name of an axillary ligule.

"2. If the stipular and axillary regions only persist, the sheathing regions having disappeared, we have an axillary stipule.

"3. If finally the axillary region divides into two halves, right and left (which would not be remarkable, considering its purely parenchymatous nature), the stipular regions exist alone at the base of the petiole, and we have then stipules properly so-called.

"Stipules and the ligule are then organs of the same nature, between which it is possible to find all forms of intergradation, the stipule being a portion of the axillary ligule.

"When, finally, the manner of origin of the bundles of the stipule is studied, we arrive at the following definition of the organ: An appendage inserted on the stem, at the base of the leaf, all the bundles of which arise exclusively from the corresponding foliar bundles."

Each of the tendrils of a leaf of *Smilax* is characterized as a demi-ligule, the "stipule" of *Potamogeton* as a ligule identical with that of grasses, the ochrea of *Polygonum* and *Platanus* as axillary stipules, the stipules of *Ficus elastica* Roxb. and *Magnolia grandiflora* L. as axillary ligules.

**Ward, L. F.**—The Paleontologic History of the Genus Platanus. Proc. U. S. Nat. Mus. 11: 39–42. 1888.

Professor Ward says (p. 41) in speaking of the fossil leaves of *Platanus basilobata* Ward, of the Yellowstone valley, that some of those found had "a remarkable expansion at the base of the blade, projecting backward on the leaf-stalk and having two to five lobes or points.

"These expansions are to be interpreted as evidence that the leaves all belong to *Platanus* or to some extinct ancestral type of the genus, since something quite analagous to them is found in our American plane-tree. The ordinary leaves of this tree are, it is true, destitute of basilar expansions, but those on young shoots, and sometimes those on the lower or non-fruit-bearing branches of trees exhibit this peculiarity.

"In place of this backward expansion of the blade many sycamore leaves have an appendage similar in shape at the base of the leaf-stalk, as though the once basilar appendage had been separated from the blade and crowded down the petiole to its point of insertion." This is shown in a short-petioled, wedge-shaped leaf from a young shoot of *Platanus* corresponding to the fossil form of *Platanus appendiculata* Lesq. from the auriferous gravels of California. The indication is that "the constriction seen in the fossil forms between the blade of the leaf and the appendage would seem to represent the beginning of this process of detachment."

**Ward, L. F.**—Origin of the Plane-Trees. Am. Nat. 24: 797–810. 1890.

The same cases as those in the preceding paper are discussed, the appendages in *Platanus appendiculata* Lesq. being described as stipular, while those of *P. nobilis* Newb. and *P. basilobata* Ward are not so considered.

**Lubbock, Sir John.**—On Stipules, their Form and Function. Jour. Linn. Soc. Lond. 28: 217–243. 1890.

"The primary function of stipules seems to be to protect the bud. In other species, however, they serve as accessory or deputy leaves. Their protective function is confirmed by the fact of their early fall. Some are more persistent than the leaves and protect the leaves of the following year.

"When stipules are present [in *Helianthemum*] the petiole is always very narrow, semiterete, and tapered to the base. Where they are absent the leaf is often sessile and, whether or not, its base is always dilated and concave on the inner face, completely enclosing the bud up to a certain stage of its development."

The presence of stipules in the lower imperfect leaves of *Ailanthus glandulosa* Desf. is noticed, though the family of the Simarubiaceæ has been described as exstipulate. In *Ribes sanguineum* Pursh. the bud-scales are described as consisting of the dilated base of the petiole, the lamina being represented by a small black point. "One or two succeeding leaves bear a small lamina sessile on the sheath, which is wholly adnate to the thin dilated base of the petiole and membranous, especially outside of the three vascular bundles. The next one or two have a well-developed lamina, and the sheaths partly separated from the petiole and corresponding to stipules. Farther up the stipular sheaths are shorter and wholly adnate to the petiole."

The form and function of the stipules in a large number of species are described.

**Lesquereux, L.**—U. S. Geol. Surv., Monog. No. 117: Geology of the Dakota Group. 1892.

Well-developed stipules of a species of *Betulites* from Kansas are described (p. 65) as having been found in their original connection with the leaf, and the discovery of leaves of a *Cratægus* with large undoubted stipules, from the Devonian of Wyoming is mentioned (p. 254). Speaking of a leaf of *Aspidiophyllum* (p. 232), Professor Lesquereux says, "the basilar appendage or pelta is like a primordial form of stipules, as in *Platanus basilobata* Ward of the Laramie group of Wyoming, *P. appendiculata* Lesq. of the auriferous gravels of California and definitively in *P. occidentalis* L. of the living flora."

**Henslow, Rev. George.**—On a Theoretical Origin of Endogens from Exogens. Jour. Linn. Soc. Lond. 29: 485–528. 1893.

The absence of vascular bundles in certain stipules is noted (p. 494).

**Hollick, Arthur.**—Wing-like Appendages on the Petioles of *Liriophyllum populoides* Lesq. and *Liriodendron alatum* Newb. Bull. Torr. Bot. Club, 21: 467–471. 1894.

These peculiar wing-like appendages are described and figured. Their similarity to the appendages in fossil species of *Platanus* as described by Professors Lesquereux and Ward is mentioned, and the probability suggested that we have here an explanation of the origin of the stipules of *Liriodendron Tulipifera* L. in the same manner as that indicated for those of *Platanus occidentalis* L. by Professor Ward. The presence of an unwinged portion of the petiole next to the blade in what is evidently the mature form of the leaves of *Liriophyllum*, and its absence in the immature ones is mentioned as tending to confirm the theory.

In commenting on this paper, the *Botanical Gazette* (19 : 515, 1894) says, "The phyllopodium is to be regarded as an axis which has a tendency to develop wing-like appendages at any portion, notably, of course, in the epipodium. If stipules are branches of the hypopodium their origin has simply to do with the branching of that part of the phyllopodium, without any reference to the method of winging found in other regions."

**Lubbock, Sir John.**—On Stipules, their Form and Function. Pt. II. Jour. Linn. Soc. Lond. 30 : 463–532. 1894.

This paper is a continuation of the author's former publication. The presence of stipels in *Sambucus Ebulus* L. is noticed. The membranous protective margins of the sheath in *Thalictrum aquilegifolium* L. and the "membranous stipular processes at each trifurcation of the lamina" are mentioned, the latter "appearing to differ somewhat in their origin from the primary sheath." In treating of *Ranunculus aquatilus* L., the author says, "The terminal bud is enclosed by the stipules of the two uppermost expanded leaves. The developing leaves push their way out at the apex of the stipular sheath. Similarity of conditions have therefore developed in the aquatic Ranunculaceæ, an arrangement very similar to that of the Potamogetons."

The following remarks are of particular interest: "In *Magnolia glauca* L. the winter bud is covered by a pair of connate stipules adnate to a petiole that is less than half their length. Succeeding leaves are perfect, and the stipules are two or three times as long as the petiole, the free portions being connate by both edges, like a candle extinguisher, over the bud, so that the leaf appears to spring from the back. As they are adnate to the petiole, there is some reason to assume that the stipules once formed a sheath pure and simple to the leaf of some ancestral form."

**Franke, Martin.**—Berträge Zur Morphologie und Entwicklungsgeschichte der Stellaten. Bot. Zeit., 54: 33–60. 1896.

In the part of this paper which treats of the development of the leaf-whorl the author agrees with Eichler that the stipules originate later than the principal leaves. But he says that in the species having four-leaved whorls never more than four prominences arise to develop into the parts of the whorl, and that if the parts number six or more, there is a distinct prominence for each. In the last case the supernumerary stipules first make their appearance in the course of development of the whorl a little later than the first pair of stipules.

**Hollick, Arthur.**—Appendages to the Petioles of Liriodendra. Bull. Torr. Bot. Club, 23: 249. 1896.

The author, referring to his former paper, describes and figures some abnormal leaves of *Liriodendron* collected from saplings, seedlings and new shoots from old stumps. One in particular of these leaves is of interest on account of its similarity to the fossil leaves of *Liriophyllum populoides* Lesq. both in the form of the lamina and especially in having a short petiole with broadly winged margins which extend from the base of the petiole and connect with the base of the leaf-blade.

The question is put whether in this case we have "stipules adnate to the petiole and leaf-blade, or portions of the leaf-blade which are acting the part of stipular appendages."

Such, in brief, is the import of what has been written on the subject of stipules, so far as I have been able to learn. The results of my own observations are not at variance to any very considerable degree with the opinions of most of the botanists who have studied the subject carefully, as will appear from the following exposition of my investigations and the conclusions at which I have arrived. To these I shall pass at once, deeming unnecessary farther comment on previous writings, except such as the statement of my results may imply.

## The Nature and Origin of Stipules.

Though it is not part of the purpose of this paper to discuss the problem of the phylogeny of the plant world, it is nevertheless necessary in order to define our field of inquiry to make a brief statement concerning the probable relationship of the higher forms, namely of those in which foliar organs are developed, including in the widest interpretation the Characeæ, Bryophyta, Pteridophyta and Spermatophyta.

As, in the Characeæ and Bryophyta, the plant body represents the gametophyte stage of development, there can be no homology of the leaves of these plants with those of the Pteridophyta and Spermatophyta in which the plant body is the sporophyte. For this reason the so-called stipules of the Charas, together with the basal lobes or saclike and straplike appendages of the leaves of many Hepaticæ need not be taken into consideration.

Accepting the general theory of evolution in nature, we must admit that the origin of all the higher plants is algal, but just what the relationship of the Pteridophyta to the Spermatophyta may be is still an open question. The same is true in greater or less degree of the affinity of the Monocotyledones, Dicotyledones and Gymnospermæ in the latter group.

This question of relationship is of considerable importance in connection with the problem before us as determining the homology of the foliar appendages in the several groups. The evidence in support of the doctrine of the common origin of all the Angiospermæ is particularly strong and may be considered as conclusive. But the relationship of the Gymnospermæ to the Angiospermæ is more remote, and that of the Pteridophyta still more so-and, though there are many points of resemblance, the similar characters may be cases of parallel development rather than indications of a common origin. It is my present opinion, however, that the Gymnospermæ sprang from some generalized hetero, sporous Pteridophyte,* that the early Angiospermæ were differentiated from related forms, and that therefore, the foliar organs in the three groups may be considered as homologous. But this homology can apply to the leaves of Pteridophytes in a very general way only, namely, to such undifferentiated forms of leaves as the ancestors which gave rise to the early Gymnospermæ and Angiospermæ may be supposed to have had. While, therefore, the foliar organs in the three classes are to be considered homologous in their origin, they cannot be so considered in their differentiation and the evolution of leaf-forms in the Pteridophyta and Gymnospermæ, though analogous in many points to their evolution among the Angiospermæ, should be regarded as independent. We may then consider the "stipule" of the Ophio-

* See Campbell, Mosses and Ferns, 300. 1895.

glossaceæ, Marrattiaceae and Osmundaceæ and the "ligule" of *Selaginella* and *Isoetes* as special developments and as properly placed in a separate category from the appendages bearing these names among the Angiospermæ. The Gymnospermæ present nothing to represent either stipule or ligule and we have left for our special consideration the ligule, stipule and their homologues as they occur in the various groups of the Angiospermæ only.

Having thus defined our field, we should have, for the consideration of the problem before us, some conception of what sort of plant the earliest Angiosperm was. In the absence of geological evidence this conception must be purely hypothetical and, basing it on a generalization which would admit of the differentiation from it of all the varied forms of the modern group of Angiosperms, we can see that it must have been a plant of very simple organization indeed. For our present purpose we need not concern ourselves with any other organs of this primitive Angiosperm than the leaves which, from the point of view of the proposed generalization, must be conceived of as hardly more than the bare rudiments of leaves, mere sheathing scales at the nodes of the plant, serving slightly, if at all, the function of assimilation which was still subserved, as in its ancestors, by the general surface of the plant, but confined chiefly to that of protection. The primitive leaf was probably parallel-veined or approximately so, giving rise in its earlier differentiation to the parallel-veined leaves of the Monocotyledones. The geological evidence indicates that these appeared before the Dicotyledones* which must have sprung from them later at one or more unknown points, and netted-veined leaves are of a more recent evolution. Consequently the tendency of aquatic Dicotyledones to revert toward monocotyledonous structure is rather a case of atavistic degeneration than an indication of the origin of Monocotyledones from Dicotyledones in ancient times through the effects of aquatic habit.†

Now, as advance in evolution proceeded, the need of greater assimilative capacity arose and, as the foliar organ was the one best

* Professor L. F. Ward. Sketch of Paleobotany. Fifth Ann. Rep. U. S. Geol. Surv. 448, 1885. Professor A. C. Seward, on the contrary, does not believe that we have satisfactory evidence of pre-Cretaceous Monocotyledones. Notes on the Geologic History of Monocotyledones. Annals of Botany, 10: 220. 1896.

† See Rev. George Henslow. Jour. Linn. Soc. Lond. 29: 485–528. 1893.

adapted for specialization in this direction, it was the one upon which the office devolved. Every botanist knows what an endless variety of forms and special adaptations of particular foliar parts have arisen in the course of evolution which was inaugurated when this setting aside of the leaf to bear in future the weight of the assimilative function took place, or rather when this additional function was placed upon it, for the old protective function has always been retained, though it has become less noticeable as the new function has overshadowed the old.

There has been in the line of vegetable descent a progressive development of the foliar organ, and a history of this development, together with that of other organs, if it were obtainable, would give us a complete phylogeny of the flowering plants, and leave no morphological problem unsolved,* but as the geological record is very incomplete, and we have in the lower Cretaceous an already well developed and much differentiated angiospermous flora of the earlier history of which almost nothing is known, we must seek other sources of information in determining the homologies of parts. At this juncture we may safely follow the example of the zoölogists and turn to embryology for the evidence which geology, as yet, refuses to give except in fragments Among animals, as the phylogeny and ontogeny are found to parallel one another, so we may feel confident they will be found to do among plants when the geological record shall be more completely unearthed.

It has become a well established part of the theory of evolution that each individual organism epitomizes more or less fully in its development the historical steps in the evolution of the type to which it belongs.† By the application of this law of re-

* "On this same view of descent with modification most of the facts in morphology become intelligible, whether we look to the same pattern displayed by the different species of the same class in their homologous organs, to whatever purpose applied, or to the serial and lateral homologies in each individual animal and plant." *Charles Darwin*, Origin of Species, 1859. Am. Ed. 6, 2. 264. 1889. See also p. 239, *et seq.*

† This theory, known as Von Baer's law, was promulgated by that scientist in his Ueber Entwicklungsgeschichte der Thiere, 224. 1828–37.

See also F. M. Balfour. Comparative Embryology. Ed. 2, 1: 2. 1885.

Opposed to this law is Adam Sedgewick. On the Law of Development commonly known as Von Baer's Law. Quar. Jour. Mic. Soc. (II), 36: 35. 1894.

capitulation to the development of plants we may arrive at valuable and trustworthy conclusions. The question would at once be asked, where shall the embryology of the flowering plants be studied, and the answer would naturally be, in the development of the seed in the ovary. And here indeed, we trace in outline an epitome of the course of development from the simple unicellular organism, represented by the fertilized egg-cell of the ovule to the highest thalloid form, the "embryo," with its bud (plumule) which is to develop into the full-formed plant perfect in all its parts. For a summary of the further development of the Angiosperms we must look to the growing bud which is the essential reproductive organ of the sporophyte stage and, doubtless, a more primitive one than the seed, for it is common among the more ancient Pteridophytes and these have no seed. The embryo of flowering plants does, however, correspond pretty closely to that advanced stage of development of the egg-cell of some of the higher Pteridophyta now generally spoken of as the embryo and should be regarded as a young plant in a state of arrested development. In this state it remains during a period of rest, in a highly specialized environment in the seed, awaiting favorable conditions for farther growth. Because of the highly specialized environment of the embryo, it has itself become correspondingly specialized and has been variously modified to suit the special conditions of its surroundings. The plumule cannot then be regarded as any longer representing a primitive form of bud and its development is so altered by secondary modifications that the series of phylogenetic changes is disguised and imperfectly represented. A parallel case is found among animals in the development of Echinoderms, in which the changes that have taken place through secondary modification are so great that the relationship of the group cannot be satisfactorily determined by developmental evidence.

It is not then in the seedling that we should expect to find representations of primitive leaf-forms, though later ancestral forms paralleling those of fossil leaves, of which we shall speak, are found in some seedlings, as for example in *Liriodendron.* But it is in the growth of the less specialized buds developing under more primitive conditions that we should expect to find them. Such buds are the ordinary leaf-buds of perennial plants, and especially those occurring on basal and subterranean portions which I conceive to develop under conditions somewhat more primitive than is the case with aërial buds. But in both these the recapitulation of the development of leaf-forms may be traced with a considerable degree of confidence, from the primitive sheathing protective scale to the most highly differentiated and complex of modern leaf-forms.

It is at this point that the fragmentary geological evidence sheds its strongest light on the problem under consideration. In the Cretaceous and Tertiary floras which preceded the modern, the present degree of differentiation had not as yet been attained and but few modern species made their appearance before the close of the Tertiary.* The species, however, which immediately preceded those which now exist were very closely related to them, being their immediate ancestors, and differed from them only in showing a somewhat lower degree of differentiation, and their leaf-forms are accordingly more primitive than those of the existing species which have descended from them.

Now it is a well-established fact that the lower leaves of young branches and shoots, and especially of those which spring from the stumps of felled trees, are frequently unlike the adult forms which occur higher up and bear a close resemblance to the fossil leaves of extinct species, so close indeed, as oftentimes to be indistinguishable from them. This is strong evidence in favor of the doctrine that the lower foliar organs represent not reduced leaves, as botanists have commonly supposed,† but the primitive foliar organs, and that in an ascending series from the lowest scale to the mature adult leaves of the upper part of the stem, giving a more or less perfect summary of the phylogenetic development of the foliar organ from the most primitive type upward to the most highly differentiated.‡ In other words, a single stem may represent the whole phylogeny of the foliar organs of its type. It is true that there are simple leaf-forms which have become so

* Our modern species of *Corylus* are recorded from the Eocene by Professor J. S. Newbury. Later Extinct Floras of North America. Ann. N. Y. Lyc. Nat. Hist. 9 : 59–60. 1868.

† See DeCandolle. Org. Veg. 2 : 212. 1827.

‡ "Most modern botanists now regard the varying forms of leaf seen on young shoots and near the base of trees as valuable hints at the probable stages through which the final forms have passed in the history of their development." Professor L. F. Ward. Proc. U. S. Nat. Mus. 11 : 41. 1888.

by reduction but, as an organ cannot be reduced until it has been developed, these are to be looked for above and not below the perfect leaves, and are found in bracts, involucral scales and the parts of floral envelopes, reduction taking place in inverse order to the course of development, and only the most primitive structure, the simple sheath, persists in the petals of most flowers. Reduced leaves are also common in parasites, and in the flora of desert regions as is well illustrated in some of the Leguminosæ of Australia the leaves of which are little more than spines, or are developed into bladeless phyllodia, while in the seedlings the ancestral pinnate or bipinnate forms occur.*

We thus have shown in each season's growth of a plant, though not clearly in annuals because disguised in the seedling, a more or less complete series of foliar organs which may for illustration be compared with the vertebrate series among animals, the lowest leaf-scales being comparable in degree of development to the simple structures of the fishes and the most highly developed leaves to the complicated ones of mammals. Each leaf in the series is equally perfect for the function it is intended to perform, but the lowest of a lower type of organization, as are the fishes, and representing an earlier stage in the phylogenetic series.

Now in animals we look to the developing egg of the more generalized fishes for the least abbreviated embryological recapitulation of the early development of the vertebrate branch, for in the mammals the early stages are passed through so rapidly and with so many disguises as to be of comparatively small importance in giving the history of the branch, unless viewed in the light of the embryological development of the lower types. So the lower foliar organs of a branch or shoot are embryologically of far greater importance than the upper, for in the beginning of the development of one of the upper leaves we have but the early stages of a highly organized appendage. These early stages are consequently abbreviated and more or less disguised. The formation of the stipules in the growth of the upper leaves is therefore not a salient point in the consideration of our problem though it has had much stress laid upon it, yet it is of interest to note that in general the stipules appear earlier than the leaf-blade, thus giving evidence that they are of more ancient origin. It may be added,

* See Sir John Lubbock. On Seedlings. 1: 474. 1892. See also p. 440 as to the similar case of *Lathyrus Aphaca*.

and it is a matter of common observation, that the petiole is the last portion of the leaf to develop ontogenetically and is therefore to be regarded as the most recent part to be added phylogenetically. This helps to explain the common occurrence of sessile and petiolate leaves even in different species of the same genus, as variation more readily occurs in recent than in ancient structures, while on the contrary it has been a matter of remark among even the earlier botanists that stipules when they occur usually characterize all the species of a family, an additional evidence of the antiquity of their origin.

Let us now take up, in the light of the foregoing conclusions the consideration of the destiny of the primitive foliar organ as it has been modified and developed in the course of evolution. For convenience in making our inquiry, I would divide the primitive leaf into the central-basal, axial, apical and lateral portions. Each of these figures prominently in the evolutionary history of foliar organs, for from the original condition there has been progressive development along several lines of varying degrees of relationship and the morphological result of the development of the several parts has been quite different in the divergent groups, so much so as to render the question of homology a doubtful one to many minds. We shall endeavor to establish its reality.

The lamina of the leaf, as we shall see, has been developed chiefly from the apical portion, usually from scarcely more than a mere point, though it may also include the axial and lateral portions. The true petiole, when present, is developed from the axial portion,* the sheathing petiole from the central basal together with the lateral portions, stipules and structures of the same signification from the lateral portions. It is with the lateral portions, therefore, that we are chiefly concerned.

With reference to the formation of stipules there are three principle types of leaf-development: that in which the several portions of the primitive leaf have developed together into a simple unappendaged blade, that in which a sheathing petiole is formed with or without a ligule or ochrea, and that in which stipules properly so-called are present.

In the first and simplest case the development of all the parts

*See S. H. Vines. Text-book of Botany, 1: 49. 1894.

together gives rise to such leaf-forms as are found in *Vaccinium* and *Sassafras*, the principal portion of the lamina being formed by the development of the apical portion, but including at the base the lateral, central-basal and axial portions which are contracted below into a short petiole.

If we observe the development of the leaf in *Sassafras* the relative growth of the several parts can be readily traced. The first four leaves (fig. 1) are very simple. In the fifth (fig. 2) considerable development has taken place. The apical portion, now forming about half of the organ, is provided with the three typical veins as they appear in the adult leaf, but starting out separately from the very base. The lateral portions have reached their highest development and each is furnished with a pair of veins. In the sixth leaf (fig. 3) there is a very close approach to the adult form. The upper part has expanded and the lower parts have elongated, removing the point of separation of the three principal veins of the leaf to a considerable distance from the stem. At the same time there has been a basal contraction looking toward the formation of the petiole with a considerable degeneration of the lateral portions, one of the veins having disappeared from each of them, while the other has become associated with the midvein. The seventh leaf (fig. 4) represents the unlobed adult form and differs but little from the sixth.

A similar condition is observable in *Ailanthus glandulosa* Desf. (figs. 5–10), but resulting in this case in the final separation of the lateral portions as small gland-bearing fugacious stipules, comparable to those at the base of the leaves of many of the Ranunculaceæ. The comparison of *Sassafras* and *Ailanthus* shows how small a difference in development may determine a leaf as stipulate or exstipulate.

The case of *Syringa vulgaris* L. is like that of *Sassafras*, though more difficult to trace, owing to the larger number of veins in the leaf, but the homologies of parts may be followed more or less distinctly from the second leaf up to the sixth, the first adult leaf (figs. 11–14). The lateral portions are seen to have degenerated almost entirely and, their bundles having disappeared, they remain only in the margin of the petiole.

The Compositæ furnish examples of a similar course of development but often with a closer approach to the true stipular condition, as the lateral portions are supplied with vascular tissue by small branches coming off at the base of the leaf from the main lateral bundles.

In *Erigeron annuum* (L.) Pers., for example, there are three fibro-vascular bundles in the leaf-trace which pass up through the central portion of the petiole, converging as it narrows. But almost immediately on their departure from the stem each of the lateral bundles gives off a branch in the same manner as when true stipules are present. This branch forks at once and supplies the wings of the petiole. In the cauline leaves (fig. 15) its branches can be distinctly traced into the lower lobes of the leaf. The basal leaves of *Aster undulatus* L. show a condition very closely similar to that found in *Erigeron annuum* (L.) Pers., but in the cauline leaves there is a considerable modification by which the large lobes of the base of the petiole (fig. 16) are formed. The stipular bundle curves outward through the lobe giving off branches which form a net-work supporting its parenchyma. It then passes up through the wing of the petiole and into the basal part of the leaf. In *Solidago juncea* Ait., there are eleven bundles in the leaf-trace and a stipular bundle is given off on each side, supplying the margins of the petiole. *Artemisia vulgaris* L. affords a very interesting variation. The lateral portions of the primitive leaf have branched in a very curious manner (fig. 17), forming several small leaflet-like appendages to the base of the petiole. That they belong to the lateral portions and are stipular in their character is shown by the fact that they are supported by branches of the stipular bundle which is given off a little higher up than in *Erigeron*, passes on through the wings of the petiole after giving off the branches and enters the base of the blade as in other cases. This is the nearest approach to the true stipular condition that I have observed among the Compositæ.

The embryonic development of the foliar organ among the Compositæ is in general too much abbreviated to give much evidence in the consideration of the present question, and it should be so expected from the position which the family holds at the head of the vegetable kingdom.

Petioles of the kind seen in this type of leaf-development are very often short and usually more or less margined or winged by the contracted basal parts of the lateral portions of the primitive leaf. They are evidently genetically different from the petioles of stipulate leaves which are developed by the elongation of the axial portion alone. Sessile leaves also are of this type, hence the absence of stipules, the stipular tissue being incorporated into the basal part of the blade. But even where stipules are present, the lateral basal portions of the leaves are often in the closest anatomical relation with the stipules. This may be seen in *Viola obliqua* Hill (fig. 18) in which, near the bundle which passes into the stipule, a similar one arises, takes its course up the petiole supporting its narrow wing and is distributed to a small part of the basal portion of the lamina. We shall find several cases similar to this when we come to the consideration of the Rosaceæ. There is in this a suggestion of the occasional separation of only a part of the lateral portions to form the stipules and the incorporation of the remainder into the petiole and blade.

The second case is that of the sheathing petiole as it occurs in the Graminæ, Araceæ and Umbelliferæ. In this case the central-basal portion of the primitive leaf is very largely developed and with it the lateral portions which form the margins of the sheathing petiole. The lamina and true petiole are later developments of the apical and axial tissues. We are strongly supported in this view by the fact that the sheathing petiole is interchangeable with petioles of the ordinary type accompanied by stipules. This occurs in the Umbelliferæ. In *Hydrocotyle* and a few other genera the sheathing petiole is wanting and stipules are present. The closely related *Aralia racemosa* L. also has stipules. Still more striking is the case of *Comarum palustre* L. in which the basal leaves have the sheathing petiole remarkably developed with no indication of stipules (fig. 19), while the upper leaves possess well developed stipules adnate for not more than half their length (fig. 20).

But the identity of the marginal tissue of sheathing petioles is perhaps best shown in the Ranunculaceæ. In the upper basal leaves of *Ranunculus bulbosus* L., the separation of the lateral portions is seen actually to have begun, presenting exactly the appearance of adnate stipules. The development can be clearly traced from below upward. The first leaf has a short sheathing petiole of the ordinary type (fig. 21). This is slowly modified till in the fourteenth leaf (fig. 22) the vascular bundles have drawn closer together, the sheath has grown shorter and the broad lateral portions, hyaline in texture and requiring no special support other than that of the surrounding leaves, are rounded off distinctly at the top at the point of beginning of the true petiole. In the fifteenth leaf (fig. 23) there is a further reduction in size and the tips of the lateral portions are free. Another interesting case among the Ranunculaceæ is that of *Thalictrum polygamum* Muhl. in which the sheathing petiole is of a very generalized type (fig. 24). The lateral portions are chiefly hyaline, though sometimes faintly netted-veined and their margins turn in at the apex and meet in the central dorsal channel of the petiole at its base, forming a ridge between the sheathing and true petioles. This ridge supports a very narrow hyaline membrane which appears to me as the rudiment of a ligule. It would become typical by a little further development of marginal tissue. I believe this to be the origin of the ligule wherever it occurs, though it does not appear so clearly evident in highly specialized groups, nor should we expect such to be the case. There is also present at the first and second forkings of the petiole a transverse hyaline scale very much like a ligule.

It is noteworthy that the ligule always occurs in connection with the sheathing petiole, as in the Gramineæ and Cyperaceæ, or where there is evidence that there has been a sheathing petiole which has disappeared by degeneration, leaving the ligule axillary as in some of the Naiadaceæ which we shall presently consider.

When the ligule has developed sufficiently to require special support, it is supplied by the introduction of vascular bundles. These bundles have their origin most frequently as tangential branches of the main leaf-bundles at their point of passage from the sheathing petiole into the true petiole, or, where the latter is undeveloped as in the grasses, into the blade. This mode of origin of the ligular bundles is seen in some of the tropical grasses and in the ligular portion of the stipule of the Naiadaceæ and the ochrea of the Polygonaceæ. *Richardia* shows an exceptional venation of the ligule.

The best marked examples of the sheathing petiole among the Monocotyledones are found in the Araceæ, the Cyperaceæ and the Gramineæ. If we examine a developing plant of the common hot-house calla (*Richardia Africana* Kunth.), the first leaf (fig. 25) is seen to be a short, broad sheath, the second (fig. 26) has increased to a considerable length and the apical and axial tissues have developed into a minute blade and petiole. The third leaf is of the adult form, but smaller, though all the parts have increased very much in size. This is contrary to what is observed in *Ranunculus* where the sheathing petiole degenerates while the other parts advance. The margins of the sheathing petiole of *Richardia* curve inward at their apices and meet in the middle line of the leaf as in the case of *Thalictrum polygamum* L., but they are much broader and form a distinct ligule which is supported by the incurving and union of the marginal veins of the sheath instead of by tangential branches. In *Arisæma triphyllum* (L.) Torr., the transition is not so well marked, owing to the small number of leaves the first of which is but a sheath as in *Richardia*, while the second bears a mature lamina.

*Scirpus polyphyllus* Vahl. (fig. 27) will serve well to illustrate the ligule in the Cyperaceæ. It is but little developed as a slight hyaline outgrowth upon the ridge at the union of the sheath and lamina, but the sheath is closed, as is typical in the family, and a little farther development of marginal tissue would produce an ochrea. Typical of the ligule in our common grasses is that of *Phalaris arundinacea* L. (fig. 28). It consists of a considerable outgrowth of hyaline tissue which is continuous laterally with the marginal hyaline tissue of the sheath. This continuity strongly supports the position taken as to the origin of the ligule. The purpose of the ligule is evidently to prevent the flow of water from the upper parts of the leaf down between the sheathing petiole and the stem which together with the axillary bud it invests and protects, and neither the ligule nor the primitive ridge which bears it are found in those cases where the sheathing petiole does not closely invest the stem, at least in the early stages of growth, and its purpose could not be in any considerable measure fulfilled.

The usually axillary position of the "stipule" in the Naiadaceæ has occasioned considerable discussion as to its real relation to the ligule of grasses and to stipules proper. That it is in reality a development of the lateral portions of the primitive leaf, and that it corresponds to the ligule together with the margins of the sheathing petiole of grasses and is rendered more or less nearly axillary by the degeneration of the central-basal portion, becomes clear from the fact that in some species of Naiadaceæ the sheathing petiole retains a considerable degree of what should be regarded as its ancestral development, and a condition approaching that which occurs in grasses is found. *Potamogeton crispus* L. is one of our species which will serve well for an illustration. The first leaves do not develop a blade, but the lateral and central-basal portions are well developed. In the adult leaves there is present a true sheathing petiole (fig. 29). The fibro-vascular bundles of the central-basal portion pass into the blade, giving off tangentially, at the point of transition from sheath to blade, the bundles of the ligular part of the stipule. The bundles of the lateral portions do not in this case curve about to join those entering the blade but are prolonged upward, remaining parallel and supplying the lateral portions of the stipule with supporting tissue directly. In *Althenia filiformis* Petit. (fig. 30), the conditions are more primitive in the larger relative development of the lateral and central-basal portions. In *Ruppia* the ligule is not developed, and the tips of the lateral portions are free as in ordinary adnate stipules.

The condition found in *Potamogeton* is almost exactly repeated in *Polygonella articulata* (L.) Meisn. (fig. 31). The ochrea is cylindrical, surrounding the stem. The central-basal portion is long and narrow, bearing at its apex the terete lamina which is deciduous before flowering. The lateral portions form the principal part of the sheath, are parallel veined with a few anastomosing bundles and are prolonged above the central-basal portion, growing in along the ridge between it and the lamina. This middle portion shows its origin by a deep median sinus and receives its bundles typically as tangential branches from those entering the lamina. We do not have then in *Polygonella* a typical ochrea as it occurs in *Rumex* and *Polygonum*, where, because of the small development of the central-basal portion, the sheathing petiole is very short or almost wholly wanting. The lamina, being of much greater importance than in *Polygonella*, receives all the bundles of the leaf-trace. They are more or less abruptly deflected into the true petiole, generally developed in these genera, according to the degree of degeneration of the central-basal portion. The lateral portions receive their supporting bundles as branches of the lateral ones of the leaf-trace. In *Polygonum sagittatum* L. (fig. 32), the marginal tissues do not extend across the petiole and we have a stipule opposite the leaf. In *Rumex crispus* L. (fig. 33) and *Polygonum Virginianum* L. (fig. 34), the ochrea is complete and the axillary parts receive the typical tangential bundles.

The ochrea of palms is doubtless of the same character, though I have not had opportunity to examine its anatomical structure. In those species which I have examined morphologically, the case is that of the ochrea associated with a remarkable development of the sheathing petiole. There is no true petiole and the ligule may be seen even a little above the base of the blade on the upper surface of the midrib. From this point the lateral portions may be traced down the margins of the sheath, though dried up and very much torn and broken by the more rapid development of the central tissues, till they unite with those parts which in their development have formed the "ochrea." The degeneration of the sheathing petiole with the probable concomitant formation of a true petiole would give the same conditions as in *Polygonum* with its typical ochrea.

The ochreate stipule of *Platanus* differs little morphologically from the typical ochrea, except in the absence of development of the central-basal portion and the possession of a horizontal limb, but there is no fibro-vascular support for the ligular part and this usually splits, leaving apparently a single stipule opposite the leaf.

The case of the tendrils of *Smilax* is one which has occasioned much discussion, but the embryological together with the anatomical characters make it sufficiently clear that in *Smilax* the tendrils are true stipules found in connection with the sheathing petiole. If a young shoot of *Smilax rotundifolia* L. be examined, the first leaf (fig. 35) is seen to be of the typical primitive form. In the second (fig. 36), the apical portion has developed into a blade of considerable size and there is a well-marked sheathing petiole. In the third (fig. 37), the true petiole has begun to develop, the central-basal portion is degenerating and at the same time the lateral portions have begun to separate, forming rudimentary tendrils which in the adult leaves come to considerable length by secondary development in adaptation to their new and unusual function of support. In cross section the bundles of the tendrils are seen to arise as branches of those of the petiole, so that anatomically, as well as embryologically, they answer to true stipules.

*Pastinaca sativa* L. (fig. 38) furnishes a good example of the sheathing petiole among the Umbelliferæ. The lateral portions are broad and furnished with several vascular bundles parallel with those of the central basal portion. The lateral portions remain of considerable breadth to the top where they are distinctly rounded off, and their bundles, with the exception of two or three of the exterior ones. curve around and unite with those entering the petiole. This free condition of the exterior lateral bundles with the anastomosing network between them shows a considerable degree of approach to the true stipular condition.

In the third case true stipules are developed. They are formed by a very early separation of the lateral portions from the main body of the primitive leaf, a separation which can be very clearly traced progressively in the embryological history of leaf development. The function of the lateral portions in their primitive connection with the main body of the foliar organ is, in common with the other portions, protective, and while the apical portion, having had placed upon it the special function of assimilation, goes on in its development together with the accessory axial portion in adaptation to this purpose, the lateral portions usually serve their ancient function only, sharing it with the central-basal portion when this has not disappeared by degeneration. The central-basal portion also supports the main body of the leaf, a function from which the lateral portions have been freed by separation.

It is in consequence of this separation that all the main vascular bundles of the leaf-trace in the third type of leaf-development are deflected toward the central one that they may pass up through the petiole into the lamina and give the required support to these important parts. The support of the lateral portions is left to comparatively small lateral branches from the two exterior bundles of the trace, evidently developed expressly for the purpose. This we may conclude, since vascular tissue is the most modern of plant tissues and introduced because of the necessity of support in the evolutionary development of the primitive ground tissues. It would, therefore, follow and not precede the evolution of leaf-forms, being introduced where needed and disappearing again when degeneration or other support of particular parts renders its presence unnecessary. This will appear in some of our examples. In the first and second types of leaf-development the lateral portions may retain in greater or less degree their independent venation.

As the other portions of the primitive leaf have been so wonderfully modified in the course of their development and altered from their original condition, so the freed lateral portions to which we may now apply the term *stipules* have not retained their primitive proportions in adult leaves nor the identity of all their parts. But as the central basal portion has often almost wholly degenerated, the same thing has happened to the basal parts of the lateral portions. The parallel degeneration of the two portions has brought the stipules into closer and closer apparent relation to the stem, so much so as to lead to the enquiry whether they are not accessory leaves and to suggest their origin from the reduction or lack of development of a portion of the leaves as in *Selaginella* and their subsequent association in close relation to the larger ones, but in all my investigation I have not found the slightest evidence in support of this theory. The degeneration of the stipules may continue until they become vestigial or finally disappear altogether. This is evidently the case in those families of plants a few species only of which still possess stipules, as for example the Caprifoliaceæ.

But opposed to the basal degeneration of stipules, there has very commonly been a longitudinal development corresponding to that by which the lamina has been evolved. This has resulted in the adaptation of the stipules to the peculiar requirements of each genus and species. Often in this secondary development they remain membranous, serving the protective function only, and when free are early deciduous. But in numerous cases they have acquired the assimilative function also, developing abundant chlorophyll and sometimes, as in the pea (*Pisum sativium* L.), becoming of equal assimilative importance with the lamina. In *Lathyrus Aphaca* L., they even replace it almost entirely.

Among all these varying forms we should expect to find closer similarities in those plant groups of nearer relationship as we do in floral structures, and conversely these similarities of foliar development should also point to relationship, due allowance being made for parallel development in adaptation to similar environment and for secondary functional modifications which find morphological expression. Also in types more recently evolved and more highly differentiated wide divergence from the typical mode of development may be looked for. The Caprifoliaceæ, before mentioned, are of such a type, with stipules usually wholly aborted;

another is the family of the Rubiaceæ with anomalous stipular development in the group of the Stellatæ. The oaks also, though of lower organization, are an advancing type and still actively undergoing differentiation as evinced by the close relationship and difficulty of determination of the species of any given group. In this genus all but the upper part of the primitive leaf has disappeared by degeneration even in the earliest stages represented in embryonic leaf-development, and the well developed stipules are distinct and separate from the very base of a developing shoot. Not until the fifteenth node, in *Quercus rubra* L. (fig. 39), is there any appearance of lamina. The apical portion of the protophyll must however be regarded as potentially present between the stipules at their base. It begins its development unusually late in the series and exhibits several stages, of which the twentieth leaf (fig. 40) is illustrative, before reaching adult size. The axial portion of the protophyll being aborted, the petiole, here again a short one, is formed by the contraction of the basal part of the lamina itself. The case of *Fagus* is very similar, but the lamina appears as early as the eighth node (fig. 41), indicating a less degree of specialization. In related genera a different course has been followed. The lamina develops still earlier and the stipules of the lowest nodes are united, separating only on the appearance of the first accompanying lamina.

In the family of the Juglandaceæ the genus *Hicoria* furnishes a very interesting example. The lower foliar organs are of the primitive type with an unusual development in size in some species. The transition to the adult leaf-form is commonly rather abrupt, but I have observed, in both *Hicoria alba* (L.) Britton and *H. microcarpa* (Nutt.) Britton, the frequent occurrence of intermediate forms, the lateral portions remaining as typical adnate stipules (fig. 42).

I have not seen the typical representation of embryonic leaf-development better exemplified than in the case of *Baptisia tinctoria* (L.) R. Br. where at a glance one is struck with its clearness. It is also especially full and accurate as occurring in the development of subterreanean buds. The first five leaves are extremely primitive, completely surrounding the node, though only slightly developed on one side. The fifth (fig. 43) shows at its apex a minute apical tooth, the beginning of the lamina which is farther developed in the sixth leaf. In the seventh (fig. 44) the three leaflets are plainly distinguishable, the petiole has begun its development and the separation of the stipules has made considerable advance. The ninth leaf (fig. 45) is well developed, with the large stipules still showing considerable adnation. But in the tenth (fig. 46) they are wholly free and much reduced, and higher up disappear altogether. We could hardly have a more complete series in illustration of the formation of stipules than this, giving as it does all the stages from an extremely primitive leaf-form to that very highly organized condition where the stipules have entirely disappeared. By a comparison of the venation in the seventh and ninth leaves, it will appear that the separate condition of the stipules has been attained in the manner already described, partly by the formation of an apical cleft, partly by the degeneration of the central-basal portion bringing the base of the cleft lower down. Meanwhile there has also been a considerable apical development of the stipule itself. But this increase in size is lost again in the tenth leaf and the reduction continues to final abortion. *Melilotus alba* Lam. presents very similar though somewhat less primitive conditions.

While considering leguminous plants, a few words concerning stipels, which are so characteristic of the family, would be in place. They have been denominated as "the stipules of leaflets," but I am convinced that they have no connection with stipules whatever, but that they represent rudimentary leaflets which have their origin in a tendency to increased compounding. The habit has become so fixed in the Leguminosæ that evidence of its origin is seldom met with. I have however seen, in *Lespedeza capitata* Michx., one of the earliest leaves with the terminal leaflet only developed and the two lateral ones represented by stipels.

I have found more light on the question in other families where the same tendency to increased compounding often occurs. In *Sanguisorba Canadensis* L. (fig. 47) for example, very vigorous plants sometimes show rudimentary leaflets, more developed indeed than typical stipels, but in the same position. Their character as leaflets of secondary rank is evinced by their occasional removal to a little distance from the primary petiole. A more striking case is that of *Sambucus Canadensis* L. In this species the leaves of young shoots springing up where the bushes have been cleared away are frequently partially bicompound and there are all gradations between the ordinary pinnate form and the bipinnate condition (figs. 48–50). In this case it is remarkable that the first appearance of the secondary leaflet is in the shape of a small body with both the form and position of a stipel, with the same small supporting vein and differing only in greater thickness. These facts seem to give evidence sufficiently conclusive that stipels are in reality rudimentary leaflets. That their development is not confined to the Leguminosæ is farther shown by their characteristic occurrence in *Staphylea trifolia* L.

Another frequent foliar variation among the Leguminosæ is the development of the phyllodium, which might be thought to have some connection with stipules, but the presence of both together in some genera disproves the idea.* The stipules in the Leguminosæ often take the form of spines which serve for the general protection of the plant. We have an example in the well known *Robinia Pseudacacia* L. (fig. 51). In some of the tropical Acacias, as for example *A. spadicigera* C. & S. (fig. 52), they take the form of enormous hollow horns which are appropriated as homes by some species of ants.†

*Sambucus Canadensis* L. presents another remarkable character. The leaves of the vernal shoots from subterranean buds are furnished with stipules of the same form and in the same position as those of *Sambucus Ebulus* L., but smaller. There are four of them at each node, they are ovate or nearly orbicular in form, small, rather fleshy and persist but a short time. Each is supplied with a small vascular bundle, originating as a branch of the nodal girdle which connects the leaf-traces. These facts give evidence of the close relationship of these two species of *Sambucus*, and of the characteristic presence of stipules in the ancestral form. In *Sambucus Ebulus* L., they are still typically developed, but in our species have become so far vestigial as to appear only in connection with the early leaves of shoots from subterranean buds, an additional evidence of the importance of the leaf-forms successively developed from such buds, in their bearing on the evolutionary development of modern adult forms.

If now we turn to the family of the Rosaceæ we shall find many illustrative examples of the same facts as those born out in the case of *Baptisia tinctoria* (L.) R. Br. But it frequently happens that basal degeneration does not take place or is only partial, re-

* Bentham and Mueller. Flora of Australia, 2: 304. 1864.

† Belt. Naturalist in Nicaraugua, 218. 1874.

sulting in the adnate stipules characteristic of so many genera and species of the family. *Agrimonia striata* Michx., in the development of its subterranean buds in the spring, presents an excellent series of embryonic leaf-forms. The lower ones are all simple sheathing scales completely surrounding the stem at their insertion. Not until the eleventh leaf (fig. 53), which is three-toothed at the apex, does the differentiation of parts begin. The central tooth is the beginning of the blade with its petiole; the lateral portions with their tips now free are the stipules. To say that they are "adnate" indicates only that they retain their primitive connection with the central-basal portion. In the twelfth leaf (fig. 54), there has been some basal degeneration, as shown by the lower point at which the three main bundles of the leaf converge and the lower position of the zigzag plexus of the stipular veins. The free tips, on the other hand, have increased in size and a small blade supported by a petiole is present in consequence of the development of the central tooth. The fifteenth leaf (fig. 55) shows a stronger development of all the parts, and a branch of the main stipular bundle is seen to pass up the petiole. The adult form is attained in the seventeenth leaf (fig. 56). In it some further basal degeneration has taken place, but the adnation of the stipules is still very prominent.

*Prunus Cerasus* L. gives a very good morphological series, but the venation is obscure. A view of the several forms can be had by an examination of the tenth, thirteenth, fifteenth, sixteenth and seventeenth leaves (figs. 57–61). They show the transition from the simple primitive scale to the mature condition in which the stipules are rendered entirely free. The series is similar in *Rubus occidentalis* L., *Pyrus Malus* L. and *Pyrus communis* L. In *Rubus villosus* Ait. (figs. 62–66), the basal degeneration is not carried quite so far and the stipules in the adult leaf-forms remain adnate for some distance from the base of the leaf. The tips of the stipules have taken a larger comparative development than in *Agrimonia*. Anatomically, however, *Rubus villosus* Ait. resembles the latter in having a vein which enters the petiole, neighboring to the main stipular bundle much as in *Viola obliqua* Hill (fig. 18). The venation in *Pyrus Malus* L. (fig. 67) is still more like that in *Agrimonia*.

The stipules of *Fragaria* and *Rosa* show the highest degree of adnation and little, if any, basal degeneration seems to have taken place, though the lateral leaf bundles curve in toward the median one at but a short distance from the stem. This arrangement of the bundles is probably secondary in these forms for the purpose of giving a firmer support to the leaf by an axial concentration of the vascular tissue in the sheath and a corresponding thickening of the surrounding tissues, a firmer support than could be given by only three bundles if they did not converge till they approached the point of their entering the petiole. The venation of the stipules is also peculiar. In *Fragaria Virginiana* Duchesne (fig. 68), there is a single strong bundle running out into the free tip of the stipule. From this are sent out one or two weak veins above, and below there is a faint vascular network confined mostly to the region of the tip and extending in a long curve toward the outer portion of the base, where it gradually fades out without forming any connection with other vascular tissue below. This condition seems to indicate a former basal connection of these stipular bundles, either with the lateral bundle of the leaf or possibly with those of the stem, forming an additional leaf-trace bundle distributed to the stipules only. The former case is far more likely. A probable explanation of this degeneration of the basal stipular bundles can be found by a consideration of the conditions of the environment. All the leaves being basal, the stipules are clustered together and are supported by one another and by the surrounding soil. They are more or less fleshy, destitute of chlorophyll, and in their moist surroundings loss of water by evaporation is comparatively slight. All these circumstances lessen the necessity of the supply of fresh sap. The rapidly conducting vascular tissue has come into disuse, and its degeneration and disappearance is the natural consequence. The same arrangement in forms with leafy stems is not so readily explainable except by the supposition that the arrangement is ancestral. This seems rather evident in the case of *Agrimonia striata* Michx. (figs. 53–56), where the same condition of the bundles occurs, for the earliest leaves representing the ancestral forms develop under the same conditions as the adult leaves of *Fragaria*. But in *Rosa* it would be by no means clear did we not have such intermediate types as *Agrimonia*. *Rosa humilis* Marsh. (fig. 69) may be taken as typical of the genus. The venation of the tip of the stipules is nearly like that in *Fragaria*, but with a little larger development above the main bundle. The vascular network below is much more extensive and is reënforced by several small branches from the lateral bundle which enters the petiole, below the main stipular branch. This additional supply of vascular tissue is evidently rendered necessary by the exposure of the stipules to the light and air and the development of chlorophyll. It seems to be of secondary introduction.

The nearest approach to the stipular conditions occurring in *Fragaria* and *Rosa* which I have observed among the Leguminosæ is found in the adnate stipules of *Trifolium pratense* L. ( fig. 70 ). There are two sets of stipular bundles. One of these supplies the tip of the stipule and consists of three veins of which the lowest corresponds to the single large bundle of the tip of the stipules of *Fragaria* and *Rosa.* The other has its origin as branches from the lateral bundle of the leaf-trace at the base of the leaf, the usual point of origin of the veins of free stipules. This set of veins is distributed to the lateral and basal parts of the stipules and apparently corresponds to the lower network of the stipules in *Fragaria.* These stipules are mainly protective in function. Their meshes are filled with hyaline tissue, but there is some green parenchyma along the veins.

Two very interesting cases in the family of the Rosaceæ are those of *Cliffortia graminea* L. f. of South Africa ( fig. 71 ) and *Potentilla fruticosa* L. ( fig. 72 ). In the former the leaves very closely simulate those of grasses with the linear lamina sessile upon a sheathing petiole. They differ in having the tips of the lateral portions ( stipules ) free instead of turning in across the insertion of the lamina to form a ligule. In the latter the conditions are very closely similar to those of the ochrea of *Polygonum.* There is a short sheathing petiole, above the apex of which the tips of the stipules rise. Each of them is supported by a strong vein which has its origin at the base of the true petiole. But instead of being free from one another as in *Rosa*, the stipules are connected back of the petiole by a hyaline ligular tissue. The lateral portions of the sheathing petiole are also united to one another on the opposite side of the stem, at least in young leaves, to a considerable degree. Thus an ochrea is formed, not quite a typical one it is true, yet more nearly so than that of *Polygonum sagittatum* L. ( fig. 32 ).

The fact that such forms as these can occur in the same family of plants along with typical stipules, both adnate and free, goes to show how small is the real difference between the various stipular forms. Not all stipules possess supporting tissues but, just as is the case in the ligule of most grasses, may be without any fibro-vascular bundles whatever. This is the case in *Vitis*, in *Parthenocissus* and *Hydrocotyle*. *Vitis Labrusca* L. (fig. 73) shows a somewhat thickened central streak at the base of the membranous stipule, but in *Hydrocotyle Americana* L. (fig. 74), the thickness is uniform and the stipule very thin. These facts give some authority to the supposition that the pectinate interpetiolar appendages which occur in the Composite *Willoughbya scandens* (L.) Kuntze (fig. 75) are true stipules. They are hyaline in texture, without supporting tissue, and may possibly be merely of epidermal origin. To determine this point requires opportunity to examine their development.

It is of importance to state that the tendril of the Cucurbitaceæ, regarded by many as a stipule, has been determined by anatomical examination to represent the first leaf of the axillary bud.* The spines of *Xanthium spinosum* L., simulating stipules in position, are degenerate pistillate flowers. As proof of this, they often bear a greater or less number of hooked prickles like those of the flowers, and there may be a spine on one side and a flower on the other, showing them to be of the same significance.†

The stipules of *Comptonia peregrina* (L.) Coulter (fig. 76) denied by some to be properly so-called, do not differ anatomically from other stipules notwithstanding their peculiar morphology, and are to be included under the term. One of the chief reasons for their exclusion seems to have been the absence of stipules in *Myrica*. This is doubtless a case parallel with that of *Viburnum*, of which most of the species have lost their stipules by degeneration.

While it is not a generally accepted view, there is no good reason why stipules should not sometimes be distinguishable in floral parts. They are clearly present in the sepals of *Rosa* and *Rhodotypus*, and the smaller intermediate lobes of the calyx of *Potentilla* probably represent pairs of united stipules, one from each neighboring calyx-lobe in the manner of interpetiolar stipules.‡ The teeth of the filament in *Deutzia* are very suggestive of stipules in

* See Lestiboudois, Bull. Soc. Bot. Fr. 4: 746–747. 1857. Cited on p. 6.

† See also Clos. Mem. Acad. Sci. Toulouse, (IV), 6: 66–75. 1875.

‡ See Engler and Prantl. Pflanzen Familien. 3: Abt. 3, 6. 1894.

stamens, and the corona of *Silene* may very probably represent a ligule. The glands of the leaves of Ranunculaceæ which have been homologized with stipules, as already stated, can often be traced up into the flowers and are familiar in connection with the petals of *Ranunculus*.

One of the most interesting families of plants in the development of its stipules is that of the Rubiaceæ, the development being very unusual in the group of the Stellatæ. Though the foliar anomaly in this group was early remarked upon and was anatomically explained as early as 1840,* there are considerations which make its present discussion desirable.

In the greater part of the family the leaves are opposite, or occasionally in whorls of three as in *Cephalanthus occidentalis* L., and are usually stipulate. The stipules are of variable character and often interpetiolar, the adjoining stipules on each side of the stem being connate. In the group of the Stellatæ however, comprising ten or twelve genera, the stipules usually are apparently wanting and the leaves in whorls. There is a tendency toward a verticillate arrangement of the leaves in others of the Rubiaceæ, as shown by the frequent occurrence of whorls of three in usually opposite-leaved species. Now an anatomical examination of the whorled leaves of *Mollugo verticillata* L., *Silene stellata* (L.) Ait. f., *Leptandra Virginica* (L.) Nutt. and *Cephalanthus occidentalis* L. reveals the fact that in other families, as well as in the Rubiaceæ exclusive of the Stellatæ, each leaf of any whorl receives its fibro-vascular bundles directly from the cauline cylinder. But in *Galium* the case is different. Two leaves only of the whorl receive their bundles in the manner stated, and only these two produce buds in their axils. All the others receive their vascular supply from what may be termed a nodal girdle, each half of which is formed by the union of two bundles arising, one from each of the two leaf-traces in the same manner as those supplying stipules of the ordinary form. From this girdle arise the bundles which supply the additional leaves, whether there be only one on each side, as in *Galium circæzans* Michx. and *G. lanceolatum* Torr., two, as in *G. triflorum* Michx. and *G. tinctorium* L., or even three or four, as occurs in *G. Aparine* L. The distribution of the vascular bundles may be seen in a cross section of the node of *Galium tinctorium* L. (fig. 77).

* See page 6.

This anatomical arrangement shows that the so-called additional leaves of the whorls in *Galium* are in reality stipules and that the Stellatæ agree with the rest of the Rubiaceæ in having opposite leaves. The tendency of the family however to produce verticillate leaves has been strongly felt in this group but has taken an unusual course, the increased assimilative area having been evolved through the stipules instead of by an increase in the number of true leaves. The explanation is thus made comparatively simple except in those cases where the number of stipules at a node is more than four.

As a general rule, in plants with stipulate leaves, each leaf is provided with two stipules. But when the leaves are opposite, the two on the same side of the node often coalesce, forming a single interpetiolar stipule, as in the case of *Cephalanthus* (fig. 78). That this coalescence is secondary is shown by the fact that the distal portions only of the veins of the two stipules have united. Now in the Stellatæ also, this must have been the original condition, but the interpetiolar stipules have been greatly developed to serve assimilative purposes, the veins having meanwhile united completely to form a midrib. The increase in size has advanced until in *Galium* the stipules are of the same size and form as the leaves and morphologically indistinguishable from them, except in *G. bifolium* where the stipules are smaller. In this condition they remain in the broader-leaved species, as *G. pilosum* Ait., *G. latifolium* Michx. and *G. lanceolatum* Torr. But in the narrower-leaved species, a still greater foliar expansion being desirable, separation has been re-accomplished, proceeding probably from the tip downward, as is illustrated in *Rubia peregrina* L. with whorls of four. In this species stipules are occasionally found with two midribs (fig. 79), most widely separated at the apex or even coalescing toward the base. In *Galium Aparine* L. and other species in which the number of stipules is abnormal, we may suppose this condition to have arisen from a repetition of the process of division which has produced the six-leaved whorls. This is not improbable, since even in the four-leaved forms the stipules have already entirely lost their original morphological character and have taken on a more generalized nature, making them fit material for development along new lines of evolution. Embryological evidence is not wholly wanting, although the family stands so near the head of the plant series. In

*Galium Aparine* L., in common with the six-leaved species, the earlier whorls are of four leaves only, representing the ancestral condition. In *Rubia tinctorium* L., the opposite leaves of the subterranean portion of the stem are exstipulate. At the first aërial node there is a whorl of four, interpetiolar stipules being present, and in the higher whorls there are six leaves.* This is a series of long range, though lacking in intermediate steps.

Another case in which there is present a nodal girdle from which the stipular bundles arise is that of *Humulus Lupulus* (fig. 80), but there are three bundles in each leaf-trace. They are placed at about equal distances around the circumference of the stem, and the girdle-bundles proper occupy only about one-third of the periphery on each side. From them a part of the stipular bundles arise, the remainder originating directly from the lateral bundles of the leaf-traces.

It would be to small purpose that examples should be further multiplied. From those already cited we may confidently deduce the following conclusions :

1. The sheathing petiole has its origin independently of the true petiole and is formed by a concomitant development of the lateral and central-basal portions of the primitive leaf.

2. The ligule is a special development of the apical parts of the lateral portions of the primitive leaf along the ridge between the sheathing petiole and the distal parts of the leaf. It may be supplied with veins either by the marginal bundles of the sheath or by tangential branches from those entering the blade. The sheathing petiole may disappear by degeneration, rendering the ligule axillary as in many species of *Potamogeton*.

3. The ochrea is related to the ligule and is generally associated with the sheathing petiole. It consists of the apical tissues developed in those cases where the sheathing petiole completely surrounds the stem or did so in the ancestral condition. The part of the ochrea posterior to the lamina or petiole may be called its ligular portion and is usually supplied by bundles arising tangentially from the main ones.

4. The lateral portions of the primitive leaf, when separated in greater or less degree, constitute stipules in the usual acceptation of the term. They are variously modified by subsequent evolu-

*Sir John Lubbock. Jour. Lin. Soc. Lond. 30 : 504. 1894.

tionary changes, by increased development, by basal or total degeneration, by secondary adnations and various textural modifications. They receive their vascular bundles typically as branches of the lateral ones of the leaf-trace.

5. The lateral portions of the primitive leaf therefore represent in potential the ligule, the ochrea, the margins of sheathing petioles and stipules, but they are often incorporated with the other portions as the wings of petioles and as lateral basal portions of leaf-blades.

## II.—*The Ascidian Half-Embryo.*

BY HENRY E. CRAMPTON, JR.

Read March 8, 1897.

The development of isolated blastomeres of the ascidian egg has afforded a subject of considerable discussion on the part of many theoretical embryologists. Chabry* approached the subject from the experimental side, and, from the results of his many detailed observations and experiments, was led to the conclusion that one of the isolated blastomeres of the two-celled stage produced a strict half-embryo. As it was well known that the first cleavage-plane divided the egg into right and left halves, this conclusion seemed altogether probable and of considerable interest.

A number of writers, however, among them Hertwig,† Driesch,‡ Weismann,§ Barfurth|| and Roux,¶ were led, on the grounds of Chabry's results, to opinions more or less at variance with his. Barfurth considered Chabry to be in greater part correct. Roux and Weismann believed that during the later development the missing part was supplied by the other cells through " postgeneration." Hertwig states that, in his opinion, Chabry was in error; and Driesch also argued that a typical total development occurred. Finally, Driesch** in 1893 repeated Chabry's experiments, upon the eggs of *Phallusia mammillata*, and by the results wholly confirmed the theoretical conclusions of his previous paper.

* Chabry L. Contribution à l'embryologie normale et teratologique des ascidies simples. Journ. de l'anat. et de la phys. XXIII. 1887.

† Hertwig, R. Urmund und Spina bifida. Arch. f. mikr. Anat. XXXIX. 1892.

‡ Driesch, H. Der Werth der beiden ersten Furchungszellen in der Echinodermentwickelung. Zeit. f. wiss. Zool. LIII.

§ Weismann, A. Das Keimplasma. 1882.

|| Barfurth, D. Halbbildung oder Ganzbildung von halber Grösse. Anat. Anz. VIII. 1893.

¶ Roux, W. Über des entwickelungsmechanische Vermögen jeder der beiden ersten Furchungszellen des Eies. Verhandl. d. Anat. Ges. Wien. 1892.

** Driesch, H. Von der Entwickelung einzelner Ascidienblastomeren. Archiv für Entwick. der Organismen. I. 3. 1895.

Although at that time reluctant to admit anywhere the occurrence of "partial" development, Driesch has since proved, in connection with Morgan, the existence of a partial *early* development in the ctenophore egg.* And in a recent paper by the writer † it has been shown that the isolated blastomere of the snail possesses the power of forming only a corresponding portion of an embryo. In a later paper, Driesch,‡ developing an idea suggested by Prof. E. B. Wilson and myself (loc. cit.), recognized the existence of a series among animal eggs, from the nearly isotropic eggs of the medusa, Amphioxus, fish, sea-urchin, etc., at one extreme, to forms such as the frog and ctenophore, and finally to the snail, at the other extreme, where the blastomere possesses such an organization that but a part of an embryo can be formed and postgeneration cannot occur.

The ascidian egg, however, remained unexplained by the contradictory results of Chabry and Driesch. From this consideration the author was led to an examination of the facts in another ascidian. The results will, it is hoped, clear up the confusion to some extent, and will show how far the development is a "partial" one and in what respects it is "total."

The experiments were performed during the past summer at the Marine Biological Laboratory, Wood's Holl, upon the eggs of *Molgula manhattensis*, which grows very abundantly upon the piles and wharves at New Bedford, Mass. Artificial cross-fertilization was resorted to, and the eggs at the desired stage were spurted in a watch-glass by means of a fine spiral pipette.§ Those eggs presenting isolations were placed separately in watch-glasses, and camera drawings of successive stages were made at intervals, using a Zeiss oc. 4, and obj. C.

As to nomenclature, the system proposed by Kofoid || and ap-

* Driesch, H., and Morgan T. H. Von der Entwickelung einzelner Ctenophórenblastomeren. Archiv für Entwick. der Organismen. II. 2. 1895.

† Crampton, H. E., Jr. Experimental Studies on Gasteropod Development, with an appendix on Cleavage and Mosaic Work, by E. B. Wilson. Archiv für Entwick. der Organismen. III. 1. 1896.

‡ Driesch, H. Betrachtung über die Organisation des Eies und ihre Genese. Archiv für Entwick. der Organismen. IV. 1. 1896.

§ As previously described in connection with the gasteropod experiments.

|| Kofoid, C. On some laws of Cleavage in Simax. Proc. Amer. Acad. Arts and Sciences. Vol. XXIX. 1894.

plied by Castle * to the *Ciona* egg has been used for obvious reasons. According to this system, now well known, each cell is designated by a letter referring to the particular quadrant of the four-cell stage from which it arose; in addition it receives an exponent denoting the generation to which it belongs, and a second exponent denoting its place in that generation, counting from below upward.

## Detailed Description of Cleavage.

A. *Normal Cleavage.*—The cleavage of the *Molgula* egg is precisely the same as that of *Ciona* and other ascidians, as far as it has been followed. Therefore, it is unnecessary to discuss the normal phenomena further than to emphasize a few of the facts which are important in connection with the cleavage of the fragments.

The first and second cleavage-planes are meridional, while the third is equatorial. An eight-cell stage results (fig. 1) which, seen from the side, consists of two tiers of four cells each. The upper tier is shifted anteriorly upon the lower, so that the *posterior upper* cells are in contact with the *anterior ventral* cells. This relation is constant, and characteristic of probably all ascidian eggs (Castle. loc. cit., p. 228). Passing to the 16-cell stage, all the eight blastomeres divide. The spindle axes are inclined in such a manner that the *anterior* products of the *anterior* cells (fig. 2: $B^{5 \cdot 2}$, $b^{5 \cdot 4}$) lie slightly *below* the median products; while the *posterior* products of the *posterior* cells lie slightly *above* the other cells (fig. 2: $C^{5 \cdot 1}$, $c^{5 \cdot 3}$). When activity is again resumed, the dorsal cells remain quiescent, while the ventral cells segment, and a 24-cell stage results (fig. 3). After a period of rest the dorsal cells pass into the same generation (sixth) with the ventral cells, and a morula of 32-cells results. Then the ventral cells divide at about the same time, while the dorsal cells remain quiescent, giving a 48-cell stage.

Further details are unnecessary for our purpose. We emphasize the fact that, beginning with the 16-cell stage, there is a well-marked alternation of activity between the cells of the upper and those of the lower hemisphere of the embryo.

* Castle, W. E. The Early Embryology of Ciona intestinalis. Bulletin of Mus. of Comp. Zool. Harvard. Jan. 1896.

B. *Cleavage of the $\frac{1}{2}$ blastomere.*—As is well known, the isolation of an ascidian blastomere is effected by the death of its neighboring cell or cells, and not by an actual separation. The dead cell partially disintegrates and exerts upon the living cell no modifying influence, such as mechanical obstruction to rounding during division, etc.

$\frac{2}{4}$. At the normal time, viz: at the time of division of control eggs, the injured blastomere divides about equally (figs. 4 and 13). Often when the eggs are operated upon when passing into the 4-cell stage, evidence of division in the dead cell will remain. In such cases the division plane of the living cell is seen to be meridional and at right angles to the first. Therefore, it corresponds with the second cleavage-plane of the normal embryo. In all cases where it is possible to ascertain the facts this relation obtains. Driesch finds in *Phallusia* that no such constancy of relation exists.

$\frac{4}{8}$. After a normal period of rest the two cells divide at the same time. There are thus produced four cells which are arranged in a manner exactly similar to the half of a normal 8-celled embryo. Seen from the side (figs. 5, 9) the cells lie so that two are separated, while two are in contact; these latter are the posterior dorsal and the anterior ventral cells, as shown by the succession of the cleavage planes of the fragment. Precisely as in the normal 8-celled embryo, there is an anterior shifting of the dorsal cells upon the lower cells. According as this shifting is to the right or left, in lateral view, one is confronted by a right or left half-embryo. From a comparison of the figures, it is seen that the embryo in fig. 5 is the same as the half turned toward the observer of fig. 1; while that shown in fig. 9 is derived from a right $\frac{1}{2}$ blastomere. The appearance of the $\frac{4}{8}$ embryo in end view is shown in fig. 14, and a characteristic crossing of the spindle axes is exhibited, which is similar to their crossing in the complete egg (vide Castle for figures). The four-celled fragment, then, is in nowise a counterpart of the normal four-celled embryo, but, on the contrary, corresponds in *every* particular to the half of an eight-celled embryo.

From Chabry's fig. 106, it appears that a typical $\frac{4}{8}$ stage occurs also in *Ascidiella*.

$\frac{8}{16}$. At the next cleavage, all the cells divide (figs. 6, 10). Exactly as in the origin of corresponding normal cells, (fig. 2) the *anterior* products of the *anterior* cells (fig. 6 : $B^{5\cdot1}$, $b^{5\cdot3}$ ; figs. 10 and 16: $A^{5\cdot1}$, $a^{5\cdot3}$) lie slightly below the other cells; and the *posterior* products of the *posterior* cells (fig. 6 : $C^{5\cdot2}$, $c^{5\cdot4}$ ; figs 10 and 16 : $D^{5\cdot2}$, $d^{5\cdot4}$) lie slightly above the median products. On a comparison of fig. 6 and fig. 2, it will be seen, however, that the topographical relations of the cells of the fragment are quite different from the normal. For example in fig. 6, the cell $c^{5\cdot4}$ is in contact with $B^{5\cdot1}$ and $b^{5\cdot3}$, while in the normal egg it lies at the other end of the embryo. A similar rearrangement is still better shown in fig. 10, that of a right $\frac{8}{16}$ embryo, where $D^{5\cdot2}$ is in contact with $A^{5\cdot1}$, while $d^{5\cdot4}$ is in contact with $A^{5\cdot1}$ and $a^{5\cdot3}$. This rearrangement is obviously rendered possible by the absence of the other half of the embryo, so that the cells cohere in a spherical form just as a corresponding number of soap-bubbles. It cannot be considered as a "gliding," for the spindle-axes are from the first accommodated to the changed conditions. That is (figs. 15, 16), the anterior end of the anterior spindles, and the posterior ends of the posterior mitotic figures are swung somewhat toward the original first cleavage-plane of the embryo.

Chabry's fig. 113 leaves no doubt that the $\frac{8}{16}$ embryo of *Ascidiella* is precisely the same as that described above for *Molgula*. From Driesch's fig. 5, there is no doubt that in *Phallusia* the eight cells are arranged as the normal 8 cells.

$\frac{8}{16}-\frac{12}{24}$. When activity is again resumed, only the four lower cells are affected, while the dorsal cells remain quiescent. A 12-celled fragment results (figs. 7 and 11), which is exactly equivalent to a half of the normal 24-cell stage (fig. 3). The quiescence of the dorsal cells during the division of the ventral cells is the first indication of the alternation of activity in the rhythm of cleavage, which was found to be characteristic of this type of segmentation. As in the preceding stage, when the resting condition is assumed, there is a passive rearrangement of the cells. For example, the cells $A^{6\cdot3}$ and $A^{6\cdot4}$ were segmented along an axis inclined at an angle of 45° to the axis joining their centres at the resting stage. Again the cells $D^{6\cdot3}$ and $D^{6\cdot4}$ have retreated around the posterior end of the fragment.

$\frac{16}{32}$. While the eight cells of the lower hemisphere are resting, the four dorsal cells likewise pass into the sixth generation, and a $\frac{16}{32}$ stage results (figs. 8, 12). Its resemblance to the half of a normal 32-cell stage is still less marked than that of a $\frac{12}{24}$ embryo to a half of the normal 24-celled stage. This is so, for the reason that further passive rearrangements of the cells occur, obscuring the partial character of their origin, and causing the cell complex in its solid, or "complete," condition to resemble a normal or "complete" embryo. Nevertheless, the succession of rhythmic cleavages, relation of successive cleavage-planes, etc., point to the operation of factors which are counterparts of those operating in a *half* of the normal embryo.

Later development. The embryo is now "complete," and gives rise to a complete blastula and larva. Although the process of gastrulation has not been carefully observed, enough of the later development has been ascertained to prove that a larva arises which resembles the normal larva, except as regards its smaller size and certain minor defects. My results, therefore, are entirely confirmatory of those of Driesch upon *Phallusia.*

C.—*Cleavage of the $\frac{1}{4}$ blastomeres.*—One of the isolated blastomeres of the four-cell stage, is divided at the next cleavage by a plane which is seen to be at right angles to both of the preceding planes. Therefore it corresponds to the third cleavage plane of the normal embryo. The $\frac{2}{8}$ stage is shown in fig. 17. A subsequent cleavage cuts each of the cells equally, and a $\frac{4}{16}$ stage results (figs. 18, 19), until this time, one is left in doubt as to the true nature of the fragment, that is, whether it will segment as a quarter or as an entire egg. However, from this time on, the character of cleavage is exactly that of a quadrant of a normal embryo.

When division next occurs, only the two cells toward the observer segment (fig. 20), and a stage of six cells results, which is evidently comparable to a $\frac{6}{24}$ embryo only, and not to any stage of the normal development. After a normal period, the dorsal cells (lower in the figure) pass into the sixth generation, and an $\frac{8}{32}$ embryo (fig. 21) is the result. As in the previously described fragments, passive rearrangements occur when the resting condition is assumed, and the cells flatten down upon one another (fig. 22). The cells of the ventral half segment at the next period of activity (fig. 23), while the dorsal cells remain undivided. The resulting $\frac{12}{48}$ stage, although solid, is nevertheless derived from the $\frac{1}{4}$ blastomere through a segmentation of a partial character. This partial character is expressed chiefly in the characteristic rhythm of cleavage.

Concerning the later stages, the results of Driesch are again confirmed. The young larvæ represented in Figs. 25, 26 of this paper illustrate one point further, although of minor consequence. It will be seen that the long axis of the $\frac{1}{4}$ larva in fig. 25, and the long axes of the $\frac{1}{4}$ larvæ derived from the same egg, in fig. 26, are approximately parallel to the principal dorso-ventral-axis of the original egg.

## Summary and Conclusion.

An isolated blastomere of the Molgula egg segments as if still forming a corresponding part of an entire embryo. The *cleavage phenomena* are strictly *partial*, as regards the origin of cells, the inclination of cleavage-planes, and especially in respect to the rhythm of segmentation. The general appearance of the fragment differs materially from that of a half of a complete embryo, for the reason that rearrangements of the blastomeres occur, which tend progressively to mask the partial nature of development. The end result is a larva of less than normal size, and with defects in certain of its systems. These defects are undoubtedly due to the fact that but a portion of the normal amount of material is available for the formation of the larva; that, for instance, the chorda of a larva derived from a one-half blastomere, receives but one-half of the normal number of cells, and consequently a chorda of one row, and not two rows of cells, results.

In conclusion, one is constrained to adopt the view of Roux-namely, that in Molgula as in the well-known case of the echino, derms (Driesch, Wilson, and others) the development begins as a partial one, but that the missing part is gradually supplied by the cells already present. Driesch is also entirely correct, as far as the end result, a nearly complete larva, is concerned.

## Explanation of Plate IV.

Magnification of figs. 1–3 about 280 diameters; of all other figures, 250 diameters. The arrows show the direction of cleavage.

Fig. 1, 8-cell stage of *Ciona* from Castle (fig. 23), from the left side.

Fig. 2, 16-cell stage of *Ciona* from Castle (fig. 24), from the left side.

Fig. 3, 24-cell stage of *Ciona* from Castle (fig. 43), from the right side.

Figs. 4–8, cleavage of the left $\frac{1}{2}$ blastomere of *Molgula*, from the side.

Fig. 4, $\frac{2}{4}$ embryo.

Fig. 5, $\frac{4}{8}$ embryo.

Fig. 6, $\frac{8}{16}$ embryo.
Fig. 7, passage to $\frac{12}{24}$ embryo.
Fig. 8, $\frac{16}{32}$ embryo.
Figs. 9–12, cleavage of the right $\frac{1}{2}$ blastomere, from the side.
Fig. 9, $\frac{4}{8}$ embryo.
Fig. 10, $\frac{8}{16}$ embryo.
Fig. 11, $\frac{12}{24}$ embryo.
Fig. 12, $\frac{16}{32}$ embryo.
Figs. 13–16, cleavage of the right $\frac{1}{2}$ blastomere, from the front.
Fig. 13, $\frac{2}{4}$ embryo.
Fig. 14, $\frac{4}{8}$ embryo.
Fig. 15, passage to $\frac{8}{16}$ embryo.
Fig. 16, complete $\frac{8}{16}$ embryo.

## Explanation of Plate V.

Figs. 17–24, cleavage of the $\frac{1}{4}$ blastomere, ventral view.
Fig. 17, $\frac{2}{8}$ embryo.
Fig. 18, passage to $\frac{4}{16}$.
Fig. 19, complete $\frac{4}{16}$.
Fig. 20, $\frac{6}{24}$ embryo.
Fig. 21, $\frac{8}{32}$ embryo, immediately after division.
Fig. 22, $\frac{8}{32}$ embryo, in resting condition.
Fig. 23, passage to $\frac{12}{48}$ stage.
Fig. 24, complete $\frac{12}{48}$ embryo.
Fig. 25, $\frac{1}{4}$ larva. The arrow indicates the long axis.
Fig. 26, two $\frac{1}{4}$ larvæ, from same egg. The arrows indicate the principal axes.

## III.—*The Rutherfurd Photographic Measures of Sixty-five Stars near 61 Cygni.*

BY HERMAN S. DAVIS.

Read May, 1897.

**1.** It was but natural that MR. RUTHERFURD, in developing the art of astronomical photography, should try his skill upon that star which has attracted the attention of so many investigators ever since BESSEL proved by it the possibility of determining stellar parallax.

Of these photographs of *61 Cygni* and its surrounding stars taken by Mr. RUTHERFURD, nineteen, exposed between 1871, Nov. 9, and 1874, June 13, were measured by Miss Ida Martin more than twenty years ago, but have remained unreduced until recently placed in my hands for that purpose by Professor J. K. REES, Director of the Observatory. The present paper contains the results of measures of position of stars surrounding *61 Cygni*, and will be followed by a second paper containing the results of an investigation of the *Parallax of 61¹ Cygni.* The methods of reduction used so far as measures of distance are concerned are those presented by Dr. HAROLD JACOBY in earlier *Contributions* from this Observatory.

**2.** In Table I are given the general data of exposure of the plates, including the computed values of the zenith-distance, parallactic angle and refraction factor.

**3.** Table II contains the *means* of the refractions computed for the Eastern and Western impressions from the data of Table I by the formulæ

$$\frac{\sigma - s}{s} = \kappa\,[\tan^2\zeta \cos^2(p - q) + 1]$$

$$\pi - p = -\tfrac{1}{2}\kappa \operatorname{cosec} 1'' \tan^2\zeta \sin 2\,(p - q).$$

The argument for entering this table is $p$.

**4.** Table III.—The corrections to the position-angle due to precession, nutation and aberration will be found in column two. These were computed by the formulæ

$$\alpha' = 20.''06 \sin\alpha \sec\delta \qquad \gamma' = \cos\alpha \tan\delta$$
$$\beta' = \cos\alpha \sec\delta \qquad \delta' = \sin\alpha \tan\delta$$
$$\Delta p = (T - t)\,\alpha' - A\alpha' - B\beta' - C\gamma' - D\delta'.$$

The epoch $T = 1873.0$ has been selected to which to reduce all the observations. The substitution of the coördinates of *61*[1] *Cygni* for this epoch gives:

$$\Delta p_{71} = -36'' + [1.254]\,A + [9.956_n]\,B + [9.746_n]\,C + [9.742]\,D.$$
$$\Delta p_{72} = -18 \ + [1.254]\,A + [9.956_n]\,B + [9.746_n]\,C + [9.742]\,D.$$
$$\Delta p_{73} = \ \ 0 \ + [1.254]\,A + [9.956_n]\,B + [9.746_n]\,C + [9.742]\,D.$$
$$\Delta p_{74} = +18 \ + [1.254]\,A + [9.956_n]\,B + [9.746_n]\,C + [9.742]\,D.$$

Where $\Delta p_{71}$ denotes the correction to be applied to the position-angle for the plates made in 1871, and so on in the other years as denoted by the subscripts.

**5.** Precession and nutation have no effect upon the distances; but aberration does have, and its amount is given by:

$$\gamma'' = (\tan\varepsilon \sin\delta + \sin\alpha \cos\delta) \sin 1''$$
$$\delta'' = -\cos\alpha \cos\delta \sin 1''$$
$$\Delta s = (C\gamma'' + D\delta'')\,s$$

For *61*[1] *Cygni* this becomes

$$\Delta s = \{[4.141_n]\,C + [4.433_n]\,D\}\,s \qquad \text{for all years,}$$

and is additive to the distances to reduce them to 1873.0. This factor of $s$ is given in column three of Table III.

**6.** The logarithms of the Besselian day-numbers, taken from the *American Ephemeris*, are:

| Plates. | log A. | log B. | log C. | log D. |
|---|---|---|---|---|
| 1, | 9.692 | $0.035_n$ | 1.104 | 1.178 |
| 2, 3, | 9.699 | $0.022_n$ | 1.077 | 1.198 |
| 4, | 9.774 | $0.583_n$ | 0.840 | 1.279 |
| 5, 6, | 9.816 | $0.580_n$ | 0.244 | 1.309 |
| 7, | 9.821 | $0.582_n$ | 0.038 | 1.310 |
| 8, 9, | 9.788 | $0.807_n$ | 1.043 | 1.218 |
| 10, | 9.800 | $0.802_n$ | 0.985 | 1.244 |
| 11, 12, 13, | 9.805 | $0.801_n$ | 0.958 | 1.253 |
| 15, | 9.336 | $0.857_n$ | $0.776_n$ | $1.287_n$ |
| 16, 17, | 9.411 | $0.854_n$ | $0.418_n$ | $1.306_n$ |
| 18, 19, 20. | 9.417 | $0.854_n$ | $0.364_n$ | $1.307_n$ |

**7.** In the second portion of Table III. is given the mean of the

East and West zero-corrections computed for each by the formula *

$$v = \tfrac{1}{2} k z \tan \delta - y + x$$

in which $v$ is the zero-correction to be added to all observed position angles of each plate.

In the next column are the special corrections † required by the position-angles of the Western impressions in consequence of using the same zero-point in measuring both Eastern and Western impressions.‡ The sum of these two columns is then given in column six, which, therefore, contains the final correction as actually applied in the reductions.

**8.** In Table IV. is given the tangent correction. This is always negative and its unit is .0001 divisions of the micrometer. It has been computed by the formula:

$$\text{Correction} = -\tfrac{1}{3} s^3 d^2 \sin^2 1'' = [1.7887_n] \, s^3$$

where $s$ denotes the distance in divisions of the glass scale and $d$ is the value of one division of the scale in seconds of arc.

## Table V.—Measures of Distance.

**9.** The first column contains the numbers of the stars in order of right ascension and also in parentheses, for convenience of reference to the original measures and plates, are the numbers as assigned by Rutherfurd. The number of the plate is given in column two, after which follows the *observed* distances for the Eastern and Western impressions. The numbers set down are the fractional part of the measured distance expressed in divisions of the glass scale, the whole number of divisions being ordinarily the same as that given in the *final corrected distance.* Where there is a change of .8 or .9 in the observed distance, it is an indication of a change of a unit in the whole number of divisions in passing from the observed distance to the corrected mean. In columns five, six and seven are placed the corrections as applied for refraction,§ aberration‖ and scale¶ respectively; these, with addition of

* Annals N. Y. Acad. of Sci., Vol. VI., p. 272.

† Ibid., p. 278.

‡ Ibid., p. 240.

§ Table II and Paragraph 2.

‖ Table III and Paragraph 4.

¶ *Pleiades*, pp. 242–251.

the tangent correction only—which may be obtained directly from Table IV, being practically constant for each star—present all the corrections which have been applied to the observed *mean* distance of the East and West impressions to get the *corrected mean* of column eight.

**10.** It is noticeable that among these corrected means the distances belonging to some of the plates are always larger than the average and to other plates always smaller. To get rid of this variation of scale value, whatever may be its cause, I have selected the following four stars as standards:

| No. | Distance. | sin p. | cos p. |
|---|---|---|---|
| 5 | 77.2926 | —0.998 | +0.054 |
| 23 | 89.2118 | —0.068 | +0.998 |
| 32 | 77.0019 | +0.127 | —0.992 |
| 48 | 50.7333 | +0.962 | —0.274 |
| Sums | 294.2396 | +0.02 | —0.21 |

Now, if $s_5$, $s_{23}$, $s_{32}$, $s_{48}$ represent the distances of stars 5, 23, 32 and 48 from *61*[1] *Cygni* on any given plate and $\sum s_s$ the sum of the standard distances, there must be added to every distance on that plate for any other star its proportional part of the difference between the mean of the sums of the distances of the standard stars and their separate sums for that particular plate, or:

$$\text{Scale variation} = \frac{\Sigma s_s - (s_5 + s_{23} + s_{32} + s_{48})}{\Sigma s_s} s$$

The following table gives the value of this coefficient of $s$ for each plate. The individual values of *scale variation* are given in column nine of Table V.

| Plate. | Scale Variation Factor × $10^3$. |
|---|---|
| 1 | + .1948 |
| 2 | + .2275 |
| 3 | + .1666 |
| 4 | — .0027 |
| 5 | + .0439 |
| 6 | + .0894 |
| 7 | + .0928 |
| 8 | — .1272 |
| 9 | — .0442 |
| 10 | — .0408 |
| 11 | — .0714 |
| 12 | — .0598 |
| 13 | — .0129 |
| 15 | — .1047 |
| 16 | — .0670 |
| 17 | — .0714 |
| 18 | — .0537 |
| 19 | — .0326 |
| 20 | — .1241 |

**11.** The measures of distance are next to be corrected for the proper motion of the central star. For this purpose let:

$t$ = date of the plate.
$\tau = t - 1873.0$
$\rho$ = annual motion on great circle
$\chi$ = position-angle of that great circle

$$S_1 = \cos(\chi - p)$$
$$S_2 = -\frac{1}{2s}\sin^2(\chi - p)$$
$$P_1 = \tau\rho$$
$$P_2 = \tau^2\rho^2$$

The correction for proper motion, additive to observed distances, will then be:

$$\Delta s = S_1 P_1 + S_2 P_2$$

I have adopted AUWERS's values of

$$\mu = +0\overset{s}{.}3444, \qquad \mu' = +3\overset{''}{.}230,$$

as given in the *Fundamental Catalog*. Corresponding to these are:

$$\rho = 5\overset{''}{.}1904 = 0\overset{d}{.}18528, \qquad \chi = 51^\circ\ 30'\ 56''$$

The values of $p$ used in the above formulæ were the means after correction for "zero" and refraction, as explained in paragraph 7; and the values of $s$ were after correction for scale variation.

**12.** The values of $S_1$ and $S_2$ will be found in columns two and three of Table VII. The following table gives $\tau$, $P_1$, and $P_2$:

| Plate. | $\tau$ | For Proper Motion. $P_1$ | For Proper Motion. $P_2$ |
|---|---|---|---|
| 1 | — 1.142 | — 0.2116 | + 0.045 |
| 2 | — 1.134 | — 0.2101 | + 0.044 |
| 3 | — 1.134 | — 0.2101 | + 0.044 |
| 4 | — 0.085 | — 0.0157 | + 0.000 |
| 5 | — 0.041 | — 0.0076 | + 0.000 |
| 6 | — 0.041 | — 0.0076 | + 0.000 |
| 7 | — 0.036 | — 0.0067 | + 0.000 |
| 8 | + 0.876 | + 0.1623 | + 0.026 |
| 9 | + 0.876 | + 0.1623 | + 0.026 |
| 10 | + 0.890 | + 0.1649 | + 0.027 |
| 11 | + 0.895 | + 0.1658 | + 0.027 |
| 12 | + 0.895 | + 0.1658 | + 0.027 |
| 13 | + 0.895 | + 0.1658 | + 0.027 |
| 15 | + 1.418 | + 0.2627 | + 0.069 |
| 16 | + 1.448 | + 0.2683 | + 0.072 |
| 17 | + 1.448 | + 0.2683 | + 0.072 |
| 18 | + 1.451 | + 0.2688 | + 0.072 |
| 19 | + 1.451 | + 0.2688 | + 0.072 |
| 20 | + 1.451 | + 0.2688 | + 0.072 |

**13.** As the quantity which depends on the square of the time is always small for a star having even so large a proper motion as *61 Cygni*, its values may be tabulated for limiting values of $S_2$. Such a table as used in the present paper is:

| $S_2 P_2$ \ Plates | 1 | 2, 3 | 4, 5, 6, 7 | 8, 9 | 10, 11, 12, 13 | 15 | 16, 17, 18, 19, 20 |
|---|---|---|---|---|---|---|---|
| — .0000 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| — 1 | 11.2 | 11.3 | 140.0 | 19.0 | 18.2 | 7.2 | 6.9 |
| — 2 | 33.5 | 34.0 | | 57.0 | 54.8 | 21.7 | 20.7 |
| — 3 | 55.8 | 56.7 | | 95.0 | 91.2 | 36.2 | 34.7 |
| — 4 | 78.2 | 79.3 | | 133.1 | 127.8 | 50.7 | 48.5 |
| — 5 | 100.5 | 102.0 | | | 164.2 | 65.2 | 62.4 |
| — 6 | 122.8 | 124.6 | | | 200.8 | 79.7 | 76.2 |
| — 7 | 145.1 | 147.3 | | | | 94.2 | 90.1 |
| — 8 | | | | | | 108.7 | 104.0 |
| — .0009 | | | | | | 123.2 | 117.8 |
| | | | | | | 137.7 | 131.7 |

The figures at the tops of the columns are the numbers of the plates to which the columns are applicable as determined by their values of $P_2$. Selecting, therefore, the proper column and using $S_2$ as the argument in the body of the table (where it is expressed in units of the fourth decimal place), one will find in the first column the desired value of $S_2 P_2$, expressed in divisions of the scale. Column ten of Table V gives the total proper motion correction.

**14.** A correction for parallax of the principal star was next applied. Using AUWERS's values of the coördinates of *61*[1] *Cygni* reduced to 1873.0

$$\alpha = 21^h \; 01^m \; 12^s.329$$

$$\delta = 38^\circ \; 07' \; 33''.40$$

and the almanac values of $r$ and $\odot$, the radius vector and longitude of the sun respectively, the values of $S_3$, $S_4$, $P_3$ and $P_4$ were computed by the formulæ

$$g \sin G = \sin \delta \cos \alpha \qquad\qquad h \sin H = \sin \delta \sin \alpha$$
$$g \cos G = \sin \alpha \qquad\qquad h \cos H = -\cos \delta$$

$$f \sin F = h \sin (H + \varepsilon)$$
$$f \cos F = -\cos \alpha \cos \varepsilon$$

$$S_3 = f \sin (p + F)$$
$$S_4 = g \sin (p + G)$$

$$P_3 = -r \sin \odot$$
$$P_4 = -r \cos \odot$$

The value of $p$ used here was the mean of the position-angles after correction for proper motion and orientation variation, as described in paragraphs 17 and 19. The values of $P_3$ and $P_4$ are:

| Plates. | For Parallax. | |
|---|---|---|
| | $P_3$ | $P_4$ |
| 1 | + 0.727 | + 0.672 |
| 2 | + 0.761 | + 0.632 |
| 3 | + 0.761 | + 0.632 |
| 4 | + 0.915 | + 0.366 |
| 5 | + 0.979 | + 0.096 |
| 6 | + 0.979 | + 0.095 |
| 7 | + 0.982 | + 0.061 |
| 8 | + 0.798 | + 0.583 |
| 9 | + 0.798 | + 0.583 |
| 10 | + 0.845 | + 0.511 |
| 11 | + 0.862 | + 0.481 |
| 12 | + 0.862 | + 0.480 |
| 13 | + 0.862 | + 0.480 |
| 15 | — 0.962 | — 0.322 |
| 16 | — 1.006 | — 0.142 |
| 17 | — 1.006 | — 0.142 |
| 18 | — 1.008 | — 0.125 |
| 19 | — 1.008 | — 0.125 |
| 20 | — 1.008 | — 0.125 |

In Table VIII, columns two and three, will be found $S_3$ and $S_4$. The *coefficient* of the parallax, as printed in column eleven of Table V is

$$S_3P_3 + S_4P_4$$

and the correction, additive to the distances, is

$$(S_3P_3 + S_4P_4)\,\frac{\Pi}{28.''0124}$$

where $\Pi$ is the parallax expressed in seconds of arc. Table XI gives values of this quantity corresponding to limiting values of the coefficient. The method of using this table is the same as described in paragraph 13. In its construction I used*

$$\Pi = +\,0.''3597$$

**15.** The distances thus corrected for all known disturbances affecting the central star, *61*[1] *Cygni*, are given in column twelve of Table V. In this column are also the *means* of the distances.

### Table VI.—Measures of Position-angle.

**16.** This table has been put on pages opposite the correspond-

* The Parallax of *61*[1] *Cygni* as deduced from Rutherfurd Photographic Measures, by Herman S. Davis. *Contribution No. 13.*

ing measures of distance in Table V. The first column is a repetition of the number of the plate. In columns two and three are given the *observed* angles for the eastern and western impressions. The number of degrees for the *west* column are the same as printed in the *east* column, except where there is an obvious change of $\pm 1^\circ$ indicated by a difference of nearly $60'$ in the minutes of the two columns.

In column four are placed the zero-corrections of paragraph 7 plus the special corrections due to the precession, etc., mentioned in the same paragraph. This quantity is taken from the last column of Table III. The correction for refraction from Table II is in column five. The mean of the east and west impressions thus corrected is placed in column six.

**17.** In column seven of Table VI is the correction due to proper motion of the central star. This has been computed from the following formulæ:*

Let $t$, $\tau$, $S_1$, $P_1$, $P_2$, $\rho$ and $\chi$ have the same meaning as in paragraph 11; also let

$$S_5 = \sin(\chi - p)$$
$$S_6 = \frac{1}{\sigma}$$
$$S_7 = S_5 S_6$$
$$P_5 = \tau\rho \operatorname{cosec} 1''$$
$$K = -\left\{ P_1 \sin\chi \tan\delta + \tfrac{1}{2} P_2 \sin 1'' \sin\chi \cos\chi \,(1 + 2\tan^2\delta) \right\}$$

Then will the correction for proper motion, additive to observed angles, be

$$\Delta p = S_7 P_5 \,(1 + S_1 P_1 \cdot S_6) + K.$$

Throughout these formulæ $\rho$ and $\sigma$ are to be expressed in divisions of the scale, whereas $K$ and $\Delta p$ are in seconds of arc. The convenience of expressing $\Delta p$ in this form is more noticeable when it is remembered that $S_1 P_1$ has already been computed for use in correcting the distances; see paragraph 11. Here $\sigma$ is to represent the value of $s$ after being corrected for scale variation and proper motion.

**18.** As $K$ is obviously a constant for all stars on the same plate, being only that part of the variation in $(\chi - p)$ due to the

* Handbuch der Vermessungskunde von Dr. W. Jordan, Bd. III. S. 359. Vierte Auflage.

effect of meridian-convergence upon the value of $\chi$ at different dates, we have for *61¹ Cygni:*

$$K = -17''.2094\ P_1$$

the term in $P_2$ being neglected, as its maximum value in the present research is only $\pm 0.''00015$.

The following table gives $K$ for the various plates, and also the values of $P_5$; while in columns four, five and six of Table VII will be found $S_5$, $S_6$ and $S_7$.

| Plate. | For Proper Motion. | |
|---|---|---|
| | $K$ | $P_5$ |
| 1 | + 3.″6 | — 43644. |
| 2 | + 3.6 | — 43338. |
| 3 | + 3.6 | — 43338. |
| 4 | + 0.3 | — 3248. |
| 5 | + 0.1 | — 1567. |
| 6 | + 0.1 | — 1567. |
| 7 | + 0.1 | — 1376. |
| 8 | — 2.8 | + 33478. |
| 9 | — 2.8 | + 33478. |
| 10 | — 2.8 | + 34013. |
| 11 | — 2.8 | + 34204. |
| 12 | — 2.8 | + 34204. |
| 13 | — 2.8 | + 34204. |
| 15 | — 4.5 | + 54191. |
| 16 | — 4.6 | + 55338. |
| 17 | — 4.6 | + 55338. |
| 18 | — 4.6 | + 55452. |
| 19 | — 4.6 | + 55452. |
| 20 | — 4.6 | + 55452. |

**19.** *Orientation Variation.*—When the angles have been corrected as described above, observation of the *corrected mean* plus *proper motion* in Table VI reveals a variation of measures on some of the plates from the mean of all that is erratic, and in some cases very considerable in magnitude. This is undoubtedly due to the method which Rutherfurd used for the orientation of his plates.

It was his custom in making the exposures to take two impressions of the stars on each plate. After the second, or western impression, the telescope clock was stopped, and the stars were allowed to trail across the plate for a distance of sixty to eighty scale-divisions. The clock was then again made to run long enough to permit the formation of another image of the central star. The line joining this last image with the central image was used as the origin of the position-angles. Angles so measured were made in the present paper to conform to the custom of counting from the north point towards the east by addition of 270° to the observed readings, as seen in Table VI.

Of course the position-angle of this last impression of the principal star is not exactly 270°, however, unless there has been absolutely no shifting of the telescope in declination during the formation of the trail, or when clamping in the clock for the final image. It is *a priori* probable that such shifting did occur; but with such alterations in the balance-weights of the tube, in the pointing of the telescope, and in the other conditions of exposure of many plates during the course of several years, we may fairly assume, on the other hand, that such shifting in declination is not systematically in the same direction; that, consequently, the mean of the position-angles of a given star as determined from all the plates is its most probable value. Hence, if all the stars were found on all the plates, it would be unnecessary to apply a correction for error of orientation. But such is not the case. Furthermore it is desirable to use the individual measures separately for a determination of the parallax.

This correction may be deduced from standard stars by taking from the mean of all the angles of all the plates the angle measured on each plate separately, and regarding the residual as the orientation variation of that plate. For any particular star such residuals would not, however, be the true correction; for it would contain the effect of both the proper motion and the parallax of the central star. Several stars should, therefore, be selected as standards; and they should be so distributed in distance and angle as to eliminate both parallax and proper motion from the mean of their residuals for each plate severally. Since the probable error of measures of angle vary inversely as the distance, these means should be taken by weight proportional to the square of the distance.

Expressed symbolically these conditions are:

A. $$\frac{\Sigma\sigma^2 S_8}{\Sigma\sigma^2} = 0 \quad \text{and} \quad \frac{\Sigma\sigma^2 S_9}{\Sigma\sigma^2} = 0$$

B. $$\Sigma S_7 = 0.$$

The significance of $S_8$ and $S_9$ will be found in paragraph 22, and of $S_7$ in paragraph 17.

**20.** It is easily seen that both $A$ and $B$ cannot be satisfied at the same time, unless the direction of proper motion of the principal star coincide with the major or the minor axis of the parallactic ellipse. This fortunately is very nearly the case with *61[1] Cygni;* wherefore it would have been immaterial here whether the angles of the standard stars had been corrected for proper motion or not, though as a matter of fact they were so corrected; as would ordinarily be necessary.

**21.** If stars can be found on all the plates which will satisfy only very closely, but not exactly, condition $A$, the *residuum* of the parallactic effect may be more nearly eliminated by adding to the orientation variation deduced from such stars the quantity

$$\left\{ \frac{(P_3' - P_3)\,\Sigma\sigma^2 S_8}{\Sigma\sigma^2} + \frac{(P_4' - P_4)\,\Sigma\sigma^2 S_9}{\Sigma\sigma^2} \right\} \Pi'$$

where the primed $P_3'$ and $P_4'$ are the means of the values of $P_3$ and $P_4$ for all the plates, and where $\Pi'$ is an approximate value of the parallax, or a value deduced from the measures of distance.

In this paper the following six stars were selected as the standards:

| Star | $\sigma^2 S_8$ | $\sigma^2 S_9$ | $S_7$ | $\sigma^2$ |
|---|---|---|---|---|
| 5 | —423898.2 | +227748.4 | +0.008588 | 5962. |
| 6 | — 90170.0 | +550938.7 | — .000240 | 9017. |
| 13 | —611921.1 | —381846.5 | + .009566 | 9667. |
| 23 | —459811.3 | —441482.6 | + .009229 | 7969. |
| 32 | +418587.4 | +364040.6 | — .011118 | 5929. |
| 48 | +322758.0 | — 85914.0 | — .016022 | 2580. |

These give:

$$\frac{\Sigma\sigma^2 S_8}{\Sigma\sigma^2} = -20.5 \qquad \frac{\Sigma\sigma^2 S_9}{\Sigma\sigma^2} = +5.7 \qquad \Sigma S_7 = -.000003$$

which shows that they are admirably adapted to the present purpose. From these stars, therefore, and with $\Pi' = +0.''40$ have been deduced the following corrections, additive to observed position-angles.

| Plate. | Orientation Variation. |
|---|---|
| | ′ ″ |
| 1 | + 0 13 |
| 2 | + 1 0 |
| 3 | + 0 6 |
| 4 | — 0 35 |
| 5 | — 0 8 |
| 6 | + 0 17 |
| 7 | + 3 21 |
| 8 | — 0 12 |
| 9 | — 0 30 |
| 10 | — 0 21 |
| 11 | — 0 31 |
| 12 | + 0 11 |
| 13 | + 0 24 |
| 15 | — 0 19 |
| 16 | — 0 29 |
| 17 | — 2 5 |
| 18 | — 0 50 |
| 19 | — 0 1 |
| 20 | + 0 14 |

**22.** In column eight of Table VI are given the parallax coefficients. They have been computed by the formulæ:

$$S_8\,P_3 + S_9\,P_4$$

where:

$$S_8 = \frac{f \operatorname{cosec} 1''}{28.''0124}\,S_6 \cos(\pi + F)$$

$$S_9 = \frac{g \operatorname{cosec} 1''}{28.''0124}\,S_6 \cos(\pi + G)$$

$$S_6 = \frac{1}{\sigma}$$

and where $f$, $g$, $F$, $G$, $P_3$, and $P_4$ have the same meaning as in paragraph 14. The value of the position-angle used here, $\pi$, is the angle $p$ corrected for proper motion and orientation variation. The quantities $S_8$, $S_9$, and $S_6$ are in columns four and five of Table VIII and five of Table VII respectively. $P_3$ and $P_4$ are tabulated in paragraph 14.

**23.** After adding to the observed angle the correction

$$(S_8\,P_3 + S_9\,P_4)\ \Pi$$

taken from Table XI with the parallax coefficient of column eight, Table VI, as the argument we have the final corrected angle given in the last column of Table VI.

**24.** Table IX.—Column three contains the mean of the final position-angles of Table VI, and column two the mean of the distances, converted to seconds of arc by the scale value 28.″0124. These are followed in columns four and five by the differences of right ascension and of declination derived by aid of the formulæ :

| | Logarithms for Plates of $61^1$ *Cygni* only. |
|---|---|
| $n = \sigma \sin \pi$ | |
| $m = \sigma \cos \pi$ | |
| $P = \sec \delta$ | $= [0.104215]$ |
| $Q = [4.685575\ ] \tan \delta \sec \delta$ | $= [4.6846\ ]$ |
| $R = [8.89403_n\ ] \tan^2 \delta \sec \delta$ | $= [8.7878_n\ ]$ |
| $S = [8.89403\ ] \sec \delta\ (1 + 3 \tan^2 \delta)$ | $= [9.4528\ ]$ |
| $T = [4.384545_n] \tan \delta$ | $= [4.2793_n\ ]$ |
| $U = [8.59300_n\ ]\ (1 + 3 \tan^2 \delta)$ | $= [9.0475_n\ ]$ |
| $V = [3.57960_n\ ] \sec \delta \tan \delta\ (1 + 3 \tan^2 \delta)$ | |
| $W = [3.57960\ ] \sec \delta \tan \delta\ (2 + 3 \tan^2 \delta)$ | |

$$\alpha' - \alpha = Pn + Qnm + Rn^3 + Snm^2 + (Vn^3m + Wnm^3)$$
$$\delta' - \delta = m + Tn^2 + Un^2m$$

where $\sigma$ and $\pi$ are the final corrected mean distance and position-angle respectively of the star whose $\alpha'$ and $\delta'$ are desired. It was found also that the terms in $V$ and $W$ were not needed, since they are so nearly equal and have contrary signs.

In column six is the number of plates on which the image of the star was impressed; though it is proper to state that the given position is the result of at least twenty measures of distance and twelve of position-angle for *each* plate recorded in this column.

In columns seven and eight are the *Durchmusterung* number and magnitude for as many of the stars as could be identified. A few of those found in the *Durchmusterung* but not found on these plates, though of much brighter magnitude than many which are on the plates, no doubt are missing because of their color; as obviously light from reddish stars affects the plate but little, though optically it may appear quite bright.

**25.** Table X is on pages opposing Table IX and gives the right ascensions and declinations of each star. These were obtained by adding the $\alpha' - \alpha$, $\delta' - \delta$ of Table X to AUWERS's position of $61^1$ *Cygni* reduced to 1873.0 with the constants given in the *Fundamental Catalog:*

$$\left.\begin{array}{l} \alpha = 21^{h}\ 01^{m}\ 12^{s}.329 \\ \delta = 38^{\circ}\ 07'\ 33''.40 \end{array}\right\} 1873.0$$

The other columns contain the precession constants, whereby the positions of these stars may be reduced to another epoch, $T$, by the formulæ :

$$a_T = a_{1873} + J(T - 1873) + K\frac{(T - 1873)^2}{200}.$$

$$\delta_T = \delta_{1873} + L(T - 1873) + M\frac{(T - 1873)^2}{200}.$$

TABLE I.—GENERAL DATA.—Observatory of L. M. Rutherfurd, New York.

Lat. $= 40^\circ\ 43'\ 48''.5$ Long. $= 4^h\ 55^m\ 56^s.62$ W

| Plate. | Date. | | Sidereal Time. | Hour Angle. | Barom. | Att. Therm. | Ext. Therm. | Tel. Therm. | Focus. | Zero. | $\zeta$ | $q$ | Log. $\kappa$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | h m s | h m s | | ° | ° | ° | | | ° | ° | |
| 1 | 1871 | Nov. 9 | 0 11 5 | 3 9 56 | 29.988 | 45 | 42 | 45 | 7.7 | 70.38 | 36.32 | +70.57 | 6.4559 |
| 2 | | Nov. 12 | 23 58 5 | 2 56 56 | 30.460 | 38 | 35 | 38 | 7.8 | 77.08 | 33.91 | +71.38 | 6.4690 |
| 3 | | Nov. 12 | 0 28 20 | 3 27 11 | 30.460 | 38 | 35 | 40 | 7.8 | 77.19 | 39.50 | +69.38 | 6.4685 |
| 4 | 1872 | Nov. 29 | 0 18 47 | 3 17 35 | 29.748 | 25 | 22 | 25 | 8.0 | 69.72 | 37.74 | +70.04 | 6.4706 |
| 5 | | Dec. 15 | 0 14 47 | 3 13 35 | 30.150 | 35 | 34 | 35 | 7.9 | 63.56 | 37.01 | +70.31 | 6.4654 |
| 6 | | Dec. 15 | 1 21 2 | 4 19 50 | 30.150 | 35 | 34 | 35 | 7.8 | 63.18 | 49.07 | +65.33 | 6.4641 |
| 7 | | Dec. 17 | 0 45 52 | 3 44 40 | 30.328 | 33 | 32 | 33 | 7.9 | 69.44 | 42.71 | +68.10 | 6.4695 |
| 8 | 1873 | Nov. 15 | 0 28 20 | 3 27 7 | 29.716 | 35 | 35 | 35 | 8.0 | 70.05 | 39.50 | +69.38 | 6.4581 |
| 9 | | Nov. 15 | 1 8 12 | 4 6 59 | 29.716 | 35 | 35 | 35 | 7.9 | 76 95 | 46.76 | +66.40 | 6.4574 |
| 10 | | Nov. 20 | 23 26 2 | 2 24 49 | 30.070 | 32 | 30 | 32 | 7.9 | 71.01 | 27.88 | +73.13 | 6.4682 |
| 11 | | Nov. 22 | 23 5 47 | 2 4 34 | 30.392 | 38 | 37 | 40 | 7.8 | 77.15 | 24.10 | +73.95 | 6.4667 |
| 12 | | Nov. 22 | 23 47 2 | 2 45 48 | 30.392 | 38 | 37 | 40 | 7.8 | 84.37 | 31.82 | +72.05 | 6.4663 |
| 13 | | Nov. 22 | 0 24 47 | 3 23 33 | 30 392 | 38 | 37 | 40 | 7.8 | 70.29 | 38.83 | +69 67 | 6.4660 |
| 15 | 1874 | June 1 | 18 12 47 | 21 11 30 | 29.984 | 60 | 55 | 60 | 7.7 | 68.32 | 32.33 | —71.88 | 6.4442 |
| 16 | | June 12 | 16 49 32 | 19 48 15 | 29.950 | 71 | 69 | 70 | 7.64 | (63.00) | 47.64 | —66.03 | 6.4303 |
| 17 | | June 12 | 17 19 22 | 20 18 5 | 29 950 | 71 | 69 | 70 | 7.64 | 63.18 | 42.20 | —68.33 | 6.4312 |
| 18 | | June 13 | 16 59 2 | 19 57 45 | 30.300 | 59 | 57 | 60 | 7.7 | (62.88) | 45.90 | —66.77 | 6.4461 |
| 19 | | June 13 | 17 29 32 | 20 28 15 | 30.300 | 59 | 57 | 60 | 7.7 | 63.67 | 40.34 | —69.07 | 6.4466 |
| 20 | | June 13 | 18 3 2 | 21 1 45 | 30.300 | 59 | 57 | 60 | 7.7 | 70.22 | 34.14 | —71.30 | 6.4472 |

## Table II.—Corrections for Refraction.

| Position Angle, $p$. | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ | Position Angle, $p$. | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ |
|---|---|---|---|---|---|---|---|
| Plate 1. | | | | Plate 2. | | | |
| 71° | 251° | +.440 | ″ 0.0 | 71° | 251° | +.427 | ″ 0.0 |
| 81 | 261 | .436 | — 5.4 | 81 | 261 | .423 | — 4.7 |
| 91 | 271 | .422 | —10.2 | 91 | 271 | .411 | — 8.8 |
| 101 | 281 | .402 | —13.8 | 101 | 281 | .394 | —11.9 |
| 111 | 291 | .377 | —15.7 | 111 | 291 | .372 | —13.5 |
| 121 | 301 | .350 | —15.7 | 121 | 301 | .349 | —13.5 |
| 131 | 311 | .325 | —13.8 | 131 | 311 | .327 | —11.9 |
| 141 | 321 | .304 | —10.2 | 141 | 321 | .310 | — 8.8 |
| 151 | 331 | .291 | — 5.4 | 151 | 331 | .298 | — 4.7 |
| 161 | 341 | .286 | 0 0 | 161 | 341 | .294 | 0.0 |
| 171 | 351 | .291 | + 5.4 | 171 | 351 | .298 | + 4.7 |
| 181 | 1 | .304 | +10.2 | 181 | 1 | .310 | + 8.8 |
| 191 | 11 | .325 | +13.8 | 191 | 11 | .327 | +11.9 |
| 201 | 21 | .350 | +15.7 | 201 | 21 | .349 | +13.5 |
| 211 | 31 | .377 | +15.7 | 211 | 31 | .372 | +13.5 |
| 221 | 41 | .402 | +13.8 | 221 | 41 | .394 | +11.9 |
| 231 | 51 | .422 | +10.2 | 231 | 51 | .411 | + 8.8 |
| 241 | 61 | .436 | + 5.4 | 241 | 61 | .423 | + 4.7 |
| 251 | 71 | +.440 | 0.0 | 251 | 71 | +.427 | 0.0 |
| Plate 3. | | | | Plate 4. | | | |
| 69° | 249° | +.494 | ″ 0.0 | 70° | 250° | +.473 | ″ 0.0 |
| 79 | 259 | .488 | — 7.0 | 80 | 260 | .468 | — 6.3 |
| 89 | 269 | .471 | —13.2 | 90 | 270 | .453 | —11.8 |
| 99 | 279 | .444 | —17.8 | 100 | 280 | .429 | —15.8 |
| 109 | 289 | .411 | —20.3 | 110 | 290 | .400 | —18.0 |
| 119 | 299 | .377 | —20.3 | 120 | 300 | .369 | —18.0 |
| 129 | 309 | .344 | —17.8 | 130 | 310 | .340 | —15.8 |
| 139 | 319 | .318 | —13.2 | 140 | 320 | .317 | —11.8 |
| 149 | 329 | .300 | — 7.0 | 150 | 330 | .301 | — 6.3 |
| 159 | 339 | .294 | 0.0 | 160 | 340 | .296 | 0.0 |
| 169 | 349 | .300 | + 7.0 | 170 | 350 | .301 | + 6.3 |
| 179 | 359 | .318 | +13.2 | 180 | 0 | .317 | +11.8 |
| 189 | 9 | .344 | +17.8 | 190 | 10 | .340 | +15.8 |
| 199 | 19 | .377 | +20.3 | 200 | 20 | .369 | +18.0 |
| 209 | 29 | .411 | +20.3 | 210 | 30 | .400 | +18.0 |
| 219 | 39 | .444 | +17.8 | 220 | 40 | .429 | +15.8 |
| 229 | 49 | .471 | +13.2 | 230 | 50 | .453 | +11.8 |
| 239 | 59 | .488 | + 7.0 | 240 | 60 | .468 | + 6.3 |
| 249 | 69 | +.494 | 0.0 | 250 | 70 | +.473 | 0.0 |

TABLE II.—CORRECTIONS FOR REFRACTION. (*Continued.*)

| Position Angle, $p$. | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ | Position Angle, $p$. | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ |
|---|---|---|---|---|---|---|---|
| PLATE 5. | | | | PLATE 6. | | | |
| | | | ″ | | | | ″ |
| 70° | 250° | +.458 | 0.0 | 65° | 245° | +.678 | 0.0 |
| 80 | 260 | .453 | — 5.8 | 75 | 255 | .666 | —13.6 |
| 90 | 270 | .439 | —11.0 | 85 | 265 | .633 | —25.7 |
| 100 | 280 | .417 | —14.8 | 95 | 275 | .581 | —34.6 |
| 110 | 290 | .390 | —16.8 | 105 | 285 | .518 | —39.3 |
| 120 | 300 | .361 | —16.8 | 115 | 295 | .451 | —39.3 |
| 130 | 310 | .333 | —14.8 | 125 | 305 | .388 | —34.6 |
| 140 | 320 | .312 | —11.0 | 135 | 315 | .336 | —25.7 |
| 150 | 330 | .297 | — 5.8 | 145 | 325 | .303 | —13.6 |
| 160 | 340 | .292 | 0.0 | 155 | 335 | .291 | 0.0 |
| 170 | 350 | .297 | + 5.8 | 165 | 345 | .303 | +13.6 |
| 180 | 0 | .312 | +11.0 | 175 | 355 | .336 | +25.7 |
| 190 | 10 | .333 | +14.8 | 185 | 5 | .388 | +34.6 |
| 200 | 20 | .361 | +16.8 | 195 | 15 | .451 | +39.3 |
| 210 | 30 | .390 | +16.8 | 205 | 25 | .518 | +39.3 |
| 220 | 40 | .417 | +14.8 | 215 | 35 | .581 | +34.6 |
| 230 | 50 | .439 | +11.0 | 225 | 45 | .633 | +25.7 |
| 240 | 60 | .453 | + 5.8 | 235 | 55 | .666 | +13.6 |
| 250 | 70 | +.458 | 0.0 | 245 | 65 | +.678 | 0.0 |
| PLATE 7. | | | | PLATE 8. | | | |
| | | | ″ | | | | ″ |
| 68° | 248° | +.546 | 0.0 | 69° | 249° | +.482 | 0.0 |
| 78 | 258 | .539 | — 8.9 | 79 | 259 | .476 | — 6.9 |
| 88 | 268 | .517 | —16.7 | 89 | 269 | .459 | —12.9 |
| 98 | 278 | .484 | —22.4 | 99 | 279 | .433 | —17.4 |
| 108 | 288 | .443 | —25.5 | 109 | 289 | .402 | —19.8 |
| 118 | 298 | .399 | —25.5 | 119 | 299 | .367 | —19.8 |
| 128 | 308 | .358 | —22.4 | 129 | 309 | .336 | —17.4 |
| 138 | 318 | .325 | —16.7 | 139 | 319 | .310 | —12.9 |
| 148 | 328 | .303 | — 8.9 | 149 | 329 | .293 | — 6.9 |
| 158 | 338 | .295 | 0.0 | 159 | 339 | .287 | 0.0 |
| 168 | 348 | .303 | + 8.9 | 169 | 349 | .293 | + 6.9 |
| 178 | 358 | .325 | +16.7 | 179 | 359 | .310 | +12.9 |
| 188 | 8 | .358 | +22.4 | 189 | 9 | .336 | +17.4 |
| 198 | 18 | .399 | +25.5 | 199 | 19 | .367 | +19.8 |
| 208 | 28 | .443 | +25.5 | 209 | 29 | .402 | +19.8 |
| 218 | 38 | .484 | +22.4 | 219 | 39 | .433 | +17.4 |
| 228 | 48 | .517 | +16.7 | 229 | 49 | .459 | +12.9 |
| 238 | 58 | .539 | + 8.9 | 239 | 59 | .476 | + 6.9 |
| 248 | 68 | +.546 | 0.0 | 249 | 69 | +.482 | + 0.0 |

Table II.—Corrections for Refraction. (*Continued.*)

| Position Angle, $p$ | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ | Position Angle, $p$ | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ |
|---|---|---|---|---|---|---|---|
| Plate 9. | | | | Plate 10. | | | |
| 66° | 246° | +.612 | ″ 0.0 | 73° | 253° | +.376 | ″ 0.0 |
| 76 | 256 | .602 | —11.5 | 83 | 263 | .374 | — 2.9 |
| 86 | 266 | .574 | —21.5 | 93 | 273 | .367 | — 5.5 |
| 96 | 276 | .531 | —29.0 | 103 | 283 | .356 | — 7.3 |
| 106 | 286 | .477 | —33.0 | 113 | 293 | .342 | — 8.4 |
| 116 | 296 | .421 | —33.0 | 123 | 303 | .328 | — 8.4 |
| 126 | 306 | .368 | —29.0 | 133 | 313 | .314 | — 7.3 |
| 136 | 316 | .325 | —21.5 | 143 | 323 | .304 | — 5.5 |
| 146 | 326 | .297 | —11.5 | 153 | 333 | .296 | — 2.9 |
| 156 | 336 | .287 | 0.0 | 163 | 343 | .294 | 0.0 |
| 166 | 346 | .297 | +11.5 | 173 | 353 | .296 | + 2.9 |
| 176 | 356 | .325 | +21.5 | 183 | 3 | .304 | + 5.5 |
| 186 | 6 | .368 | +29.0 | 193 | 13 | .314 | + 7.3 |
| 196 | 16 | .421 | +33.0 | 203 | 23 | .328 | + 8.4 |
| 206 | 26 | .477 | +33.0 | 213 | 33 | .342 | + 8.4 |
| 216 | 36 | .531 | +29.0 | 223 | 43 | .356 | + 7.3 |
| 226 | 46 | .574 | +21.5 | 233 | 53 | .367 | + 5.5 |
| 236 | 56 | .602 | +11.5 | 243 | 63 | .374 | + 2.9 |
| 246 | 66 | +.612 | 0.0 | 253 | 73 | +.376 | 0.0 |
| Plate 11. | | | | Plate 12. | | | |
| 74° | 254° | +.352 | ″ 0.0 | 72° | 252° | +.406 | ″ 0.0 |
| 84 | 264 | .350 | — 2.1 | 82 | 262 | .403 | — 4.0 |
| 94 | 274 | .345 | — 3.9 | 92 | 272 | .393 | — 7.5 |
| 104 | 284 | .337 | — 5.2 | 102 | 282 | .378 | —10.0 |
| 114 | 294 | .327 | — 6.0 | 112 | 292 | .359 | —11.4 |
| 124 | 304 | .317 | — 6.0 | 122 | 302 | .339 | —11.4 |
| 134 | 314 | .308 | — 5.2 | 132 | 312 | .321 | —10.0 |
| 144 | 324 | .300 | — 3.9 | 142 | 322 | .306 | — 7.5 |
| 154 | 334 | .295 | — 2.1 | 152 | 332 | .296 | — 4.0 |
| 164 | 344 | .293 | 0.0 | 162 | 342 | .293 | 0.0 |
| 174 | 354 | .295 | + 2.1 | 172 | 352 | .296 | + 4.0 |
| 184 | 4 | .300 | + 3.9 | 182 | 2 | .306 | + 7.5 |
| 194 | 14 | .308 | + 5.2 | 192 | 12 | .321 | +10.0 |
| 204 | 24 | .317 | + 6.0 | 202 | 22 | .339 | +11.4 |
| 214 | 34 | .327 | + 6.0 | 212 | 32 | .359 | +11.4 |
| 224 | 44 | .337 | + 5.2 | 222 | 42 | .378 | +10.0 |
| 234 | 54 | .345 | + 3.9 | 232 | 52 | .393 | + 7.5 |
| 244 | 64 | .350 | + 2.1 | 242 | 62 | .403 | + 4.0 |
| 254 | 74 | +.352 | 0.0 | 252 | 72 | +.406 | 0.0 |

TABLE II. CORRECTIONS FOR REFRACTION. (*Continued.*)

| Position Angle, $p$. | | $\frac{\sigma-s}{s}\times 10^3$ | $\pi-p$ | Position Angle, $p$. | | $\frac{\sigma-s}{s}\times 10^3$ | $\pi-p$ |
|---|---|---|---|---|---|---|---|
| PLATE 13. | | | | PLATE 14. | | | |
| | | | ″ | | | | |
| 70° | 250° | +.481 | 0.0 | | | | |
| 80 | 260 | .475 | — 6.7 | | | | |
| 90 | 270 | .459 | —12.5 | | | | |
| 100 | 280 | .434 | —16.9 | | | | |
| 110 | 290 | .403 | —19.2 | | | | |
| 120 | 300 | .370 | —19.2 | | | | |
| 130 | 310 | .339 | —16.9 | | | | |
| 140 | 320 | .314 | —12.5 | | | | |
| 150 | 330 | .298 | — 6.7 | | | | |
| 160 | 340 | .292 | 0.0 | | | | |
| 170 | 350 | .298 | + 6.7 | | | | |
| 180 | 0 | .314 | +12.5 | | | | |
| 190 | 10 | .339 | +16.9 | | | | |
| 200 | 20 | .370 | +19.2 | | | | |
| 210 | 30 | .403 | +19.2 | | | | |
| 220 | 40 | .434 | +16.9 | | | | |
| 230 | 50 | .459 | +12.5 | | | | |
| 240 | 60 | .475 | + 6.7 | | | | |
| 250 | 70 | +.481 | 0.0 | | | | |
| PLATE 15. | | | | PLATE 16. | | | |
| | | | ″ | | | | ″ |
| 288° | 108° | +.389 | 0.0 | 294° | 114 | +.593 | 0.0 |
| 298 | 118 | .386 | — 3.9 | 304 | 124 | .583 | —11.4 |
| 308 | 128 | .376 | — 7.4 | 314 | 134 | .555 | —21.5 |
| 318 | 138 | .362 | —10.0 | 324 | 144 | .512 | —28.9 |
| 328 | 148 | .343 | —11.3 | 334 | 154 | .459 | —32.9 |
| 338 | 158 | .324 | —11.3 | 344 | 164 | .403 | —32.9 |
| 348 | 168 | .306 | —10.0 | 354 | 174 | .350 | —28.9 |
| 358 | 178 | .291 | — 7.4 | 4 | 184 | .307 | —21.5 |
| 8 | 188 | .281 | — 3.9 | 14 | 194 | .279 | —11.4 |
| 18 | 198 | .278 | 0.0 | 24 | 204 | .269 | 0.0 |
| 28 | 208 | .281 | + 3.9 | 34 | 214 | .279 | +11.4 |
| 38 | 218 | .291 | + 7.4 | 44 | 224 | .307 | +21.5 |
| 48 | 228 | .306 | +10.0 | 54 | 234 | .350 | +28.9 |
| 58 | 238 | .324 | +11.3 | 64 | 244 | .403 | +32.9 |
| 68 | 248 | .343 | +11.3 | 74 | 254 | .459 | +32.9 |
| 78 | 258 | .362 | +10.0 | 84 | 264 | .512 | +28.9 |
| 88 | 268 | .376 | + 7.4 | 94 | 274 | .555 | +21.5 |
| 98 | 278 | .386 | + 3.9 | 104 | 284 | .583 | +11.4 |
| 108 | 288 | +.389 | 0.0 | 114 | 294 | +.593 | 0.0 |

TABLE II.—CORRECTIONS FOR REFRACTIONS. (*Concluded.*)

| Position Angle, $p$. | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ | Position Angle, $p$. | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ |
|---|---|---|---|---|---|---|---|
| PLATE 17. | | | | PLATE 18. | | | |
| | | | ″ | | | | ″ |
| 292° | 112° | +.492 | 0.0 | 293° | 113° | +.576 | 0.0 |
| 302 | 122 | .485 | — 7.8 | 303 | 123 | .567 | —10.5 |
| 312 | 132 | .466 | —14.7 | 313 | 133 | .541 | —19.7 |
| 322 | 142 | .437 | —19.8 | 323 | 143 | .501 | —26.6 |
| 332 | 152 | .400 | —22.6 | 333 | 153 | .453 | —30.2 |
| 342 | 162 | .362 | —22.6 | 343 | 163 | .402 | —30.2 |
| 352 | 172 | .326 | —19.8 | 353 | 173 | .353 | —26.6 |
| 2 | 182 | .296 | —14.7 | 3 | 183 | .314 | —19.7 |
| 12 | 192 | .277 | — 7.8 | 13 | 193 | .288 | —10.5 |
| 22 | 202 | .270 | 0.0 | 23 | 203 | .279 | 0.0 |
| 32 | 212 | .277 | + 7.8 | 33 | 213 | .288 | +10.5 |
| 42 | 222 | .296 | +14.7 | 43 | 223 | .314 | +19.7 |
| 52 | 232 | .326 | +19.8 | 53 | 233 | .353 | +26.6 |
| 62 | 242 | .362 | +22.6 | 63 | 243 | .402 | +30.2 |
| 72 | 252 | .400 | +22.6 | 73 | 253 | .453 | +30.2 |
| 82 | 262 | .437 | +19.8 | 83 | 263 | .501 | +26.6 |
| 92 | 272 | .466 | +14.7 | 93 | 273 | .541 | +19.7 |
| 102 | 282 | .485 | + 7.8 | 103 | 283 | .567 | +10.5 |
| 112 | 292 | +.492 | 0.0 | 113 | 293 | +.576 | 0.0 |
| PLATE 19. | | | | PLATE 20. | | | |
| | | | ″ | | | | ″ |
| 291° | 111° | +.482 | 0.0 | 289° | 109° | +.409 | 0.0 |
| 301 | 121 | .476 | — 7.1 | 299 | 119 | .405 | — 4.5 |
| 311 | 131 | .459 | —13.4 | 309 | 129 | .394 | — 8.6 |
| 321 | 141 | .432 | —18.0 | 319 | 139 | .377 | —11.5 |
| 331 | 151 | .399 | —20.5 | 329 | 149 | .356 | —13.1 |
| 341 | 161 | .363 | —20.5 | 339 | 159 | .333 | —13.1 |
| 351 | 171 | .331 | —18.0 | 349 | 169 | .312 | —11.5 |
| 1 | 181 | .304 | —13.4 | 359 | 179 | .295 | — 8.6 |
| 11 | 191 | .286 | — 7.1 | 9 | 189 | .284 | — 4.5 |
| 21 | 201 | .280 | 0.0 | 19 | 199 | .280 | 0.0 |
| 31 | 211 | .286 | + 7.1 | 29 | 209 | .284 | + 4.5 |
| 41 | 221 | .304 | +13.4 | 39 | 219 | .295 | + 8.6 |
| 51 | 231 | .331 | +18.0 | 49 | 229 | .312 | +11.5 |
| 61 | 241 | .363 | +20.5 | 59 | 239 | .333 | +13.1 |
| 71 | 251 | .399 | +20.5 | 69 | 249 | .356 | +13.1 |
| 81 | 261 | .432 | +18.0 | 79 | 259 | .377 | +11.5 |
| 91 | 271 | .459 | +13.4 | 89 | 269 | .394 | + 8.6 |
| 101 | 281 | .476 | + 7.1 | 99 | 279 | .405 | + 4 5 |
| 111 | 291 | +.482 | 0.0 | 109 | 289 | +.409 | 0.0 |

TABLE III.—CORRECTIONS FOR PRECESSION, ETC., TO 1873 AND ZERO CORRECTIONS.

| Plate No. | Precession, etc. | | Zero Correction ½ (East + West) | Special Correction Mean. | Adopted Mean. |
|---|---|---|---|---|---|
| | Position Angle Correction. | Distance Factor × $10^3$ | | | |
| | ″ | | ′ ″ | ″ | ′ ″ |
| 1 | —25. | —.0584 | +12 29 | —27 | +12 2 |
| 2 | —24. | —.0593 | 13 52 | —24 | 13 28 |
| 3 | —24. | —.0593 | 13 58 | —24 | 13 34 |
| 4 | + 3. | —.0611 | 13 1 | —22 | 12 39 |
| 5 | + 8. | —.0576 | 11 57 | —19 | 11 38 |
| 6 | + 8. | —.0576 | 12 12 | —34 | 11 38 |
| 7 | + 8. | —.0568 | 13 9 | —17 | 12 52 |
| 8 | +20. | —.0601 | 13 23 | —20 | 13 3 |
| 9 | +20. | —.0601 | 14 50 | —20 | 14 30 |
| 10 | +21. | —.0609 | 13 27 | —20 | 13 7 |
| 11 | +22. | —.0611 | 14 34 | —21 | 14 13 |
| 12 | +22. | —.0611 | 15 56 | —21 | 15 35 |
| 13 | +22. | —.0611 | 13 27 | —19 | 13 8 |
| 15 | +21. | +.0608 | 12 45 | —32 | 12 13 |
| 16 | +19. | +.0584 | 11 27 | —29 | 10 58 |
| 17 | +19. | +.0584 | 11 38 | —28 | 11 10 |
| 18 | +19. | +.0582 | 11 29 | —26 | 11 3 |
| 19 | +19. | +.0582 | 11 45 | —23 | 11 22 |
| 20 | +19. | +.0582 | +13 3 | —25 | +12 38 |

TABLE IV.—TANGENT CORRECTION.

This correction is always *negative*, and is here expressed in terms of the *fourth* decimal place of the micrometer readings.

| Distance | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|---|---|---|---|---|---|---|---|---|---|---|
| **20.** | — 0 | — 0 | — 0 | — 0 | — 0 | — 1 | — 1 | — 1 | — 1 | — 1 |
| **30.** | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| **40.** | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 7 |
| **50.** | 8 | 8 | 8 | 9 | 9 | 10 | 10 | 11 | 11 | 12 |
| **60.** | 13 | 13 | 14 | 15 | 16 | 17 | 17 | 18 | 19 | 20 |
| **70.** | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 30 | 31 |
| **80.** | 32 | 34 | 35 | 36 | 37 | 38 | 40 | 41 | 42 | 43 |
| **90.** | 45 | 46 | 48 | 50 | 52 | 53 | 55 | 57 | 59 | 61 |
| **100.** | 62 | 64 | 65 | 67 | 69 | 71 | 73 | 75 | 77 | 79 |
| **110.** | 81 | 83 | 85 | 87 | 90 | 93 | 95 | 98 | 100 | 103 |
| **120.** | 106 | 109 | 112 | 114 | 117 | 120 | 123 | 126 | 129 | 132 |
| **130.** | —135 | —138 | —141 | —145 | —148 | —151 | —155 | —158 | —162 | —165 |

## Table V.—Results of Measures of Distance.

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Parallax *Coefficient.* | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | .5188 | .5206 | 479 | —79 | 4 | .5452 | +262 | +.0502 | +0.612 | 134.6295 |
| **1** | 2 | .4992 | .5242 | 458 | —80 | 4 | .5349 | +306 | +.0499 | + .582 | .6229 |
| | 3 | .5392 | .5166 | 479 | —80 | 2 | .5531 | +224 | +.0499 | + .582 | .6329 |
| (16) | 5 | .5864 | .6211 | 464 | —78 | 12 | .6285 | + 59 | +.0018 | + .157 | .6382 |
| | 6 | .5898 | .6182 | 513 | —78 | 5 | .6330 | +120 | +.0018 | + .157 | .6488 |
| | 7 | .6063 | .6018 | 493 | —77 | 10 | .6316 | +125 | +.0016 | + .129 | .6474 |
| | 10 | .6539 | .6502 | 439 | —82 | 10 | .6737 | — 55 | —.0394 | + .490 | .6351 |
| | 15 | .6880 | .7412 | 516 | +82 | 5 | .7599 | —141 | —.0629 | — .343 | .6785 |
| | 16 | .5970 | .6074 | 774 | +79 | 6 | .6731 | — 90 | —.0643 | — .197 | .5973 |
| | 17 | .6227 | .6303 | 650 | +79 | 6 | .6851 | — 96 | —.0643 | — .197 | .6087 |
| | | | | | | Mean | | | | | 134.6339 |
| | 3 | .7912 | .7799 | 532 | —65 | 112 | .8357 | +181 | +.2096 | +0.925 | 109.0753 |
| **2** | 11 | .2029 | .2003 | 384 | —67 | 117 | .2371 | — 78 | —.1654 | + .970 | .0764 |
| | 12 | .1825 | .1745 | 438 | —67 | 112 | .2189 | — 65 | —.1654 | + .970 | .0595 |
| (25) | 13 | .1650 | .1473 | 517 | —67 | 112 | .2045 | — 14 | —.1654 | + .970 | .0502 |
| | 15 | .2923 | .2717 | 355 | +66 | 106 | .3267 | —114 | —.2621 | —1.011 | .0402 |
| | 19 | .3074 | .3010 | 382 | +63 | 112 | .3519 | — 36 | —.2682 | —0.991 | .0674 |
| | | | | | | Mean | | | | | 109.0615 |
| | 2 | .0674 | .0344 | 474 | —68 | 105 | .0930 | +260 | +.2100 | +0.892 | 114.3405 |
| **3** | 11 | .4735 | .4343 | 397 | —70 | 123 | .4897 | — 82 | —.1658 | + .950 | .3279 |
| | 13 | .4314 | .4084 | 533 | —70 | 114 | .4685 | — 15 | —.1658 | + .950 | .3134 |
| (26) | 15 | .5538 | .5548 | 361 | +70 | 105 | .5987 | —120 | —.2626 | —1.004 | .3112 |
| | 18 | .5716 | .5540 | 395 | +67 | 107 | .6106 | — 62 | —.2687 | —0.997 | .3229 |
| | | | | | | Mean | | | | | 114.3232 |
| **4** | 2 | .5200 | .5410 | 451 | —66 | 114 | .5722 | +252 | +.2094 | +0.868 | 110.8179 |
| | 12 | .8999 | .9155 | 435 | —68 | 114 | .9475 | — 66 | —.1653 | + .932 | .7876 |
| (27) | | | | | | Mean | | | | | 110.8028 |
| **5** | 1 | .0086 | .0100 | 327 | —45 | 115 | .0462 | +150 | +.1583 | +0.934 | 77.2315 |
| | 2 | .0038 | .0036 | 320 | —46 | 115 | .0398 | +175 | +.1571 | + .925 | .2263 |
| (19) | 3 | .0032 | .0030 | 360 | —46 | 115 | .0432 | +128 | +.1571 | + .925 | .2250 |
| | 4 | .2026 | .1564 | 350 | —47 | 115 | .2185 | — 2 | +.0117 | + .827 | .2406 |
| | 5 | .1722 | .1676 | 339 | —44 | 115 | .2080 | + 34 | +.0057 | + .670 | .2257 |
| | 6 | .1544 | .1458 | 463 | —44 | 117 | .2009 | + 69 | +.0057 | + .670 | .2221 |
| | 7 | .1684 | .1552 | 397 | —44 | 115 | .2058 | + 72 | +.0050 | + .646 | .2263 |
| | 8 | .3030 | .2988 | 352 | —46 | 115 | .3401 | — 98 | —.1216 | + .912 | .2204 |
| | 9 | .2870 | .2860 | 438 | —46 | 115 | .3343 | — 34 | —.1216 | + .912 | .2210 |
| | 10 | .3072 | .2922 | 289 | —47 | 115 | .3325 | — 32 | —.1235 | + .889 | .2172 |
| | 11 | .3110 | .3048 | 271 | —47 | 115 | .3389 | — 55 | —.1242 | + .877 | .2205 |
| | 12 | .3072 | .3017 | 307 | —47 | 115 | .3391 | — 46 | —.1242 | + .877 | .2216 |
| | 13 | .3002 | .2900 | 355 | —47 | 115 | .3345 | — 10 | —.1242 | + .877 | .2206 |
| | 15 | .3853 | .3863 | 300 | +47 | 117 | .4293 | — 81 | —.1968 | — .824 | .2138 |
| | 16 | .3727 | .3607 | 432 | +45 | 116 | .4231 | — 52 | —.2010 | — .720 | .2077 |
| | 17 | .3793 | .3739 | 368 | +45 | 116 | .4266 | — 55 | —.2010 | — .720 | .2109 |
| | 18 | .3771 | .3737 | 424 | +45 | 116 | .4310 | — 42 | —.2014 | — .709 | .2163 |
| | 19 | .3878 | .3854 | 358 | +45 | 116 | .4356 | — 25 | —.2014 | — .709 | .2226 |
| | 20 | .3781 | .3947 | 313 | +45 | 116 | .4309 | — 96 | —.2014 | — .709 | .2108 |
| | | | | | | Mean | | | | | 77.2211 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE.

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 1 | 37 37 13 | 38 1 | 12 2 | —16 | 49 23 | —5 11 | —41 | 307 44 10 |
| 2 | 35 58 | 36 24 | 13 28 | —13 | 49 26 | —5 9 | —43 | 45 2 |
| 3 | 36 36 | 37 10 | 13 34 | —18 | 50 9 | —5 9 | —43 | 44 51 |
| 5 | 33 34 | 33 42 | 11 38 | —15 | 45 1 | —0 11 | —51 | 44 24 |
| 6 | 33 2 | 33 30 | 11 38 | —32 | 44 22 | —0 11 | —51 | 44 10 |
| 7 | 29 2 | 29 22 | 12 52 | —23 | 41 41 | —0 10 | —52 | 44 33 |
| 10 | 27 3 | 27 33 | 13 7 | — 8 | 40 17 | +4 3 | —46 | 43 42 |
| 15 | 25 8 | 25 34 | 12 13 | — 7 | 37 27 | +6 26 | +52 | 43 53 |
| 16 | 26 53 | 27 27 | 10 58 | —18 | 37 50 | +6 34 | +54 | 44 14 |
| 17 | 28 18 | 28 40 | 11 10 | —12 | 39 27 | +6 34 | +54 | 44 15 |
| | | | | Mean | | | | 307 44 19.4 |
| 3 | 325 11 34 | 12 22 | 13 34 | +10 | 25 42 | —0 23 | +21 | 235 25 33 |
| 11 | 10 54 | 11 18 | 14 13 | + 3 | 25 22 | +0 18 | +12 | 25 13 |
| 12 | 8 2 | 8 58 | 15 35 | + 6 | 24 11 | +0 18 | +12 | 24 44 |
| 13 | 11 20 | 11 12 | 13 8 | +10 | 24 34 | +0 19 | +12 | 25 21 |
| 15 | 12 55 | 13 37 | 12 13 | +11 | 25 40 | +0 29 | — 3 | 25 49 |
| 19 | 13 8 | 13 48 | 11 22 | +18 | 25 8 | +0 30 | + 9 | 25 40 |
| | | | | Mean | | | | 235 25 23.3 |
| 2 | 319 54 34 | 54 28 | 13 28 | + 9 | 8 8 | +0 13 | +26 | 230 9 30 |
| 11 | 54 45 | 55 27 | 14 13 | + 4 | 9 23 | —0 10 | +17 | 8 48 |
| 13 | 55 22 | 55 25 | 13 8 | +13 | 8 45 | —0 10 | +17 | 9 5 |
| 15 | 57 15 | 58 12 | 12 13 | +10 | 10 6 | —0 16 | — 8 | 9 28 |
| 18 | 57 48 | 59 32 | 11 3 | +25 | 10 8 | —0 16 | + 3 | 9 3 |
| | | | | Mean | | | | 230 9 10.8 |
| 2 | 316 42 20 | 43 42 | 13 28 | +10 | 56 39 | +0 35 | +30 | 226 58 25 |
| 12 | 42 20 | 43 42 | 15 35 | + 9 | 58 45 | —0 27 | +22 | 58 37 |
| | | | | Mean | | | | 226 58 31.0 |
| 1 | 3 0 28 | 1 28 | 12 2 | —11 | 12 49 | —6 12 | —26 | 273 6 41 |
| 2 | 2 58 36 | 59 32 | 13 28 | — 9 | 12 25 | —6 9 | —30 | 7 5 |
| 3 | 59 6 | 59 40 | 13 34 | —15 | 12 42 | —6 9 | —30 | 6 28 |
| 4 | 55 20 | 55 48 | 12 39 | —13 | 8 0 | —0 28 | —51 | 6 39 |
| 5 | 55 50 | 56 35 | 11 38 | —12 | 7 38 | —0 13 | —66 | 6 53 |
| 6 | 55 4 | 56 52 | 11 38 | —33 | 7 3 | —0 13 | —66 | 6 43 |
| 7 | 50 38 | 51 27 | 12 52 | —20 | 3 34 | —0 12 | —68 | 6 19 |
| 8 | 49 32 | 49 50 | 13 3 | —15 | 2 29 | +4 44 | —35 | 6 48 |
| 9 | 48 3 | 48 53 | 14 30 | —26 | 2 32 | +4 44 | —35 | 6 33 |
| 10 | 48 35 | 49 33 | 13 7 | — 5 | 2 6 | +4 49 | —41 | 6 19 |
| 11 | 47 56 | 48 22 | 14 13 | — 4 | 2 33 | +4 50 | —43 | 6 37 |
| 12 | 45 58 | 46 20 | 15 35 | — 8 | 1 36 | +4 50 | —43 | 6 22 |
| 13 | 48 28 | 49 23 | 13 8 | —13 | 1 51 | +4 50 | —43 | 6 50 |
| 15 | 46 7 | 47 10 | 12 13 | + 6 | 58 57 | +7 40 | +56 | 6 38 |
| 16 | 47 32 | 47 38 | 10 58 | +23 | 58 56 | +7 49 | +66 | 6 40 |
| 17 | 48 15 | 49 23 | 11 10 | +13 | 0 12 | +7 49 | +66 | 6 20 |
| 18 | 46 56 | 47 58 | 11 3 | +20 | 58 50 | +7 50 | +67 | 6 14 |
| 19 | 46 37 | 47 11 | 11 22 | +12 | 58 28 | +7 50 | +67 | 6 41 |
| 20 | 45 18 | 45 46 | 12 38 | + 7 | 58 17 | +7 50 | +67 | 6 45 |
| | | | | Mean | | | | 273 6 36.6 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Corrected Mean. | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | $s$ | | | | $\sigma$ |
| **6** | 1 | .6858 | .6818 | 401 | —55 | 131 | .7262 | +185 | +.2115 | +0.871 | 94.9674 |
| | 2 | .6928 | .6910 | 393 | —56 | 130 | .7333 | +215 | +.2100 | + .892 | .9763 |
| (24) | 3 | .6920 | .6812 | 455 | —56 | 130 | .7342 | +158 | +.2100 | + .892 | .9715 |
| | 4 | .8981 | .8831 | 437 | —58 | 134 | .9365 | — 3 | +.0157 | + .971 | .9644 |
| | 5 | .9014 | .8962 | 423 | —55 | 138 | .9441 | + 42 | +.0076 | + .962 | .9683 |
| | 6 | .8773 | .8578 | 626 | —55 | 132 | .9326 | + 85 | +.0076 | + .962 | .9611 |
| | 7 | .8896 | .8944 | 503 | —54 | 138 | .9454 | + 88 | +.0067 | + .956 | .9732 |
| | 8 | .0688 | .0660 | 445 | —57 | 134 | .1143 | —121 | —.1623 | + .916 | .9517 |
| | 9 | .0571 | .0546 | 561 | —57 | 135 | .1145 | — 42 | —.1623 | + .916 | .9598 |
| | 10 | .0923 | .0755 | 352 | —58 | 134 | .1214 | — 39 | —.1649 | + .942 | .9647 |
| | 11 | .0848 | .0872 | 330 | —58 | 134 | .1213 | — 68 | —.1658 | + .950 | .9609 |
| | 12 | .0814 | .0812 | 376 | —58 | 136 | .1214 | — 57 | —.1658 | + .950 | .9621 |
| | 13 | .0632 | .0488 | 444 | —58 | 134 | .1027 | — 12 | —.1658 | +0.950 | .9479 |
| | 15 | .1924 | .1991 | 300 | +58 | 132 | .2394 | —100 | —.2626 | —1.005 | .9539 |
| | 16 | .1892 | .1790 | 322 | +56 | 132 | .2298 | — 64 | —.2682 | —1.000 | .9424 |
| | 17 | .2069 | .2078 | 323 | +56 | 132 | .2531 | — 68 | —.2682 | —1.000 | .9653 |
| | 18 | .1939 | .1912 | 328 | +55 | 132 | .2388 | — 51 | —.2687 | —0.998 | .9522 |
| | 19 | .2206 | .1926 | 319 | +55 | 136 | .2523 | — 31 | —.2687 | — .998 | .9677 |
| | 20 | .2064 | .2074 | 304 | +55 | 132 | .2506 | —118 | —.2687 | — .998 | .9573 |
| | | | | | | Mean | | | | | 94.9615 |
| **7** | 2 | .0818 | .1088 | 341 | —48 | 125 | .1337 | +185 | +.2097 | +0.923 | 81.3738 |
| | 13 | .4722 | .4627 | 244 | —50 | 126 | .4960 | — 11 | —.1655 | + .969 | .3418 |
| (23) | | | | | | Mean | | | | | 81.3578 |
| **8** | 2 | .0438 | .0356 | 213 | —36 | 100 | .0660 | +139 | +.0676 | +0.650 | 61.1558 |
| | 3 | .0383 | .0341 | 228 | —36 | 100 | .0640 | +102 | +.0676 | + .650 | .1501 |
| (17) | 11 | .1636 | .1495 | 196 | —37 | 100 | .1811 | — 44 | —.0538 | + .541 | .1298 |
| | 12 | .1595 | .1823 | 209 | —37 | 100 | .1967 | — 37 | —.0538 | + .541 | .1461 |
| | 13 | .1678 | .1622 | 214 | —37 | 100 | .1913 | — 8 | —.0538 | + .541 | .1436 |
| | 15 | .1983 | .2245 | 237 | +37 | 96 | .2471 | — 64 | —.0854 | — .426 | .1498 |
| | | | | | | Mean | | | | | 61.1459 |
| **9** | 2 | .4752 | .4860 | 416 | —68 | 115 | .5178 | +260 | +.1873 | +0.631 | 114.7392 |
| | 3 | .5146 | .4676 | 458 | —68 | 122 | .5331 | +191 | +.1873 | + .631 | .7476 |
| (29) | 11 | .8372 | .8280 | 371 | —70 | 120 | .8654 | — 82 | —.1478 | + .740 | .7189 |
| | 13 | .8130 | .8001 | 449 | —70 | 120 | .8473 | — 15 | —.1478 | + .740 | .7075 |
| | 15 | .9240 | .9426 | 327 | +70 | 121 | .9758 | —120 | —.2343 | — .849 | .7186 |
| | 18 | .9489 | .9477 | 328 | +67 | 120 | .9905 | — 62 | —.2398 | — .912 | .7328 |
| | | | | | | Mean | | | | | 114.7274 |
| **10** | 10 | .0253 | .0063 | 300 | —60 | 132 | .0469 | — 40 | +.0296 | +0.097 | 99.0737 |
| | 12 | .0295 | .9887 | 298 | —60 | 132 | .0400 | — 49 | +.0298 | + .069 | .0648 |
| (78) | 15 | .9722 | .9822 | 337 | +60 | 128 | .0236 | —104 | +.0470 | + .077 | .0612 |
| | 18 | .9556 | .9712 | 460 | +58 | 132 | .0223 | — 53 | +.0480 | + .233 | .0680 |
| | 19 | .9687 | .9714 | 404 | +58 | 132 | .0233 | — 32 | +.0480 | + .233 | .0711 |
| | 20 | .9906 | .9534 | 352 | +58 | 132 | .0201 | —123 | +.0480 | + .233 | .0588 |
| | | | | | | Mean | | | | | 99.0663 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. *π* |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 1 | 319 59 30 | 59 52 | 12 2 | +11 | 11 54 | + 0 14 | + 34 | 230 12 33 |
| 2 | 57 56 | 57 56 | 13 28 | + 9 | 11 33 | + 0 14 | + 31 | 12 58 |
| 3 | 58 5 | 58 24 | 13 34 | +13 | 12 1 | + 0 14 | + 31 | 12 32 |
| 4 | 59 48 | 0 13 | 12 39 | +12 | 12 52 | + 0 1 | + 13 | 12 23 |
| 5 | 320 0 48 | 1 28 | 11 38 | +11 | 12 57 | + 0 1 | — 4 | 12 49 |
| 6 | 0 18 | 0 34 | 11 38 | +20 | 12 24 | + 0 1 | — 4 | 12 41 |
| 7 | 319 55 52 | 56 2 | 12 52 | +13 | 9 2 | + 0 0 | — 6 | 12 21 |
| 8 | 59 28 | 59 12 | 13 3 | +12 | 12 35 | — 0 11 | + 28 | 12 22 |
| 9 | 57 45 | 58 38 | 14 30 | +18 | 12 59 | — 0 11 | + 28 | 12 28 |
| 10 | 59 27 | 0 13 | 13 7 | + 6 | 13 3 | — 0 11 | + 23 | 12 39 |
| 11 | 58 34 | 59 12 | 14 13 | + 4 | 13 10 | — 0 11 | + 21 | 12 36 |
| 12 | 56 38 | 56 58 | 15 35 | + 8 | 12 31 | — 0 11 | + 21 | 12 39 |
| 13 | 58 15 | 59 5 | 13 8 | +13 | 12 1 | — 0 11 | + 21 | 12 22 |
| 15 | 320 00 40 | 1 35 | 12 13 | +10 | 13 31 | — 0 18 | — 10 | 12 50 |
| 16 | 1 28 | 2 12 | 10 58 | +27 | 13 15 | — 0 18 | + 1 | 12 28 |
| 17 | 2 50 | 3 45 | 11 10 | +20 | 14 48 | — 0 18 | + 1 | 12 25 |
| 18 | 1 5 | 1 57 | 11 3 | +25 | 12 59 | — 0 18 | + 2 | 11 52 |
| 19 | 1 22 | 1 57 | 11 22 | +18 | 13 19 | — 0 18 | + 2 | 13 1 |
| 20 | 319 59 30 | 59 55 | 12 38 | +12 | 12 32 | — 0 18 | + 2 | 12 29 |
| | | | | Mean | | | | 230 12 33.1 |
| 2 | 325 1 15 | 1 43 | 13 28 | + 6 | 15 3 | — 0 31 | + 29 | 235 15 42 |
| 13 | 0 15 | 0 59 | 13 8 | — 3 | 13 42 | + 0 24 | + 16 | 14 36 |
| | | | | Mean | | | | 235 15 9.0 |
| 2 | 32 40 22 | 41 24 | 13 28 | —13 | 54 7 | —11 8 | — 89 | 302 43 27 |
| 3 | 40 16 | 40 45 | 13 34 | —19 | 53 46 | —11 8 | — 89 | 42 12 |
| 11 | 20 2 | 21 20 | 14 13 | — 6 | 34 48 | + 8 46 | —100 | 42 27 |
| 12 | 18 40 | 18 37 | 15 35 | —11 | 34 2 | + 8 46 | —100 | 42 23 |
| 13 | 21 10 | 21 48 | 13 8 | —17 | 34 20 | + 8 46 | —100 | 42 54 |
| 15 | 16 8 | 15 24 | 12 13 | — 5 | 27 54 | +13 53 | +101 | 42 4 |
| | | | | Mean | | | | 302 42 34.5 |
| 2 | 294 17 35 | 18 20 | 13 28 | +14 | 31 40 | + 2 55 | + 48 | 204 35 52 |
| 3 | 17 33 | 18 48 | 13 34 | +20 | 32 4 | + 2 55 | + 48 | 35 22 |
| 11 | 23 23 | 24 5 | 14 13 | + 6 | 38 3 | — 2 18 | + 41 | 35 29 |
| 13 | 22 47 | 23 22 | 13 8 | +19 | 36 31 | — 2 18 | + 41 | 34 52 |
| 15 | 26 32 | 28 41 | 12 13 | + 2 | 39 51 | — 3 38 | — 35 | 35 41 |
| 18 | 27 52 | 28 53 | 11 3 | + 2 | 39 27 | — 3 43 | — 26 | 34 45 |
| | | | | Mean | | | | 204 35 20.2 |
| 10 | 61 42 56 | 44 10 | 13 7 | — 3 | 56 37 | + 5 35 | — 73 | 332 1 25 |
| 12 | 40 24 | 41 48 | 15 35 | — 4 | 56 37 | + 5 37 | — 73 | 1 59 |
| 15 | 40 38 | 40 37 | 12 13 | —11 | 52 40 | + 8 54 | + 75 | 1 42 |
| 18 | 41 12 | 42 16 | 11 3 | —30 | 52 17 | + 9 6 | + 72 | 0 59 |
| 19 | 39 25 | 41 23 | 11 22 | —21 | 51 25 | + 9 6 | + 72 | 0 56 |
| 20 | 39 43 | 40 13 | 12 38 | —13 | 52 23 | + 9 6 | + 72 | 2 9 |
| | | | | Mean | | | | 332 1 31.7 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | | | | | |
| **11** | 11 | .1390 | .1408 | 223 | —45 | 124 | .1675 | — 53 | +.0261 | +0.090 | 74.1895 |
| | 12 | .1531 | .1270 | 225 | —45 | 124 | .1679 | — 44 | +.0261 | + .090 | .1908 |
| (77) | 15 | .1319 | .1356 | 255 | +45 | 123 | .1736 | — 78 | +.0412 | + .056 | .2077 |
| | | | | | | Mean | | | | | 74.1960 |
| **12** | 11 | .6700 | .6604 | 166 | —33 | 99 | .6874 | — 38 | —.0056 | +0.276 | 53 6815 |
| | 13 | .6836 | .6730 | 172 | —33 | 99 | .7011 | — 7 | —.0056 | + .276 | .6983 |
| (15) | 15 | .6732 | .6743 | 195 | +33 | 96 | .7053 | — 56 | —.0090 | — .138 | .6889 |
| | | | | | | Mean | | | | | 53.6896 |
| **13** | 1 | .3524 | .3614 | 285 | —57 | 136 | .3874 | +192 | —.0720 | +0.092 | 98.3358 |
| | 2 | .3630 | .3550 | 293 | —58 | 136 | .3901 | +224 | —.0715 | + .050 | .3416 |
| (14) | 3 | .3642 | .3513 | 295 | —58 | 138 | .3894 | +164 | —.0715 | + .050 | .3349 |
| | 4 | .2984 | .2968 | 297 | —60 | 136 | .3289 | — 3 | —.0053 | — .191 | .3208 |
| | 5 | .3068 | .2918 | 293 | —57 | 136 | .3305 | + 43 | —.0026 | — .394 | .3271 |
| | 6 | .2970 | .2951 | 299 | —57 | 136 | .3278 | + 88 | —.0026 | — .394 | .3289 |
| | 7 | .3014 | .3063 | 298 | —56 | 136 | .3356 | + 91 | —.0023 | — .419 | .3370 |
| | 10 | .2354 | .2393 | 294 | —60 | 136 | .2684 | — 40 | +.0559 | — .066 | .3195 |
| | 11 | .2419 | .2395 | 294 | —60 | 136 | .2716 | — 70 | +.0562 | — .094 | .3196 |
| | 12 | .2335 | .2293 | 293 | —60 | 136 | .2624 | — 59 | +.0562 | — .094 | .3115 |
| | 13 | .2352 | .2496 | 293 | —60 | 136 | .2734 | — 13 | +.0562 | — .094 | .3271 |
| | 15 | .1947 | .1884 | 317 | +60 | 136 | .2369 | —103 | +.0889 | + .242 | .3186 |
| | 16 | .1811 | .1681 | 413 | +57 | 136 | .2293 | — 66 | +.0908 | + .378 | .3184 |
| | 17 | .1604 | .1670 | 366 | +57 | 136 | .2137 | — 70 | +.0908 | + .378 | .3024 |
| | 18 | .1569 | .1686 | 407 | +57 | 136 | .2169 | — 53 | +.0910 | + .390 | .3076 |
| | 19 | .1873 | .1810 | 361 | +57 | 136 | .2336 | — 32 | +.0910 | + .390 | .3264 |
| | 20 | .1854 | .1686 | 329 | +57 | 136 | .2233 | —122 | +.0910 | + .390 | .3071 |
| | | | | | | Mean | | | | | 98.3226 |
| **14** | 2 | .5585 | .5620 | 127 | —21 | 106 | .5811 | + 79 | +.0881 | +0.723 | 34.6864 |
| | 3 | .5667 | .5729 | 135 | —21 | 105 | .5914 | + 58 | +.0881 | + .723 | .6946 |
| (18) | 10 | .7285 | .7121 | 119 | —21 | 104 | .7402 | — 14 | —.0698 | + .646 | .6773 |
| | 11 | .7369 | .7223 | 115 | —21 | 105 | .7492 | — 25 | —.0702 | + .625 | .6845 |
| | 12 | .7356 | .7166 | 123 | —21 | 105 | .7465 | — 21 | —.0702 | + .625 | .6822 |
| | 13 | .7191 | .6993 | 135 | —21 | 104 | .7307 | — 4 | —.0702 | + .625 | .6681 |
| | 15 | .7756 | .7645 | 136 | +21 | 102 | .7956 | — 36 | —.1115 | — .521 | .6738 |
| | 16 | .7510 | .7642 | 208 | +20 | 106 | .7907 | — 23 | —.1140 | — .384 | .6695 |
| | 18 | .7750 | .7772 | 203 | +20 | 108 | .8089 | — 19 | —.1142 | — .370 | .6880 |
| | 19 | .7717 | .7725 | 169 | +20 | 105 | .8012 | — 11 | —.1142 | — .370 | .6811 |
| | 20 | .7780 | .7722 | 143 | +20 | 108 | .8019 | — 43 | —.1142 | — .370 | .6786 |
| | | | | | | Mean | | | | | 34.6804 |
| **15** | 2 | .9422 | .9548 | 201 | —31 | 106 | .9753 | +118 | +.2018 | +0.760 | 52.1987 |
| | 3 | .9428 | .9546 | 227 | —31 | 110 | .9784 | + 87 | +.2018 | + .760 | .1987 |
| (22) | 10 | .3307 | .3272 | 183 | —32 | 106 | .3537 | — 21 | —.1584 | + .835 | .2039 |
| | 11 | .3287 | .3188 | 175 | —32 | 106 | .3478 | — 37 | —.1593 | + .850 | .1957 |
| | 12 | .3230 | .3271 | 194 | —32 | 106 | .3510 | — 31 | —.1593 | + .850 | .1995 |
| | 13 | .3143 | .3105 | 223 | —32 | 110 | .3416 | — 7 | —.1593 | + .850 | .1925 |
| | 15 | .4327 | .4583 | 194 | +32 | 94 | .4766 | — 55 | —.2523 | — .938 | .2068 |
| | 18 | .4623 | .4506 | 163 | +31 | 101 | .4851 | — 28 | —.2583 | — .972 | .2115 |
| | | | | | | Mean | | | | | 52.2009 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 11 | 60 27 37 | 27 48 | 14 13 | − 3 | 41 52 | + 7 33 | − 97 | 330 48 19 |
| 12 | 25 25 | 25 33 | 15 35 | − 5 | 40 59 | + 7 33 | − 97 | 48 8 |
| 15 | 23 52 | 23 32 | 12 13 | −11 | 35 44 | +11 57 | +101 | 47 58 |
| | | | | Mean | | | | 330 48 8.3 |
| 11 | 49 29 30 | 30 22 | 14 13 | − 4 | 44 5 | +10 34 | −130 | 319 53 21 |
| 13 | 30 2 | 30 36 | 13 8 | −13 | 43 14 | +10 34 | −130 | 53 25 |
| 15 | 23 57 | 24 5 | 12 13 | −10 | 36 4 | +16 44 | +137 | 53 18 |
| | | | | Mean | | | | 319 53 21.3 |
| 1 | 71 19 56 | 19 39 | 12 2 | 0 | 31 50 | − 6 54 | − 73 | 341 24 43 |
| 2 | 16 25 | 17 22 | 13 28 | 0 | 30 21 | − 6 51 | − 73 | 24 4 |
| 3 | 17 55 | 18 45 | 13 34 | + 1 | 31 55 | − 6 51 | − 73 | 24 44 |
| 4 | 13 42 | 14 30 | 12 39 | + 1 | 26 46 | − 0 31 | − 72 | 25 14 |
| 5 | 13 6 | 14 22 | 11 38 | + 1 | 25 23 | − 0 15 | − 66 | 24 36 |
| 6 | 12 30 | 13 43 | 11 38 | + 8 | 24 53 | − 0 15 | − 66 | 24 31 |
| 7 | 8 41 | 9 25 | 12 52 | + 3 | 21 58 | − 0 13 | − 65 | 24 43 |
| 10 | 7 2 | 7 11 | 13 7 | − 1 | 20 12 | + 5 23 | − 74 | 24 47 |
| 11 | 5 35 | 6 38 | 14 13 | − 1 | 20 19 | + 5 25 | − 74 | 24 46 |
| 12 | 3 48 | 3 50 | 15 35 | − 1 | 19 23 | + 5 25 | − 74 | 24 32 |
| 13 | 5 57 | 6 16 | 13 8 | + 1 | 19 15 | + 5 25 | − 74 | 24 37 |
| 15 | 3 10 | 4 4 | 12 13 | −11 | 15 39 | + 8 34 | + 74 | 24 21 |
| 16 | 4 43 | 6 21 | 10 58 | −33 | 15 57 | + 8 45 | + 69 | 24 38 |
| 17 | 6 8 | 7 37 | 11 10 | −23 | 17 39 | + 8 45 | + 69 | 24 44 |
| 18 | 4 58 | 5 50 | 11 3 | −30 | 16 51 | + 8 46 | + 69 | 25 12 |
| 19 | 3 38 | 4 32 | 11 22 | −20 | 15 7 | + 8 46 | + 69 | 24 17 |
| 20 | 2 5 | 3 3 | 12 38 | −13 | 14 59 | + 8 46 | + 69 | 24 24 |
| | | | | Mean | | | | 341 24 38.4 |
| 2 | 26 54 6 | 55 10 | 13 28 | −14 | 7 52 | −18 53 | −140 | 296 49 9 |
| 3 | 54 0 | 56 16 | 13 34 | −20 | 8 22 | −18 53 | −140 | 48 45 |
| 10 | 19 37 | 21 27 | 13 7 | − 8 | 33 31 | +14 45 | −158 | 46 58 |
| 11 | 19 26 | 19 38 | 14 13 | − 6 | 33 39 | +14 50 | −162 | 47 0 |
| 12 | 17 28 | 17 46 | 15 35 | −11 | 33 1 | +14 50 | −162 | 47 4 |
| 13 | 20 3 | 20 21 | 13 8 | −19 | 33 1 | +14 50 | −162 | 47 17 |
| 15 | 12 35 | 11 37 | 12 13 | − 3 | 24 16 | +23 28 | +185 | 48 32 |
| 16 | 10 30 | 12 42 | 10 58 | − 3 | 22 31 | +23 58 | +196 | 47 10 |
| 18 | 11 42 | 11 58 | 11 3 | − 3 | 22 50 | +24 1 | +197 | 47 12 |
| 19 | 10 10 | 12 35 | 11 22 | − 4 | 22 40 | +24 1 | +197 | 47 51 |
| 20 | 10 2 | 9 56 | 12 38 | − 3 | 22 34 | +24 1 | +197 | 48 0 |
| | | | | Mean | | | | 296 47 43.5 |
| 2 | 305 0 0 | 1 40 | 13 28 | +13 | 14 31 | + 3 55 | + 87 | 215 19 57 |
| 3 | 1 54 | 2 42 | 13 34 | +19 | 16 11 | + 3 55 | + 87 | 20 43 |
| 10 | 10 13 | 11 25 | 13 7 | + 8 | 24 4 | − 3 3 | + 74 | 21 7 |
| 11 | 9 37 | 9 55 | 14 13 | + 6 | 24 5 | − 3 4 | + 71 | 20 56 |
| 12 | 6 58 | 8 16 | 15 35 | +11 | 23 23 | − 3 4 | + 71 | 20 56 |
| 13 | 9 44 | 10 6 | 13 8 | +19 | 23 22 | − 3 5 | + 71 | 21 7 |
| 15 | 14 53 | 16 10 | 12 13 | − 9 | 27 36 | − 4 52 | − 54 | 22 6 |
| 18 | 15 43 | 15 5 | 11 3 | +18 | 26 45 | − 4 59 | − 32 | 20 44 |
| | | | | Mean | | | | 215 20 57.0 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Corrected Mean. | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | $s$ | | | | $\sigma$ |
| **16** | 2 | .0451 | .0651 | 131 | —18 | 107 | .0769 | + 68 | +.1978 | +0.976 | 30.2940 |
| | 3 | .0509 | .0502 | 151 | —18 | 107 | .0743 | + 50 | +.1978 | + .976 | .2896 |
| (20) | 10 | .4275 | .4128 | 116 | —19 | 108 | .4405 | — 12 | —.1554 | + .984 | .2965 |
| | 11 | .4162 | .4188 | 108 | —19 | 108 | .4369 | — 22 | —.1563 | + .982 | .2910 |
| | 13 | .4499 | .4011 | 148 | —19 | 108 | .4490 | — 4 | —.1563 | + .982 | .3049 |
| | 15 | .5196 | .5287 | 108 | +19 | 136 | .5503 | — 32 | —.2475 | — .984 | .2870 |
| | 16 | .5260 | .5298 | 137 | +18 | 104 | .5536 | — 21 | —.2528 | — .926 | .2868 |
| | 18 | .5404 | .5371 | 137 | +18 | 106 | .5647 | — 16 | —.2533 | — .920 | .2980 |
| | | | | | | Mean | | | | | 30.2935 |
| **17** | 2 | .4646 | .4644 | 246 | —49 | 135 | .4942 | +188 | —.0712 | +0.052 | 82.4425 |
| | 10 | .3210 | .3434 | 246 | —50 | 136 | .3618 | — 34 | +.0555 | — .064 | .4131 |
| (13) | 11 | .3304 | .3316 | 246 | —50 | 136 | .3607 | — 59 | +.0558 | — .092 | .4094 |
| | 13 | .3578 | .3466 | 246 | —50 | 136 | .3818 | — 11 | +.0558 | — .092 | .4353 |
| | 15 | .2947 | .2895 | 266 | +50 | 136 | .3338 | — 86 | +.0884 | + .240 | .4167 |
| | 20 | .2928 | .2669 | 276 | +48 | 135 | .3223 | —102 | +.0904 | + .388 | .4075 |
| | | | | | | Mean | | | | | 82.4207 |
| **18** | 2 | .9388 | .9421 | 230 | —41 | 128 | .9701 | +159 | —.0607 | +0.103 | 69.9266 |
| | 10 | .8614 | .8647 | 210 | —43 | 127 | .8903 | — 29 | +.0472 | — .013 | .9344 |
| (12) | 11 | .8696 | .8500 | 209 | —43 | 127 | .8870 | — 50 | +.0475 | — .040 | .9290 |
| | 12 | .8637 | .8578 | 209 | —43 | 128 | .8881 | — 42 | +.0475 | — .040 | .9309 |
| | 13 | .8604 | .8524 | 209 | —43 | 127 | .8836 | — 9 | +.0475 | — .040 | .9297 |
| | 15 | .8128 | .8102 | 230 | +42 | 128 | .8494 | — 73 | +.0752 | + .188 | .9197 |
| | 18 | .8071 | .8033 | 304 | +41 | 128 | .8504 | — 37 | +.0769 | + .339 | .9280 |
| | 19 | .8118 | .8030 | 251 | +41 | 127 | .8472 | — 23 | +.0769 | + .339 | .9262 |
| | 20 | .8181 | .8011 | 237 | +41 | 127 | .8480 | — 87 | +.0769 | + .339 | .9206 |
| | | | | | | Mean | | | | | 69.9272 |
| **19** | 11 | .9849 | .9861 | 397 | —79 | 23 | .0064 | — 92 | —.1211 | +0.529 | 128.8829 |
| | 12 | .9814 | .9767 | 410 | —79 | 23 | .0013 | — 77 | —.1211 | + .529 | .8793 |
| (62) | 15 | .0476 | .0500 | 366 | +78 | 23 | .0823 | —135 | —.1917 | — .662 | .8686 |
| | 19 | .0705 | .0634 | 381 | +75 | 23 | .1016 | — 42 | —.1962 | — .763 | .8914 |
| | | | | | | Mean | | | | | 128.8806 |
| **20** | 2 | .8045 | .8214 | 223 | —44 | 120 | .8403 | +168 | —.0985 | —0.087 | 73.7575 |
| | 3 | .8395 | .8172 | 226 | —44 | 120 | .8561 | +123 | —.0985 | — .087 | .7688 |
| (11) | 9 | .6494 | .6636 | 228 | —44 | 120 | .6844 | — 33 | +.0758 | — .136 | .7552 |
| | 10 | .6614 | .6699 | 221 | —45 | 120 | .6927 | — 30 | +.0770 | — .203 | .7641 |
| | 11 | .6725 | .6640 | 220 | —45 | 115 | .6948 | — 53 | +.0774 | — .230 | .7639 |
| | 12 | .6730 | .6656 | 221 | —45 | 120 | .6964 | — 44 | +.0774 | — .230 | .7664 |
| | 13 | .6560 | .6576 | 223 | —45 | 120 | .6841 | — 10 | +.0774 | — .230 | .7575 |
| | 15 | .6016 | .5942 | 228 | +45 | 120 | .6347 | — 77 | +.1225 | + .377 | .7543 |
| | 16 | .5856 | .5666 | 282 | +43 | 118 | .6179 | — 49 | +.1251 | + .502 | .7445 |
| | 18 | .5646 | .5910 | 278 | +43 | 118 | .6192 | — 40 | +.1253 | + .514 | .7471 |
| | 19 | .5870 | .5912 | 252 | +43 | 118 | .6279 | — 24 | +.1253 | + .514 | .7574 |
| | 20 | .6028 | .5880 | 233 | +43 | 118 | .6323 | — 91 | +.1253 | + .514 | .7551 |
| | | | | | | Mean | | | | | 73.7576 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 2 | 341 7 47 | 3 50 | 13 28 | 0 | 19 16 | − 8 0 | + 13 | 251 12 21 |
| 3 | 7 48 | 6 20 | 13 34 | − 2 | 20 36 | − 8 0 | + 13 | 12 47 |
| 10 | 340 53 52 | 54 38 | 13 7 | + 1 | 7 23 | + 6 12 | − 15 | 13 9 |
| 11 | 51 57 | 52 45 | 14 13 | + 1 | 6 35 | + 6 15 | − 22 | 12 11 |
| 13 | 55 44 | 55 50 | 13 8 | − 1 | 8 54 | + 6 15 | − 22 | 15 25 |
| 15 | 49 42 | 51 33 | 12 13 | +11 | 3 1 | + 9 52 | + 59 | 12 55 |
| 16 | 51 14 | 49 54 | 10 58 | +33 | 2 5 | +10 4 | + 92 | 12 13 |
| 18 | 51 43 | 51 24 | 11 3 | +30 | 3 7 | +10 5 | + 94 | 12 56 |
| | | | | Mean | | | | 251 12 59.6 |
| | | | | | | | | |
| 2 | 71 15 34 | 15 8 | 13 28 | 0 | 28 49 | − 8 11 | − 87 | 341 21 7 |
| 10 | 2 41 | 2 43 | 13 7 | − 1 | 15 48 | + 6 26 | − 88 | 21 21 |
| 11 | 1 3 | 0 38 | 14 13 | − 1 | 15 2 | + 6 28 | − 88 | 20 27 |
| 13 | 1 15 | 2 23 | 13 8 | + 1 | 14 58 | + 6 28 | − 88 | 21 18 |
| 15 | 70 58 12 | 59 25 | 12 13 | −11 | 10 50 | +10 14 | + 88 | 20 13 |
| 20 | 57 58 | 57 30 | 12 38 | −13 | 10 9 | +10 29 | + 82 | 20 22 |
| | | | | Mean | | | | 341 20 48.0 |
| | | | | | | | | |
| 2 | 68 17 43 | 17 50 | 13 28 | − 1 | 31 13 | − 9 49 | −103 | 338 21 47 |
| 10 | 1 25 | 3 22 | 13 7 | − 2 | 15 28 | + 7 43 | −103 | 22 13 |
| 11 | 1 3 | 0 58 | 14 13 | − 1 | 15 13 | + 7 46 | −104 | 21 51 |
| 12 | 67 58 2 | 58 56 | 15 35 | − 3 | 14 1 | + 7 46 | −104 | 21 21 |
| 13 | 68 0 20 | 2 15 | 13 8 | − 2 | 14 23 | + 7 46 | −104 | 21 56 |
| 15 | 67 57 33 | 57 45 | 12 13 | −11 | 9 41 | +12 18 | +105 | 22 18 |
| 18 | 58 53 | 59 22 | 11 3 | −30 | 10 34 | +12 36 | + 98 | 22 55 |
| 19 | 57 8 | 58 34 | 11 22 | −20 | 8 53 | +12 36 | + 98 | 22 3 |
| 20 | 56 12 | 57 7 | 12 38 | −13 | 9 4 | +12 36 | + 98 | 22 29 |
| | | | | Mean | | | | 338 22 5.9 |
| | | | | | | | | |
| 11 | 278 5 48 | 7 0 | 14 13 | + 4 | 20 41 | − 3 4 | + 48 | 188 17 23 |
| 12 | 4 0 | 4 20 | 15 35 | + 9 | 19 54 | − 3 4 | + 48 | 17 18 |
| 15 | 10 45 | 11 25 | 12 13 | − 4 | 23 14 | − 4 52 | − 44 | 17 47 |
| 19 | 11 47 | 11 52 | 11 22 | − 9 | 23 2 | − 4 58 | − 36 | 17 50 |
| | | | | Mean | | | | 188 17 34.5 |
| | | | | | | | | |
| 2 | 79 23 48 | 24 47 | 13 28 | + 4 | 37 50 | − 8 35 | − 98 | 349 29 40 |
| 3 | 23 40 | 25 59 | 13 34 | + 7 | 38 31 | − 8 35 | − 98 | 29 27 |
| 9 | 8 30 | 9 58 | 14 30 | +15 | 23 59 | + 6 39 | − 97 | 29 33 |
| 10 | 10 40 | 10 56 | 13 7 | + 2 | 23 57 | + 6 45 | − 96 | 29 46 |
| 11 | 10 7 | 10 20 | 14 13 | + 1 | 24 28 | + 6 48 | − 95 | 30 11 |
| 12 | 6 45 | 7 52 | 15 35 | + 3 | 22 56 | + 6 48 | − 95 | 29 21 |
| 13 | 10 12 | 11 0 | 13 8 | + 7 | 23 51 | + 6 48 | − 95 | 30 29 |
| 15 | 6 4 | 7 24 | 12 13 | −10 | 18 47 | +10 46 | + 94 | 29 48 |
| 16 | 8 53 | 9 40 | 10 58 | −31 | 19 43 | +11 0 | + 86 | 30 45 |
| 18 | 8 12 | 8 35 | 11 3 | −28 | 19 48 | +11 1 | + 86 | 30 30 |
| 19 | 6 40 | 7 37 | 11 22 | −19 | 18 11 | +11 1 | + 86 | 29 42 |
| 20 | 5 42 | 7 2 | 12 38 | −11 | 18 49 | +11 1 | + 86 | 30 35 |
| | | | | Mean | | | | 349 29 58.9 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **21** | 2 | .0277 | .0658 | 82 | —13 | 100 | .0636 | + 50 | +.1945 | +0.692 | 22.2720 |
| | 10 | .4069 | .4061 | 77 | —14 | 100 | .4227 | — 9 | —.1529 | + .775 | .2789 |
| (21) | 11 | .4056 | .3932 | 73 | —14 | 100 | .4152 | — 16 | —.1537 | + .792 | .2701 |
| | 12 | .3958 | .3944 | 80 | —14 | 100 | .4116 | — 13 | —.1537 | + .792 | .2668 |
| | 13 | .3989 | .3947 | 91 | —14 | 100 | .4144 | — 3 | —.1537 | + .792 | .2706 |
| | 15 | .5047 | .5059 | 64 | +14 | 101 | .5231 | — 24 | —.2436 | — .892 | .2656 |
| | 20 | .5184 | .5169 | 65 | +13 | 102 | .5355 | — 28 | —.2492 | — .943 | .2714 |
| | | | | | | Mean | | | | | 22.2708 |
| **22** | 2 | .7426 | .7498 | 340 | —66 | 123 | .7777 | +252 | —.1171 | —0.187 | 110.6834 |
| | 3 | .7438 | .7714 | 350 | —66 | 123 | .7901 | +185 | —.1171 | — .187 | .6891 |
| (9) | 13 | .5671 | .5651 | 345 | —68 | 128 | .5983 | — 14 | +.0922 | — .327 | .6849 |
| | 15 | .4800 | .4844 | 331 | +67 | 128 | .5266 | —116 | +.1461 | + .472 | .6672 |
| | 16 | .4590 | .4456 | 386 | +64 | 128 | .5018 | — 74 | +.1492 | + .590 | .6512 |
| | 19 | .4759 | .4712 | 358 | +64 | 128 | .5204 | — 36 | +.1495 | + .599 | .6740 |
| | 20 | .4736 | .4740 | 340 | +65 | 132 | .5193 | —137 | +.1495 | + .599 | .6628 |
| | | | | | | Mean | | | | | 110.6732 |
| **23** | 1 | .3538 | .3482 | 271 | —52 | 134 | .3820 | +174 | —.1201 | —0.156 | 89.2773 |
| | 2 | .3584 | .3390 | 276 | —53 | 134 | .3801 | +203 | —.1192 | — .199 | .2786 |
| (10) | 3 | .3613 | .3465 | 284 | —53 | 134 | .3860 | +149 | —.1192 | — .199 | .2791 |
| | 4 | .2602 | .2464 | 280 | —55 | 135 | .2849 | — 2 | —.0089 | — .430 | .2703 |
| | 5 | .2526 | .2460 | 277 | —51 | 135 | .2810 | + 39 | —.0043 | — .604 | .2728 |
| | 6 | .2462 | .2428 | 309 | —51 | 134 | .2793 | + 80 | —.0043 | — .604 | .2752 |
| | 7 | .2490 | .2478 | 290 | —51 | 135 | .2814 | + 83 | —.0038 | — .623 | .2779 |
| | 8 | .1524 | .1357 | 432 | —54 | 135 | .1910 | —113 | +.0919 | — .248 | .2684 |
| | 9 | .1444 | .1497 | 293 | —54 | 135 | .1801 | — 39 | +.0919 | — .248 | .2649 |
| | 10 | .1484 | .1524 | 270 | —54 | 135 | .1812 | — 36 | +.0933 | — .314 | .2669 |
| | 11 | .1523 | .1553 | 268 | —55 | 135 | .1843 | — 64 | +.0938 | — .339 | .2673 |
| | 12 | .1550 | .1485 | 272 | —55 | 135 | .1826 | — 53 | +.0938 | — .339 | .2667 |
| | 13 | .1528 | .1490 | 278 | —55 | 135 | .1824 | — 12 | +.0938 | — .339 | .2706 |
| | 15 | .0830 | .0692 | 267 | +54 | 135 | .1173 | — 93 | +.1485 | + .484 | .2627 |
| | 16 | .0650 | .0636 | 310 | +52 | 135 | .1096 | — 60 | +.1517 | + .600 | .2630 |
| | 17 | .0568 | .0660 | 284 | +52 | 135 | .1042 | — 64 | +.1517 | + .600 | .2572 |
| | 18 | .0544 | .0614 | 307 | +52 | 135 | .1030 | — 48 | +.1520 | + .609 | .2580 |
| | 19 | .0596 | .0628 | 288 | +52 | 135 | .1044 | — 29 | +.1520 | + .609 | .2613 |
| | 20 | .0694 | .0656 | 274 | +52 | 135 | .1093 | —111 | +.1520 | + .609 | .2580 |
| | | | | | | Mean | | | | | 89.2683 |
| **24** | 11 | .4972 | .4884 | 25 | — 5 | 29 | .4977 | — 6 | +.0292 | +0.064 | 8.5271 |
| | 13 | .4776 | .4791 | 26 | — 5 | 32 | .4837 | — 1 | +.0292 | + .064 | .5136 |
| (75) | | | | | | Mean | | | | | 8.5204 |
| **25** | | | | | | | | | | | |
| **26** | | | | | | | | | | | |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 2 | 298 44 53 | 50 40 | 13 28 | +14 | 1 28 | +12 23 | +229 | 209 16 13 |
| 10 | 299 12 10 | 13 43 | 13 7 | + 8 | 26 11 | — 9 34 | +202 | 17 29 |
| 11 | 11 45 | 10 38 | 14 13 | + 6 | 25 30 | — 9 38 | +195 | 16 31 |
| 12 | 8 36 | 5 25 | 15 35 | +11 | 22 47 | — 9 38 | +195 | 14 30 |
| 13 | 10 50 | 9 6 | 13 8 | +19 | 23 25 | — 9 38 | +195 | 15 21 |
| 15 | 21 38 | 21 3 | 12 13 | + 4 | 33 38 | —15 11 | —158 | 17 11 |
| 20 | 20 40 | 20 32 | 12 38 | + 5 | 33 19 | —15 32 | —108 | 17 22 |
| | | | | Mean | | | | 209 16 22.4 |
| 2 | 85 15 2 | 16 8 | 13 28 | + 6 | 29 9 | — 5 22 | — 64 | 355 24 24 |
| 3 | 16 17 | 17 35 | 13 34 | +11 | 30 41 | — 5 22 | — 64 | 25 2 |
| 13 | 7 0 | 7 5 | 13 8 | +10 | 20 20 | + 4 14 | — 62 | 24 36 |
| 15 | 5 40 | 5 50 | 12 13 | — 8 | 17 50 | + 6 43 | + 59 | 24 35 |
| 16 | 6 55 | 8 10 | 10 58 | —28 | 18 2 | + 6 52 | + 53 | 24 44 |
| 19 | 5 53 | 6 13 | 11 22 | —16 | 17 9 | + 6 52 | + 53 | 24 19 |
| 20 | 5 15 | 5 17 | 12 38 | — 9 | 17 45 | + 6 52 | + 53 | 25 10 |
| | | | | Mean | | | | 355 24 41.4 |
| 1 | 85 58 25 | 59 45 | 12 2 | + 8 | 11 15 | — 6 39 | — 79 | 356 4 21 |
| 2 | 56 44 | 57 45 | 13 28 | + 6 | 10 48 | — 6 36 | — 79 | 4 44 |
| 3 | 57 6 | 58 2 | 13 34 | +11 | 11 19 | — 6 36 | — 79 | 4 21 |
| 4 | 53 18 | 53 55 | 12 39 | + 9 | 6 25 | — 0 30 | — 73 | 4 54 |
| 5 | 52 30 | 53 10 | 11 38 | + 8 | 4 36 | — 0 14 | — 62 | 3 52 |
| 6 | 51 37 | 53 26 | 11 38 | +27 | 4 37 | — 0 14 | — 62 | 4 18 |
| 7 | 48 48 | 48 42 | 12 52 | +15 | 1 52 | — 0 6 | — 60 | 4 45 |
| 8 | 46 12 | 47 43 | 13 3 | — 5 | 59 56 | + 5 6 | — 78 | 4 22 |
| 9 | 45 25 | 45 34 | 14 30 | +21 | 0 21 | + 5 6 | — 78 | 4 29 |
| 10 | 46 30 | 47 30 | 13 7 | + 3 | 0 10 | + 5 11 | — 77 | 4 32 |
| 11 | 45 10 | 46 20 | 14 13 | + 2 | 0 0 | + 5 13 | — 76 | 4 15 |
| 12 | 43 18 | 44 27 | 15 35 | + 6 | 59 34 | + 5 13 | — 76 | 4 31 |
| 13 | 45 52 | 46 40 | 13 8 | +10 | 59 34 | + 5 13 | — 76 | 4 44 |
| 15 | 43 43 | 44 12 | 12 13 | — 8 | 56 3 | + 8 17 | + 73 | 4 27 |
| 16 | 45 27 | 46 0 | 10 58 | —27 | 56 15 | + 8 27 | + 66 | 4 37 |
| 17 | 45 43 | 47 46 | 11 10 | —18 | 57 37 | + 8 27 | + 66 | 4 23 |
| 18 | 45 18 | 45 28 | 11 3 | —25 | 56 46 | + 8 28 | + 65 | 4 47 |
| 19 | 44 5 | 44 6 | 11 22 | —15 | 55 13 | + 8 28 | + 65 | 4 3 |
| 20 | 43 15 | 43 37 | 12 38 | — 9 | 55 57 | + 8 28 | + 65 | 5 2 |
| | | | | Mean | | | | 356 4 29.8 |
| 11 | 61 51 28 | 55 42 | 14 13 | — 3 | 7 46 | + 6 2 | —852 | 333 8 11 |
| 13 | 62 5 29 | 1 51 | 13 8 | — 5 | 16 43 | + 6 3 | —852 | 18 4 |
| | | | | Mean | | | | 333 13 7.5 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **27** | 2 | .2265 | .2096 | 118 | —23 | 109 | .2380 | + 87 | +.1228 | +0.222 | 38.3724 |
| | 3 | .2274 | .1914 | 122 | —23 | 109 | .2298 | + 64 | +.1228 | + .222 | .3619 |
| (30) | 10 | .4421 | .4243 | 141 | —23 | 108 | .4554 | — 16 | —.0969 | + .335 | .3612 |
| | 11 | .4299 | .4405 | 116 | —23 | 108 | .4549 | — 27 | —.0974 | + .361 | .3594 |
| | 12 | .4387 | .4402 | 118 | —23 | 108 | .4593 | — 23 | —.0974 | + .361 | .3642 |
| | 13 | .4381 | .4337 | 121 | —23 | 108 | .4561 | — 5 | —.0974 | + .361 | .3628 |
| | 15 | .4898 | .4942 | 114 | +23 | 108 | .5161 | — 40 | —.1546 | — .504 | .3510 |
| | 16 | .4972 | .5186 | 129 | +22 | 108 | .5334 | — 26 | —.1579 | — .618 | .3650 |
| | 18 | .5107 | .4993 | 130 | +22 | 108 | .5306 | — 21 | —.1582 | — .627 | .3622 |
| | 20 | .4933 | .5113 | 117 | +22 | 108 | .5266 | — 48 | —.1582 | — .627 | .3555 |
| | | | | | | Mean | | | | | 38.3616 |
| **28** | 11 | .8154 | .8118 | 338 | —68 | 112 | .8433 | — 80 | —.1002 | +0.381 | 111.7400 |
| | 12 | .8212 | .8102 | 343 | —68 | 112 | .8459 | — 67 | —.1002 | + .381 | .7439 |
| (60) | 13 | .8050 | .8032 | 351 | —68 | 112 | .8351 | — 14 | —.1002 | + .381 | .7384 |
| | 15 | .8830 | .8616 | 329 | +68 | 112 | .9147 | —117 | —.1588 | — .523 | .7375 |
| | 18 | .8925 | .8660 | 374 | +65 | 112 | .9258 | — 60 | —.1625 | — .645 | .7490 |
| | 19 | .8712 | .8688 | 353 | +65 | 112 | .9145 | — 36 | —.1625 | — .645 | .7401 |
| | | | | | | Mean | | | | | 111.7415 |
| **29** | 3 | .1795 | .1523 | 129 | —21 | 112 | .1876 | + 60 | —.1601 | —0.440 | 36.0279 |
| | 11 | .8741 | .8697 | 111 | —22 | 112 | .8917 | — 26 | +.1259 | + .567 | .0077 |
| (5) | 13 | .8725 | .8763 | 125 | —22 | 112 | .8956 | — 5 | +.1259 | + .567 | .0137 |
| | | | | | | Mean | | | | | 36.0164 |
| **30** (69) | 11 | .2444 | .2182 | 60 | —11 | 78 | .2440 | — 13 | +.1536 | —0.793 | 18.3861 |
| **31** (64) | 11 | .9278 | .9310 | 179 | —37 | 102 | .9525 | — 43 | —.0820 | +0.258 | 59.8695 |
| **32** | 1 | .8124 | .7994 | 227 | —45 | 130 | .8343 | +150 | +.1095 | +0.100 | 76.9601 |
| | 2 | .8056 | .7947 | 235 | —46 | 130 | .8293 | +175 | +.1087 | + .142 | .9573 |
| (31) | 3 | .7998 | .8035 | 238 | —46 | 130 | .8311 | +128 | +.1087 | + .142 | .9544 |
| | 4 | .9032 | .9052 | 238 | —47 | 124 | .9329 | — 2 | +.0081 | + .378 | .9457 |
| | 5 | .9166 | .9137 | 235 | —44 | 124 | .9439 | + 34 | +.0039 | + .560 | .9584 |
| | 6 | .9144 | .8940 | 256 | —44 | 130 | .9356 | + 69 | +.0039 | + .560 | .9536 |
| | 7 | .9134 | .9000 | 245 | —44 | 124 | .9364 | + 71 | +.0035 | + .580 | .9544 |
| | 8 | .0047 | .0115 | 235 | —46 | 124 | .0366 | — 98 | —.0842 | + .191 | .9451 |
| | 9 | .0119 | .0014 | 246 | —46 | 124 | .0363 | — 34 | —.0842 | + .191 | .9512 |
| | 10 | .0117 | .9983 | 232 | —47 | 124 | .0331 | — 31 | —.0856 | + .258 | .9477 |
| | 11 | .0044 | .0053 | 231 | —47 | 124 | .0328 | — 55 | —.0860 | + .284 | .9449 |
| | 12 | .0090 | .0010 | 233 | —47 | 124 | .0332 | — 46 | —.0860 | + .284 | .9462 |
| | 13 | .9911 | .0017 | 236 | —47 | 124 | .0249 | — 10 | —.0860 | + .284 | .9415 |
| | 15 | .0522 | .0566 | 235 | +47 | 124 | .0922 | — 81 | —.1365 | — .430 | .9421 |
| | 16 | .0533 | .0692 | 270 | +45 | 125 | .1025 | — 52 | —.1394 | — .552 | .9508 |
| | 17 | .0687 | .0591 | 253 | +45 | 124 | .1033 | — 55 | —.1394 | — .552 | .9513 |
| | 18 | .0672 | .0500 | 276 | +45 | 124 | .1003 | — 41 | —.1396 | — .562 | .9494 |
| | 19 | .0698 | .0420 | 254 | +45 | 124 | .0954 | — 25 | —.1395 | — .562 | .9461 |
| | 20 | .0621 | .0665 | 240 | +45 | 121 | .1025 | — 96 | —.1396 | — .562 | .9461 |
| | | | | | | Mean | | | | | 76.9498 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued*).

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 2 | 266 44 0 | 44 25 | 13 28 | + 7 | 57 48 | +15 21 | +183 | 177 15 15 |
| 3 | 45 17 | 44 12 | 13 34 | +12 | 58 30 | +15 21 | +183 | 15 3 |
| 10 | 267 14 38 | 13 58 | 13 7 | − 6 | 27 19 | −11 59 | +178 | 16 3 |
| 11 | 12 58 | 13 44 | 14 13 | + 2 | 27 37 | −12 3 | +176 | 16 6 |
| 12 | 11 6 | 9 35 | 15 35 | + 6 | 26 2 | −12 3 | +176 | 15 13 |
| 13 | 11 3 | 11 43 | 13 8 | +12 | 24 43 | −12 3 | +176 | 14 7 |
| 15 | 22 30 | 24 28 | 12 13 | − 8 | 35 34 | −19 4 | −169 | 15 10 |
| 16 | 25 5 | 26 10 | 10 58 | −27 | 36 8 | −19 28 | −151 | 15 17 |
| 18 | 26 52 | 25 48 | 11 3 | −23 | 37 40 | −19 30 | −149 | 16 26 |
| 20 | 22 0 | 24 2 | 12 38 | − 9 | 35 30 | −19 30 | −149 | 15 20 |
| | | | | Mean | | | | 177 15 24.0 |
| 11 | 268 23 45 | 24 35 | 14 13 | + 2 | 38 25 | − 4 7 | + 60 | 178 34 9 |
| 12 | 21 18 | 22 28 | 15 35 | + 6 | 37 34 | − 4 7 | + 60 | 34 0 |
| 13 | 23 40 | 24 24 | 13 8 | +12 | 37 22 | − 4 7 | + 60 | 34 1 |
| 15 | 28 42 | 29 56 | 12 13 | − 7 | 41 25 | − 6 31 | − 57 | 34 13 |
| 18 | 30 20 | 30 52 | 11 3 | −25 | 41 14 | − 6 40 | − 51 | 33 26 |
| 19 | 30 22 | 30 00 | 11 22 | −15 | 41 18 | − 6 40 | − 51 | 34 19 |
| | | | | Mean | | | | 178 34 1.3 |
| 3 | 101 6 44 | 4 42 | 13 34 | +18 | 19 35 | −12 54 | −178 | 11 5 43 |
| 11 | 100 40 27 | 38 44 | 14 13 | + 5 | 53 53 | +10 15 | −165 | 2 38 |
| 13 | 42 10 | 42 40 | 13 8 | +17 | 55 50 | +10 15 | −165 | 5 30 |
| | | | | Mean | | | | 11 4 37.0 |
| 11 | 119 16 43 | 11 55 | 14 13 | + 6 | 28 38 | +11 41 | −234 | 29 38 16 |
| 11 | 260 49 18 | 50 32 | 14 13 | + 2 | 4 10 | − 8 19 | +117 | 170 56 2.0 |
| 1 | 268 18 42 | 19 55 | 12 2 | + 6 | 31 26 | + 8 10 | + 93 | 172 40 22 |
| 2 | 16 50 | 17 32 | 13 28 | + 6 | 30 45 | + 8 6 | + 93 | 40 24 |
| 3 | 17 37 | 18 22 | 13 34 | + 9 | 31 43 | + 8 6 | + 93 | 40 28 |
| 4 | 26 12 | 26 36 | 12 39 | + 8 | 39 11 | + 0 36 | + 87 | 39 43 |
| 5 | 27 43 | 27 50 | 11 38 | + 6 | 39 31 | + 0 18 | + 75 | 40 8 |
| 6 | 26 38 | 27 51 | 11 38 | +23 | 39 16 | + 0 18 | + 75 | 40 18 |
| 7 | 22 58 | 23 47 | 12 52 | +12 | 36 26 | + 0 15 | + 73 | 40 28 |
| 8 | 33 25 | 33 30 | 13 3 | + 8 | 46 38 | − 6 15 | + 92 | 40 44 |
| 9 | 31 55 | 32 2 | 14 30 | +18 | 46 46 | − 6 15 | + 92 | 40 34 |
| 10 | 33 5 | 33 55 | 13 7 | + 3 | 46 40 | − 6 20 | + 91 | 40 32 |
| 11 | 32 24 | 33 5 | 14 13 | + 2 | 46 59 | − 6 23 | + 90 | 40 37 |
| 12 | 30 31 | 31 8 | 15 35 | + 5 | 46 30 | − 6 23 | + 90 | 40 50 |
| 13 | 32 30 | 33 5 | 13 8 | + 8 | 46 3 | − 6 23 | + 90 | 40 36 |
| 15 | 38 40 | 40 8 | 12 13 | − 8 | 51 31 | −10 6 | − 88 | 40 34 |
| 16 | 40 45 | 41 30 | 10 58 | −30 | 51 35 | −10 19 | − 80 | 40 18 |
| 17 | 42 13 | 43 27 | 11 10 | −19 | 53 41 | −10 19 | − 80 | 40 48 |
| 18 | 262 40 53 | 41 27 | 11 3 | −27 | 52 46 | −10 20 | − 79 | 41 8 |
| 19 | 40 12 | 40 58 | 11 22 | −17 | 51 40 | −10 20 | − 79 | 40 51 |
| 20 | 37 53 | 38 32 | 12 38 | −10 | 50 40 | −10 20 | − 79 | 40 6 |
| | | | | Mean | | | | 172 40 30.0 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Corrected Mean. | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | $s$ | | | | $\sigma$ |
| **33** | 2 | .9723 | .9735 | 124 | —21 | 115 | .9944 | + 80 | —.1815 | —0.587 | 34.8134 |
| | 3 | .9855 | .9747 | 137 | —21 | 115 | .0029 | + 58 | —.1815 | — .587 | .8197 |
| (4) | 11 | .6619 | .6613 | 111 | —21 | 115 | .6818 | — 25 | +.1430 | — .701 | .8133 |
| | 12 | .6594 | .6642 | 118 | —21 | 115 | .6827 | — 21 | +.1430 | — .701 | .8146 |
| | 13 | .6615 | .6579 | 131 | —21 | 115 | .6819 | — 4 | +.1430 | — .701 | .8155 |
| | 15 | .5516 | .5545 | 98 | +21 | 113 | .5759 | — 36 | +.2264 | + .815 | .8092 |
| | 18 | .5535 | .5761 | 99 | +20 | 116 | .5880 | — 19 | +.2317 | + .887 | .8292 |
| | | | | | | Mean | | | | | 34.8164 |
| **34** | 2 | .4744 | .4310 | 106 | —20 | 116 | .4726 | + 78 | +.0184 | —0.296 | 34.4950 |
| | 11 | .4828 | .5022 | 105 | —21 | 113 | .5119 | — 25 | —.0154 | — .158 | .4920 |
| (37) | 13 | .5002 | .4982 | 106 | —21 | 113 | .5187 | — 4 | —.0154 | — .158 | .5009 |
| | | | | | | Mean | | | | | 34.4960 |
| **35** | 11 | .5791 | .5869 | 73 | —14 | 105 | .5993 | — 16 | +.0507 | —0.529 | 22.6416 |
| | 13 | .5724 | .5822 | 79 | —14 | 101 | .5938 | — 3 | +.0507 | — .529 | .6374 |
| (66) | | | | | | Mean | | | | | 22.6395 |
| **36** | 2 | .5805 | .5901 | 97 | —13 | 102 | .6039 | + 51 | —.1805 | —0.967 | 22.4161 |
| | 3 | .5566 | .5800 | 111 | —13 | 104 | .5884 | + 38 | —.1805 | — .967 | .3993 |
| (1) | 10 | .2344 | .2589 | 84 | —14 | 102 | .2637 | — 9 | +.1412 | — .952 | .3918 |
| | 11 | .2540 | .2531 | 79 | —14 | 102 | .2702 | — 16 | +.1420 | — .945 | .3985 |
| | 12 | .2634 | .2490 | 91 | —14 | 102 | .2741 | — 13 | +.1420 | — .945 | .4027 |
| | 13 | .2619 | .2501 | 106 | —14 | 102 | .2553 | — 3 | +.1420 | — .945 | .4049 |
| | 15 | .1350 | .1192 | 63 | +13 | 98 | .1444 | — 23 | +.2249 | + .918 | .3788 |
| | 18 | .1366 | .1154 | 112 | +13 | 102 | .1487 | — 12 | +.2301 | + .826 | .3882 |
| | | | | | | Mean | | | | | 22.3977 |
| **37** | 2 | .6800 | .6808 | 146 | —28 | 114 | .7029 | +109 | +.0296 | —0.246 | 46.7402 |
| | 3 | .6756 | .6848 | 145 | —28 | 114 | .7026 | + 79 | +.0296 | — .246 | .7369 |
| (35) | 4 | .7040 | .6981 | 146 | —29 | 114 | .7234 | — 1 | +.0022 | — .007 | .7254 |
| | 5 | .7052 | .7086 | 145 | —27 | 114 | .7294 | + 21 | +.0011 | + .210 | .7353 |
| | 6 | .7098 | .6964 | 144 | —27 | 118 | .7259 | + 43 | +.0011 | + .210 | .7340 |
| | 7 | .7106 | .6976 | 146 | —27 | 114 | .7267 | + 44 | +.0010 | + .236 | .7351 |
| | 8 | .7296 | .7294 | 141 | —29 | 114 | .7514 | — 61 | —.0236 | — .200 | .7191 |
| | 9 | .7345 | .7399 | 142 | —29 | 114 | .7592 | — 21 | —.0236 | — .200 | .7309 |
| | 10 | .7349 | .7305 | 145 | —29 | 114 | .7550 | — 20 | —.0239 | — .133 | .7274 |
| | 11 | .7333 | .7332 | 145 | —29 | 114 | .7556 | — 34 | —.0241 | — .106 | .7267 |
| | 12 | .7322 | .7305 | 145 | —29 | 114 | .7537 | — 29 | —.0241 | — .106 | .7253 |
| | 13 | .7242 | .7366 | 145 | —29 | 114 | .7527 | — 6 | —.0241 | — .106 | .7266 |
| | 15 | .7390 | .7317 | 164 | +29 | 118 | .7658 | — 50 | —.0383 | — .039 | .7220 |
| | 16 | .7152 | .7370 | 232 | +28 | 117 | .7631 | — 32 | —.0391 | — .184 | .7184 |
| | 17 | .7358 | .7275 | 197 | +28 | 114 | .7648 | — 34 | —.0391 | — .184 | .7199 |
| | 18 | .7323 | .7253 | 232 | +28 | 114 | .7655 | — 26 | —.0392 | — .196 | .7212 |
| | 19 | .7366 | .7198 | 195 | +28 | 114 | .7612 | — 16 | —.0392 | — .196 | .7179 |
| | 20 | .7277 | .7378 | 172 | +28 | 116 | .7637 | — 59 | —.0392 | — .196 | .7161 |
| | | | | | | Mean | | | | | 47.7266 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Corrections plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | | ′ ″ | ′ ″ | | ° ′ ″ |
| 2 | 111 10 24 | 10 52 | 13 28 | +14 | 24 20 | —10 22 | —165 | 21 13 59 |
| 3 | 10 48 | 11 30 | 13 34 | +20 | 25 3 | —10 22 | —165 | 13 48 |
| 11 | 110 54 46 | 55 46 | 14 13 | + 6 | 9 35 | + 8 15 | —147 | 16 26 |
| 12 | 51 35 | 51 35 | 15 35 | +11 | 7 21 | + 8 15 | —147 | 14 54 |
| 13 | 53 10 | 55 24 | 13 8 | +19 | 7 46 | + 8 15 | —147 | 15 32 |
| 15 | 49 17 | 48 43 | 12 13 | + 1 | 1 14 | +13 6 | +126 | 14 46 |
| 18 | 52 48 | 52 7 | 11 3 | — 2 | 3 29 | +13 25 | + 97 | 16 39 |
| | | | | Mean | | | | 21 15 9.1 |
| 2 | 236 3 27 | 3 30 | 13 28 | — 7 | 16 49 | +20 56 | +199 | 146 39 57 |
| 11 | 41 28 | 40 4 | 14 13 | — 4 | 54 55 | —16 30 | +207 | 39 8 |
| 13 | 40 23 | 40 53 | 13 8 | — 8 | 53 38 | —16 30 | +207 | 38 46 |
| | | | | Mean | | | | 146 39 17.0 |
| 11 | 213 17 2 | 17 24 | 14 13 | — 6 | 31 20 | —24 2 | +269 | 123 8 24 |
| 13 | 17 25 | 17 40 | 13 8 | —17 | 30 23 | —24 3 | +269 | 8 21 |
| | | | | Mean | | | | 123 8 22.5 |
| 2 | 171 48 14 | 47 43 | 13 28 | — 5 | 1 22 | +16 30 | + 44 | 82 19 8 |
| 3 | 45 48 | 51 2 | 13 34 | — 9 | 1 50 | +16 30 | + 44 | 18 42 |
| 10 | 172 18 12 | 19 36 | 13 7 | — 3 | 31 58 | —13 8 | + 83 | 18 59 |
| 11 | 18 17 | 20 29 | 14 13 | — 2 | 33 34 | —13 13 | + 91 | 20 23 |
| 12 | 18 48 | 16 43 | 15 35 | — 4 | 33 17 | —13 13 | + 91 | 20 48 |
| 13 | 19 20 | 18 40 | 13 8 | — 8 | 32 0 | —13 13 | + 91 | 19 44 |
| 15 | 29 8 | 29 8 | 12 13 | + 2 | 41 23 | —21 1 | —139 | 19 13 |
| 18 | 29 55 | 31 11 | 11 3 | +27 | 42 3 | —21 30 | —183 | 18 37 |
| | | | | Mean | | | | 82 19 26.8 |
| 2 | 239 6 5 | 6 55 | 13 28 | — 5 | 19 53 | +15 3 | +146 | 149 36 49 |
| 3 | 7 28 | 8 15 | 13 34 | — 7 | 21 19 | +15 3 | +146 | 37 21 |
| 4 | 22 14 | 22 52 | 12 39 | — 7 | 35 4 | + 1 8 | +152 | 36 32 |
| 5 | 24 14 | 24 12 | 11 38 | — 6 | 35 45 | + 0 33 | +145 | 37 2 |
| 6 | 24 0 | 25 7 | 11 38 | — 7 | 36 5 | + 0 33 | +145 | 37 47 |
| 7 | 19 22 | 20 25 | 12 52 | — 8 | 32 38 | + 0 29 | +143 | 37 19 |
| 8 | 35 38 | 35 52 | 13 3 | — 6 | 48 42 | —11 37 | +148 | 37 46 |
| 9 | 34 12 | 34 12 | 14 30 | — 7 | 48 35 | —11 37 | +148 | 37 21 |
| 10 | 35 18 | 35 28 | 13 7 | — 3 | 48 28 | —11 48 | +151 | 37 13 |
| 11 | 34 18 | 34 52 | 14 13 | — 3 | 48 45 | —11 52 | +151 | 37 16 |
| 12 | 31 55 | 32 33 | 15 35 | — 5 | 47 44 | —11 52 | +151 | 36 57 |
| 13 | 34 2 | 34 35 | 13 8 | — 6 | 47 20 | —11 52 | +151 | 36 46 |
| 15 | 44 32 | 45 45 | 12 13 | —11 | 57 11 | —18 47 | —156 | 37 9 |
| 16 | 46 17 | 47 26 | 10 58 | —32 | 57 18 | —19 11 | —152 | 36 43 |
| 17 | 48 28 | 49 4 | 11 10 | —22 | 59 34 | —19 11 | —152 | 37 23 |
| 18 | 46 30 | 47 0 | 11 3 | —29 | 57 19 | —19 13 | —151 | 36 22 |
| 19 | 46 3 | 46 18 | 11 22 | —20 | 57 12 | —19 13 | —151 | 37 4 |
| 20 | 44 18 | 44 55 | 12 38 | —13 | 57 1 | —19 13 | —151 | 37 8 |
| | | | | Mean | | | | 149 37 6.6 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Cor-rected Mean. *s* | Scale Varia-tion. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. σ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | | | | | |
| **38** | 2 | .1008 | .0942 | 337 | —66 | 113 | .1274 | +255 | +.0898 | +0.043 | 112.2433 |
| | 3 | .0889 | .1011 | 340 | —66 | 113 | .1252 | +187 | +.0898 | + .043 | .2343 |
| (32) | 11 | .2728 | .2700 | 336 | —68 | 113 | .3009 | — 80 | —.0711 | + .187 | .2242 |
| | 12 | .2472 | .2810 | 335 | —68 | 113 | .2935 | — 67 | —.0711 | + .187 | .2181 |
| | 13 | .2560 | .2598 | 336 | —68 | 112 | .2873 | — 14 | —.0711 | + .187 | .2172 |
| | 15 | .3051 | .3069 | 345 | +68 | 113 | .3500 | —118 | —.1127 | — .335 | .2212 |
| | 18 | .2970 | .2856 | 334 | +65 | 113 | .3339 | — 60 | —.1154 | — .475 | .2064 |
| | 19 | .2952 | .2910 | 392 | +65 | 113 | .3415 | — 37 | —.1154 | — .475 | .2163 |
| | 20 | .2980 | .3130 | 360 | +65 | 113 | .3507 | —139 | —.1154 | — .475 | .2153 |
| | | | | | | Mean | | | | | 112.2206 |
| **39** | 1 | .8614 | .8446 | 383 | —67 | 130 | .8886 | +222 | —.1662 | —0.433 | 113.7390 |
| | 2 | .8448 | .8534 | 383 | —68 | 105 | .8822 | +259 | —.1651 | — .473 | .7369 |
| (8) | 3 | .8484 | .8438 | 415 | —68 | 106 | .8825 | +190 | —.1651 | — .473 | .7303 |
| | 6 | .7040 | .7114 | 506 | —66 | 105 | .7533 | +102 | —.0060 | — .798 | .7473 |
| | 9 | .5794 | .5372 | 466 | —69 | 103 | .5994 | — 50 | +.1274 | — .517 | .7152 |
| | 10 | .5686 | .5601 | 362 | —69 | 107 | .5955 | — 46 | +.1295 | — .575 | .7130 |
| | 11 | .5678 | .5612 | 354 | —70 | 105 | .5945 | — 81 | +.1302 | — .598 | .7089 |
| | 13 | .5601 | .5579 | 404 | —70 | 108 | .5943 | — 15 | +.1302 | — .598 | .7153 |
| | 15 | .4675 | .4617 | 322 | +69 | 108 | .5057 | —119 | +.2062 | + .724 | .7093 |
| | 16 | .4474 | .4601 | 324 | +66 | 108 | .4946 | — 76 | +.2106 | + .809 | .7080 |
| | 17 | .4422 | .4408 | 317 | +66 | 108 | .4818 | — 81 | +.2106 | + .809 | .6947 |
| | 18 | .4532 | .4473 | 331 | +66 | 108 | .4919 | — 61 | +.2110 | + .816 | .7073 |
| | 19 | .4398 | .4573 | 326 | +66 | 108 | .4897 | — 37 | +.2110 | + .816 | .7075 |
| | 20 | .4372 | .4402 | 324 | +66 | 108 | .4797 | —141 | +.2110 | + .816 | .6871 |
| | | | | | | Mean | | | | | 113.7157 |
| **40** | 2 | .1750 | .1744 | 288 | —57 | 138 | .2061 | +219 | +.0763 | —0.025 | 96.3040 |
| | 3 | .1687 | .1808 | 290 | —57 | 138 | .2063 | +160 | +.0763 | — .025 | .2983 |
| (33) | 11 | .3050 | .3063 | 287 | —59 | 138 | .3367 | — 69 | —.0605 | + .119 | .2708 |
| | 12 | .2842 | .3048 | 288 | —59 | 138 | .3256 | — 58 | —.0605 | + .119 | .2608 |
| | 13 | .3034 | .3065 | 289 | —59 | 138 | .3361 | — 12 | —.0605 | + .119 | .2759 |
| | 15 | .3279 | .3275 | 308 | +59 | 138 | .3726 | —101 | —.0959 | — .267 | .2632 |
| | 18 | .3268 | .3224 | 393 | +56 | 138 | .3777 | — 52 | —.0982 | — .414 | .2690 |
| | | | | | | Mean | | | | | 96.2774 |
| **41** | 2 | .0414 | .0432 | 120 | —20 | 126 | .0646 | + 78 | —.0685 | —0.650 | 33.9956 |
| (38) | 15 | .8546 | .8660 | 131 | +21 | 126 | .8878 | — 35 | +.0841 | + .426 | .9739 |
| | | | | | | Mean | | | | | 33.9848 |
| **42** | 2 | .2542 | .2492 | 422 | —73 | 112 | .2864 | +281 | —.1703 | —0.508 | 123.1377 |
| | 3 | .2624 | .2463 | 457 | —73 | 107 | .2920 | +205 | —.1703 | — .508 | .1357 |
| (7) | 16 | .8572 | .8356 | 345 | +72 | 112 | .8879 | — 82 | +.2172 | + .833 | .1076 |
| | 18 | .8465 | .8353 | 356 | +72 | 110 | .8833 | — 66 | +.2176 | + .839 | .1051 |
| | 19 | .8395 | .8350 | 352 | +72 | 112 | .8794 | — 40 | +.2176 | + .839 | .1038 |
| | | | | | | Mean | | | | | 123.1180 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. $p$ | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. $\pi$ |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 2 | 256 27 28 | 28 18 | 13 28 | + 2 | 41 24 | + 5 53 | + 64 | 166 48 40 |
| 3 | 28 27 | 29 48 | 13 34 | + 6 | 42 48 | + 5 53 | + 64 | 49 10 |
| 11 | 39 4 | 39 28 | 14 13 | + 1 | 53 30 | − 4 38 | + 63 | 48 44 |
| 12 | 37 35 | 37 32 | 15 35 | + 1 | 53 10 | − 4 38 | + 63 | 49 6 |
| 13 | 39 10 | 39 43 | 13 8 | + 5 | 52 39 | − 4 38 | + 63 | 48 48 |
| 15 | 44 12 | 46 52 | 12 13 | −10 | 57 35 | − 7 20 | − 62 | 49 34 |
| 18 | 46 0 | 47 10 | 11 3 | −29 | 57 9 | − 7 31 | − 58 | 48 27 |
| 19 | 46 42 | 46 48 | 11 22 | −19 | 57 48 | − 7 31 | − 58 | 49 55 |
| 20 | 44 13 | 44 55 | 12 38 | −12 | 57 0 | − 7 31 | − 58 | 49 22 |
| | | | | Mean | | | | 166 49 5.1 |
| 1 | 103 8 12 | 9 4 | 12 2 | +14 | 20 54 | − 3 54 | − 56 | 13 16 53 |
| 2 | 6 25 | 7 13 | 13 28 | +12 | 20 29 | − 3 52 | − 55 | 17 17 |
| 3 | 7 12 | 8 24 | 13 34 | +18 | 21 40 | − 3 52 | − 55 | 17 34 |
| 6 | 4 30 | 6 2 | 11 38 | +38 | 17 32 | − 0 9 | − 35 | 17 27 |
| 9 | 102 59 56 | 0 22 | 14 30 | +32 | 15 11 | + 3 0 | − 54 | 17 22 |
| 10 | 103 1 2 | 1 55 | 13 7 | + 7 | 14 42 | + 3 2 | − 52 | 17 4 |
| 11 | 102 59 52 | 0 38 | 14 13 | + 5 | 14 33 | + 3 4 | − 50 | 16 48 |
| 13 | 103 00 2 | 0 53 | 13 8 | +18 | 13 51 | + 3 4 | − 50 | 17 1 |
| 15 | 102 59 47 | 0 47 | 12 13 | − 2 | 12 28 | + 4 51 | + 45 | 17 16 |
| 16 | 103 1 13 | 2 23 | 10 58 | −12 | 12 34 | + 4 57 | + 38 | 17 16 |
| 17 | 2 22 | 3 13 | 11 10 | − 7 | 13 50 | + 4 57 | + 38 | 16 56 |
| 18 | 0 55 | 1 57 | 11 3 | −10 | 12 19 | + 4 58 | + 37 | 16 40 |
| 19 | 102 59 48 | 1 5 | 11 22 | − 2 | 11 47 | + 4 58 | + 37 | 16 57 |
| 20 | 59 16 | 59 44 | 12 38 | − 3 | 12 5 | + 4 58 | + 37 | 17 30 |
| | | | | Mean | | | | 13 17 8.6 |
| 2 | 252 27 5 | 26 16 | 13 28 | 0 | 40 8 | + 7 3 | + 74 | 162 48 38 |
| 3 | 28 4 | 28 28 | 13 34 | + 1 | 41 51 | + 7 3 | + 74 | 49 27 |
| 11 | 40 35 | 41 15 | 14 13 | 0 | 55 8 | − 5 34 | + 75 | 49 30 |
| 12 | 39 43 | 38 5 | 15 35 | + 1 | 55 30 | − 5 34 | + 75 | 50 34 |
| 13 | 40 15 | 40 53 | 13 8 | + 2 | 53 44 | − 5 34 | + 75 | 49 1 |
| 15 | 46 13 | 47 45 | 12 13 | −11 | 59 1 | − 8 48 | − 74 | 49 27 |
| 18 | 47 52 | 47 58 | 11 3 | −30 | 58 28 | − 9 1 | − 69 | 48 12 |
| | | | | Mean | | | | 162 49 15.6 |
| 2 | 212 1 28 | 2 24 | 13 28 | −13 | 15 11 | +20 8 | +158 | 122 37 16 |
| 15 | 49 32 | 51 18 | 12 13 | − 6 | 2 32 | −25 17 | −199 | 35 44 |
| | | | | Mean | | | | 122 36 30.0 |
| 2 | 105 25 50 | 26 42 | 13 28 | +12 | 39 56 | − 3 22 | − 50 | 15 37 16 |
| 3 | 27 17 | 27 13 | 13 34 | +18 | 41 7 | − 3 22 | − 50 | 37 33 |
| 16 | 21 57 | 23 13 | 10 58 | −10 | 33 22 | + 4 19 | + 33 | 37 24 |
| 18 | 21 7 | 22 12 | 11 3 | − 9 | 32 46 | + 4 20 | + 32 | 36 28 |
| 19 | 21 42 | 21 17 | 11 22 | − 4 | 32 47 | + 4 20 | + 32 | 37 18 |
| | | | | Mean | | | | 15 37 11.8 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **43** | 1 | .1198 | .1144 | 199 | —38 | 108 | .1423 | +127 | +.0087 | —0.377 | 65.1589 |
| | 2 | .1202 | .1164 | 202 | —39 | 105 | .1434 | +148 | +.0086 | — .340 | .1624 |
| (34) | 3 | .1072 | .1286 | 206 | —39 | 105 | .1434 | +108 | +.0086 | — .340 | .1584 |
| | 10 | .1334 | .1292 | 201 | —40 | 105 | .1562 | — 27 | —.0072 | — .231 | .1433 |
| | 11 | .1330 | .1302 | 199 | —40 | 105 | .1563 | — 47 | —.0072 | — .204 | .1418 |
| | 12 | .1372 | .1324 | 201 | —40 | 105 | .1597 | — 39 | —.0072 | — .204 | .1460 |
| | 13 | .1285 | .1371 | 204 | —40 | 105 | .1580 | — 8 | —.0072 | — .204 | .1474 |
| | 15 | .1291 | .1129 | 231 | +40 | 114 | .1578 | — 68 | —.0116 | + .063 | .1402 |
| | 16 | .1065 | .1251 | 339 | +38 | 110 | .1628 | — 44 | —.0120 | — .084 | .1453 |
| | 18 | .1013 | .1075 | 327 | +38 | 108 | .1500 | — 35 | —.0120 | — .098 | .1332 |
| | 19 | .1082 | .1001 | 277 | +38 | 105 | .1445 | — 21 | —.0120 | — .098 | .1291 |
| | 20 | .1226 | .1394 | 243 | +38 | 108 | .1682 | — 81 | —.0120 | — .098 | .1468 |
| | | | | | | Mean | | | | | 65.1461 |
| **44** | 2 | .1214 | .1514 | 187 | —34 | 108 | .1614 | +130 | —.0286 | —0.496 | 57.1394 |
| | 3 | .0957 | .1632 | 194 | —34 | 108 | .1552 | + 95 | —.0286 | — .496 | .1297 |
| (36) | 10 | .1050 | .0813 | 182 | —35 | 104 | .1172 | — 23 | +.0219 | — .396 | .1317 |
| | 11 | .1076 | .0924 | 179 | —35 | 107 | .1240 | — 41 | +.0221 | — .372 | .1372 |
| | 13 | .0948 | .0884 | 191 | —35 | 104 | .1165 | — 7 | +.0221 | — .372 | .1331 |
| | 15 | .0611 | .0733 | 214 | +35 | 107 | .1017 | — 60 | +.0347 | + .240 | .1335 |
| | | | | | | Mean | | | | | 57.1341 |
| **45** | 2 | .2294 | .1670 | 379 | —63 | 111 | .2336 | +253 | —.1844 | —0.609 | 106.0667 |
| | 15 | .7967 | .7729 | 300 | +64 | 111 | .8250 | —111 | +.2306 | + .832 | .0552 |
| (54) | | | | | | Mean | | | | | 106.0610 |
| **46** | 11 | .3643 | .3373 | 157 | —27 | 124 | .3757 | — 32 | +.1385 | —0.932 | 44.4990 |
| (67) | | | | | | | | | | | |
| **47** | 12 | .6216 | .5740 | 391 | —80 | 32 | .6184 | — 78 | —.0516 | +0.063 | 130.5598 |
| | 13 | .5923 | .5929 | 386 | —80 | 32 | .6127 | — 17 | —.0516 | + .063 | .5602 |
| (63) | 19 | .6220 | .6042 | 478 | +76 | 30 | .6579 | — 43 | —.0838 | — .362 | .5652 |
| | | | | | | Mean | | | | | 130.5617 |
| **48** | 1 | .8930 | .8908 | 202 | —30 | 115 | .9198 | + 99 | —.1233 | —0.849 | 50.7955 |
| | 2 | .8974 | .8948 | 198 | —30 | 114 | .9235 | +116 | —.1224 | — .832 | .8020 |
| (44) | 3 | .8927 | .9083 | 222 | —30 | 114 | .9303 | + 85 | —.1224 | — .832 | .8057 |
| | 4 | .7802 | .7702 | 214 | —31 | 114 | .8041 | — 1 | —.0091 | — .686 | .7861 |
| | 5 | .7692 | .7614 | 208 | —29 | 114 | .7938 | + 33 | —.0044 | — .499 | .7863 |
| | 6 | .7539 | .7722 | 265 | —29 | 116 | .7975 | + 45 | —.0044 | — .499 | .7912 |
| | 7 | .7687 | .7475 | 233 | —29 | 110 | .7887 | + 47 | —.0039 | — .472 | .7834 |
| | 8 | .6814 | .6796 | 213 | —30 | 114 | .7093 | — 64 | +.0941 | — .809 | .7866 |
| | 9 | .6653 | .6743 | 245 | —30 | 114 | .7019 | — 22 | +.0941 | — .809 | .7834 |
| | 10 | .6770 | .6815 | 181 | —31 | 114 | .7048 | — 21 | +.0957 | — .771 | .7885 |
| | 11 | .6818 | .6780 | 172 | —31 | 114 | .7046 | — 36 | +.0962 | — .755 | .7875 |
| | 12 | .6745 | .6767 | 192 | —31 | 114 | .7023 | — 30 | +.0962 | — .755 | .7858 |
| | 13 | .6705 | .6747 | 215 | —31 | 114 | .7016 | — 7 | +.0962 | — .755 | .7874 |
| | 15 | .6026 | .5930 | 199 | +31 | 116 | .6316 | — 53 | +.1522 | + .672 | .7871 |
| | 16 | .5727 | .5882 | 298 | +30 | 116 | .6241 | — 34 | +.1555 | + .547 | .7832 |
| | 17 | .5852 | .5900 | 251 | +30 | 116 | .6265 | — 36 | +.1555 | + .547 | .7854 |
| | 18 | .5812 | .5751 | 293 | +29 | 115 | .6211 | — 27 | +.1558 | + .534 | .7811 |
| | 19 | .5778 | .5737 | 246 | +29 | 114 | .6138 | — 16 | +.1558 | + .534 | .7749 |
| | 20 | .5964 | .5919 | 256 | +29 | 116 | .6334 | — 63 | +.1558 | + .534 | .7898 |
| | | | | | | Mean | | | | | 50.7880 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 1 | 233 26 4 | 27 20 | 12 2 | — 9 | 38 35 | +11 13 | +101 | 143 50 37 |
| 2 | 23 47 | 24 40 | 13 28 | — 8 | 37 34 | +11 8 | +104 | 50 19 |
| 3 | 25 44 | 25 45 | 13 34 | —10 | 39 8 | +11 8 | +104 | 50 59 |
| 10 | 46 0 | 47 2 | 13 7 | — 5 | 59 33 | — 8 44 | +108 | 51 7 |
| 11 | 45 4 | 45 52 | 14 13 | — 4 | 59 37 | — 8 47 | +109 | 50 58 |
| 12 | 43 15 | 43 33 | 15 35 | — 7 | 58 52 | — 8 47 | +109 | 50 55 |
| 13 | 45 53 | 45 35 | 13 8 | —11 | 58 41 | — 8 48 | +109 | 50 56 |
| 15 | 53 28 | 55 5 | 12 13 | —11 | 6 19 | —13 55 | —114 | 51 24 |
| 16 | 55 58 | 55 13 | 10 58 | —29 | 6 5 | —14 13 | —113 | 50 42 |
| 18 | 54 56 | 55 52 | 11 3 | —27 | 6 48 | —14 15 | —112 | 51 3 |
| 19 | 54 48 | 56 15 | 11 22 | —19 | 6 35 | —14 15 | —112 | 51 39 |
| 20 | 52 13 | 52 18 | 12 38 | —12 | 4 42 | —14 15 | —112 | 50 1 |
| | | | | Mean | | | | 143 50 53.3 |
| 2 | 223 19 12 | 16 18 | 13 28 | —11 | 31 2 | +12 35 | +108 | 133 45 16 |
| 3 | 17 30 | 19 20 | 13 34 | —16 | 31 43 | +12 35 | +108 | 45 3 |
| 10 | 41 55 | 41 54 | 13 7 | — 7 | 54 54 | — 9 53 | +116 | 45 22 |
| 11 | 38 43 | 41 17 | 14 13 | — 5 | 54 8 | — 9 56 | +117 | 44 23 |
| 13 | 40 55 | 40 51 | 13 8 | —16 | 53 45 | — 9 56 | +117 | 44 55 |
| 15 | 50 8 | 50 40 | 12 13 | — 9 | 2 28 | —15 45 | —126 | 45 39 |
| | | | | Mean | | | | 133 45 6.3 |
| 2 | 112 43 4 | 42 0 | 13 28 | +14 | 56 14 | — 3 12 | — 53 | 22 53 43 |
| 15 | 37 44 | 37 40 | 12 13 | + 2 | 49 57 | + 4 1 | + 40 | 53 53 |
| | | | | Mean | | | | 22 53 48.0 |
| 11 | 174 32 24 | 32 0 | 14 13 | — 2 | 46 23 | — 7 6 | + 52 | 84 39 5.0 |
| 12 | 249 19 12 | 20 30 | 15 35 | — 2 | 35 24 | — 4 12 | + 56 | 159 31 43 |
| 13 | 22 41 | 23 17 | 13 8 | — 1 | 36 6 | — 4 12 | + 56 | 32 38 |
| 19 | 28 15 | 29 0 | 11 22 | —21 | 39 38 | — 6 48 | — 53 | 32 30 |
| | | | | Mean | | | | 159 32 17.0 |
| 1 | 195 28 36 | 29 55 | 12 2 | —14 | 41 4 | +11 41 | + 68 | 105 53 22 |
| 2 | 25 48 | 26 26 | 13 28 | —12 | 39 24 | +11 36 | + 74 | 52 27 |
| 3 | 27 57 | 28 55 | 13 34 | —19 | 41 41 | +11 36 | + 74 | 53 50 |
| 4 | 38 16 | 39 26 | 12 39 | —16 | 51 15 | + 0 52 | +102 | 52 9 |
| 5 | 41 17 | 42 49 | 11 38 | —15 | 53 26 | + 0 25 | +119 | 54 26 |
| 6 | 40 58 | 41 57 | 11 38 | —39 | 52 27 | + 0 25 | +119 | 53 52 |
| 7 | 36 23 | 26 53 | 12 52 | —25 | 49 5 | + 0 22 | +121 | 53 32 |
| 8 | 48 38 | 50 8 | 13 3 | —19 | 2 7 | — 9 0 | + 80 | 53 24 |
| 9 | 48 10 | 49 2 | 14 30 | —33 | 2 33 | — 9 0 | + 80 | 53 32 |
| 10 | 48 54 | 48 46 | 13 7 | — 8 | 1 49 | — 9 9 | + 89 | 52 51 |
| 11 | 47 28 | 49 7 | 14 13 | — 6 | 2 25 | — 9 12 | + 92 | 53 15 |
| 12 | 45 25 | 47 0 | 15 35 | —10 | 1 37 | — 9 12 | + 92 | 53 9 |
| 13 | 47 28 | 48 43 | 13 8 | —18 | 0 56 | — 9 12 | + 92 | 52 41 |
| 15 | 55 32 | 57 4 | 12 13 | + 1 | 8 32 | —14 35 | —110 | 52 58 |
| 16 | 57 25 | 59 15 | 10 58 | + 9 | 9 27 | —14 54 | —121 | 53 20 |
| 17 | 59 30 | 0 18 | 11 10 | + 6 | 11 11 | —14 54 | —121 | 53 28 |
| 18 | 57 5 | 57 12 | 11 3 | + 7 | 8 18 | —14 56 | —122 | 51 48 |
| 19 | 57 7 | 57 45 | 11 22 | + 4 | 8 52 | —14 56 | —122 | 53 11 |
| 20 | 54 57 | 56 52 | 12 38 | + 1 | 8 33 | —14 56 | —122 | 53 7 |
| | | | | Mean | | | | 105 53 10.6 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Corrected Mean. s | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. σ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | | | | | |
| **49** (87) | 11 | .7198 | .6913 | 191 | —35 | 110 | .7311 | — 41 | +.0740 | —0.648 | 57.7927 |
| **50** | 1 | .8328 | .8330 | 229 | —34 | 110 | .8622 | +115 | —.1125 | —0.818 | 58.7507 |
| | 2 | .8461 | .8266 | 225 | —35 | 108 | .8650 | +134 | —.1117 | — .798 | .7565 |
| (43) | 3 | .8240 | .8310 | 245 | —35 | 108 | .8581 | + 98 | —.1117 | — .798 | .7460 |
| | 6 | .7042 | .7006 | 292 | —34 | 110 | .7380 | + 52 | —.0040 | — .447 | .7335 |
| | 9 | .6356 | .6495 | 272 | —35 | 108 | .6759 | — 26 | +.0858 | — .773 | .7492 |
| | 10 | .6264 | .6376 | 206 | —36 | 106 | .6584 | — 24 | +.0872 | — .732 | .7338 |
| | 11 | .6362 | .6416 | 197 | —36 | 108 | .6646 | — 42 | +.0877 | — .714 | .7389 |
| | 12 | .6252 | .6469 | 217 | —36 | 108 | .6637 | — 35 | +.0877 | — .714 | .7387 |
| | 13 | .6383 | .6366 | 239 | —36 | 108 | .6674 | — 8 | +.0877 | — .714 | .7451 |
| | 15 | .5651 | .5525 | 231 | +36 | 110 | .5953 | — 61 | +.1389 | + .623 | .7361 |
| | 16 | .5421 | .5413 | 350 | +34 | 112 | .5901 | — 39 | +.1418 | + .494 | .7343 |
| | 17 | .5392 | .5627 | 292 | +34 | 112 | .5935 | — 42 | +.1418 | + .494 | .7374 |
| | 18 | .5536 | .5380 | 341 | +34 | 110 | .5931 | — 31 | +.1421 | + .481 | .7383 |
| | 19 | .5278 | .5230 | 285 | +34 | 108 | .5669 | — 19 | +.1421 | + .481 | .7133 |
| | 20 | .5624 | .5660 | 242 | +34 | 108 | .6014 | — 73 | +.1421 | + .481 | .7424 |
| | | | | | | Mean | | | | | 58.7396 |
| **51** (42) | 2 | .8800 | .9059 | 340 | —63 | 118 | .9249 | +243 | —.0074 | —0.409 | 106.9365 |
| **52** | 1 | .3976 | .3860 | 312 | —45 | 137 | .4295 | +149 | —.1365 | —0.883 | 76.2966 |
| | 2 | .3822 | .3992 | 306 | —45 | 136 | .4277 | +174 | —.1355 | — .869 | .2984 |
| (45) | 3 | .3848 | .4191 | 339 | —45 | 136 | .4422 | +127 | —.1355 | — .869 | .3082 |
| | 10 | .1701 | .1525 | 277 | —46 | 136 | .1953 | — 31 | +.1061 | — .818 | .2878 |
| | 11 | .1598 | .1582 | 263 | —47 | 136 | .1915 | — 54 | +.1067 | — .802 | .2825 |
| | 12 | .1513 | .1481 | 293 | —46 | 136 | .1853 | — 46 | +.1067 | — .802 | .2771 |
| | 13 | .1288 | .1570 | 334 | —46 | 136 | .1826 | — 10 | +.1067 | — .802 | .2780 |
| | 15 | .0628 | .0610 | 299 | +46 | 140 | .1077 | — 80 | +.1689 | + .729 | .2780 |
| | 16 | .0323 | .0501 | 446 | +44 | 136 | .1011 | — 51 | +.1725 | + .611 | .2763 |
| | 18 | .0378 | .0366 | 435 | +44 | 136 | .0960 | — 41 | +.1729 | + .599 | .2725 |
| | | | | | | Mean | | | | | 76.2855 |
| **53** | 1 | .0292 | .0332 | 338 | —44 | 136 | .0715 | +148 | —.1840 | —0.969 | 75.8899 |
| | 2 | .0322 | .0274 | 326 | —45 | 136 | .0688 | +173 | —.1827 | — .970 | .8909 |
| (2) | 3 | .0089 | .0216 | 375 | —45 | 136 | .0592 | +127 | —.1827 | — .970 | .8767 |
| | 6 | .8531 | .8279 | 499 | —44 | 140 | .8973 | + 68 | —.0066 | — .798 | .8873 |
| | 7 | .8662 | .8756 | 411 | —43 | 136 | .9186 | + 70 | —.0058 | — .778 | .9098 |
| | 9 | .6960 | .7096 | 452 | —45 | 136 | .7544 | — 34 | +.1411 | — .968 | .8797 |
| | 10 | .7138 | .7182 | 288 | —46 | 136 | .7511 | — 31 | +.1433 | — .957 | .8790 |
| | 11 | .7125 | .7225 | 269 | —46 | 136 | .7507 | — 54 | +.1441 | — .952 | .8772 |
| | 12 | .7044 | .7109 | 310 | —46 | 136 | .7449 | — 45 | +.1441 | — .952 | .8723 |
| | 13 | .7131 | .7071 | 363 | —46 | 136 | .7527 | — 10 | +.1441 | — .952 | .8836 |
| | 15 | .5971 | .5812 | 281 | +46 | 140 | .6332 | — 79 | +.2283 | + .927 | .8655 |
| | 16 | .5842 | .5820 | 382 | +44 | 140 | .6370 | — 51 | +.2331 | + .848 | .8759 |
| | 17 | .5973 | .5906 | 333 | +44 | 140 | .6430 | — 54 | +.2331 | + .848 | .8816 |
| | 18 | .5763 | .5611 | 376 | +44 | 138 | .6218 | — 41 | +.2336 | + .838 | .8621 |
| | 19 | .5838 | .5694 | 333 | +44 | 134 | .6248 | — 25 | +.2336 | + .838 | .8667 |
| | 20 | .5980 | .5938 | 292 | +44 | 136 | .6404 | — 94 | +.2336 | + .838 | .8754 |
| | | | | | | Mean | | | | | 75.8796 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ | | ° ′ ″ |
| 11 | 204 39 45 | 41 48 | 14 13 | — 6 | 54 54 | — 8 53 | + 95 | 114 46 4.0 |
| 1 | 199 0 26 | 1 14 | 12 2 | —15 | 12 37 | +10 3 | + 66 | 109 23 46 |
| 2 | 198 58 34 | 59 32 | 13 28 | —13 | 12 18 | +10 28 | + 71 | 24 12 |
| 3 | 59 36 | 1 17 | 13 34 | —20 | 13 41 | +10 28 | + 71 | 24 41 |
| 6 | 199 12 8 | 13 4 | 11 38 | —39 | 23 35 | + 0 23 | +107 | 24 53 |
| 9 | 18 10 | 18 50 | 14 30 | —33 | 32 27 | — 8 7 | + 76 | 24 17 |
| 10 | 18 23 | 18 46 | 13 7 | — 8 | 31 34 | — 8 14 | + 82 | 23 29 |
| 11 | 18 7 | 18 59 | 14 13 | — 6 | 32 40 | — 8 17 | + 85 | 24 23 |
| 12 | 16 8 | 15 50 | 15 35 | —11 | 31 23 | — 8 17 | + 85 | 23 48 |
| 13 | 17 48 | 18 55 | 13 8 | —19 | 31 33 | — 8 17 | + 85 | 24 11 |
| 15 | 25 28 | 27 22 | 12 13 | — 1 | 38 37 | —13 8 | —100 | 24 34 |
| 16 | 26 21 | 28 21 | 10 58 | + 7 | 38 26 | —13 25 | —109 | 23 53 |
| 17 | 28 37 | 29 22 | 11 10 | + 2 | 40 12 | —13 25 | —109 | 24 3 |
| 18 | 27 32 | 27 36 | 11 3 | + 3 | 38 40 | —13 27 | —109 | 23 44 |
| 19 | 26 53 | 27 40 | 11 22 | + 2 | 38 41 | —13 27 | —109 | 24 34 |
| 20 | 24 43 | 26 12 | 12 38 | — 1 | 38 5 | —13 27 | —109 | 24 13 |
| | | | | Mean | | | | 109 24 10.7 |
| 2 | 229 19 12 | 20 3 | 13 28 | — 9 | 32 57 | + 6 48 | + 61 | 139 41 7.0 |
| 1 | 191 1 24 | 2 38 | 12 2 | —14 | 13 49 | + 7 20 | + 39 | 101 21 36 |
| 2 | 190 59 52 | 0 53 | 13 28 | —12 | 13 38 | + 7 17 | + 43 | 22 10 |
| 3 | 191 0 5 | 1 12 | 13 34 | —18 | 13 54 | + 7 17 | + 43 | 21 32 |
| 10 | 14 25 | 15 6 | 13 7 | — 7 | 27 46 | — 5 44 | + 53 | 22 0 |
| 11 | 13 8 | 13 45 | 14 13 | — 5 | 27 35 | — 5 46 | + 55 | 21 38 |
| 12 | 11 20 | 11 38 | 15 35 | — 9 | 26 55 | — 5 46 | + 55 | 21 40 |
| 13 | 13 55 | 14 13 | 13 8 | —17 | 26 55 | — 5 46 | + 55 | 21 53 |
| 15 | 18 23 | 19 38 | 12 13 | + 2 | 31 15 | — 9 9 | — 68 | 21 23 |
| 16 | 20 32 | 20 28 | 10 58 | +14 | 31 42 | — 9 21 | — 76 | 21 25 |
| 18 | 18 40 | 20 4 | 11 3 | +11 | 30 36 | — 9 22 | — 76 | 19 57 |
| | | | | Mean | | | | 101 21 31.4 |
| 1 | 170 48 12 | 48 55 | 12 2 | — 5 | 0 31 | + 4 47 | + 7 | 81 5 34 |
| 2 | 46 22 | 46 50 | 13 28 | — 5 | 59 59 | + 4 45 | + 11 | 5 48 |
| 3 | 47 0 | 48 15 | 13 34 | — 8 | 1 4 | + 4 45 | + 11 | 5 59 |
| 6 | 53 52 | 53 47 | 11 38 | —20 | 5 8 | + 0 10 | + 52 | 5 54 |
| 7 | 49 3 | 49 42 | 12 52 | —11 | 2 3 | + 0 9 | + 54 | 5 52 |
| 9 | 55 12 | 56 25 | 14 30 | —17 | 10 1 | — 3 41 | + 16 | 5 56 |
| 10 | 56 10 | 56 38 | 13 7 | — 2 | 9 29 | — 3 45 | + 22 | 5 31 |
| 11 | 55 16 | 56 45 | 14 13 | — 2 | 10 12 | — 3 46 | + 25 | 6 4 |
| 12 | 53 20 | 54 3 | 15 35 | — 4 | 9 13 | — 3 46 | + 25 | 5 47 |
| 13 | 56 6 | 56 52 | 13 8 | — 7 | 9 30 | — 3 46 | + 25 | 6 17 |
| 15 | 59 44 | 0 28 | 12 13 | + 9 | 12 28 | — 5 59 | — 39 | 5 56 |
| 16 | 171 1 32 | 2 18 | 10 58 | +29 | 13 22 | — 6 6 | — 52 | 6 28 |
| 17 | 1 52 | 3 37 | 11 10 | +20 | 14 14 | — 6 6 | — 52 | 5 44 |
| 18 | 1 17 | 1 6 | 11 3 | +27 | 12 42 | — 6 7 | — 52 | 5 26 |
| 19 | 0 10 | 0 48 | 11 22 | +17 | 12 8 | — 6 7 | — 52 | 5 41 |
| 20 | 170 58 45 | 59 57 | 12 38 | +11 | 12 10 | — 6 7 | — 52 | 5 58 |
| | | | | Mean | | | | 81 5 52.2 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **54** | 1 | .4460 | .4362 | 344 | —45 | 137 | .4820 | +151 | —.1890 | —0.972 | 77.2956 |
| | 2 | .4637 | .4137 | 333 | —46 | 135 | .4806 | +176 | —.1876 | — .975 | .2981 |
| (3) | 3 | .4183 | .4360 | 385 | —46 | 134 | .4716 | +129 | —.1876 | — .975 | .2844 |
| | 9 | .0746 | .0985 | 468 | —46 | 134 | .1393 | — 34 | +.1449 | — .975 | .2683 |
| | 10 | .0965 | .1053 | 294 | —47 | 134 | .1362 | — 31 | +.1472 | — .969 | .2679 |
| | 11 | .0990 | .0974 | 274 | —47 | 134 | .1315 | — 55 | +.1480 | — .964 | .2616 |
| | 12 | .0802 | .0902 | 316 | —47 | 134 | .1227 | — 46 | +.1480 | — .964 | .2537 |
| | 13 | .0853 | .0943 | 372 | —47 | 134 | .1329 | — 10 | +.1480 | — .964 | .2675 |
| | 15 | .9911 | .9729 | 227 | +47 | 130 | .0196 | — 81 | +.2344 | + .946 | .2570 |
| | 16 | .9606 | .9866 | 375 | +45 | 135 | .0263 | — 52 | +.2394 | + .873 | .2717 |
| | 17 | .9814 | .9784 | 330 | +45 | 135 | .0281 | — 55 | +.2394 | + .873 | .2732 |
| | 18 | .9590 | .9661 | 373 | +45 | 134 | .0150 | — 41 | +.2398 | + .864 | .2618 |
| | 20 | .9690 | .9765 | 293 | +45 | 135 | .0172 | — 96 | +.2398 | + .864 | .2585 |
| | | | | | | Mean | | | | | 77.2707 |
| **55** | 12 | .6444 | .6202 | 416 | —82 | 17 | .6525 | — 81 | —.0089 | —0.194 | 134.6330 |
| | 13 | .5973 | .5996 | 417 | —82 | 17 | .6186 | — 17 | —.0089 | — .194 | .6055 |
| (59) | 18 | .6110 | .5766 | 670 | +79 | 20 | .6557 | — 72 | —.0146 | — .108 | .6325 |
| | | | | | | Mean | | | | | 134.6237 |
| **56** | 2 | .3874 | .3912 | 474 | —69 | 130 | .4329 | +267 | —.2077 | —0.833 | 117.2412 |
| | 3 | .3788 | .3658 | 541 | —69 | 126 | .4222 | +196 | —.2077 | — .833 | .2234 |
| (6) | 11 | .0598 | .0434 | 398 | —71 | 122 | .0867 | — 84 | +.1639 | — .908 | .2305 |
| | 15 | .9152 | .9111 | 354 | +71 | 124 | .9584 | —122 | +.2597 | + .979 | .2185 |
| | 16 | .8690 | .8820 | 360 | +68 | 124 | .9210 | — 78 | +.2653 | + .993 | .1913 |
| | 18 | .8900 | .8905 | 372 | +68 | 124 | .9368 | — 63 | +.2658 | + .993 | .2091 |
| | 19 | .8798 | .8847 | 368 | +68 | 124 | .9285 | — 38 | +.2658 | + .993 | .2033 |
| | | | | | | Mean | | | | | 117.2168 |
| **57** (53) | 2 | .7927 | .7629 | 445 | —64 | 122 | .8204 | +245 | —.2098 | —0.881 | 107.6238 |
| **58** | 2 | .8308 | .8107 | 349 | —53 | 138 | .8597 | +205 | —.1171 | —0.815 | 89.7526 |
| | 10 | .6051 | .6227 | 316 | —55 | 138 | .6493 | — 37 | +.0917 | — .752 | .7276 |
| (47) | 11 | .6066 | .6086 | 303 | —55 | 134 | .6414 | — 64 | +.0922 | — .735 | .7178 |
| | 12 | .5642 | .5797 | 336 | —55 | 134 | .6091 | — 54 | +.0922 | — .735 | .6865 |
| | 13 | .6056 | .6115 | 374 | —55 | 134 | .6496 | — 12 | +.0922 | — .735 | .7312 |
| | 15 | .5336 | .5150 | 353 | +54 | 135 | .5741 | — 94 | +.1459 | + .649 | .7189 |
| | 16 | .5061 | .5177 | 533 | +52 | 137 | .5797 | — 60 | +.1490 | + .521 | .7294 |
| | 18 | .4881 | .4839 | 519 | +52 | 135 | .5522 | — 48 | +.1493 | + .508 | .7032 |
| | 20 | .5215 | .5150 | 371 | +52 | 132 | .5693 | —111 | +.1493 | + .508 | .7140 |
| | | | | | | Mean | | | | | 89.7201 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Corrections plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 1 | 167 59 33 | 0 3 | 12 2 | − 4 | 11 46 | + 4 18 | + 2 | 78 16 18 |
| 2 | 56 40 | 57 8 | 13 28 | − 3 | 10 19 | + 4 16 | + 6 | 15 37 |
| 3 | 57 56 | 58 47 | 13 34 | − 6 | 11 50 | + 4 16 | + 6 | 16 14 |
| 9 | 168 4 55 | 5 15 | 14 30 | −14 | 19 21 | − 3 18 | + 11 | 15 37 |
| 10 | 5 39 | 7 8 | 13 7 | − 2 | 19 29 | − 3 22 | + 17 | 15 52 |
| 11 | 5 12 | 6 10 | 14 13 | − 1 | 19 53 | − 3 23 | + 20 | 16 6 |
| 12 | 2 52 | 3 53 | 15 35 | − 3 | 18 54 | − 3 23 | + 20 | 15 49 |
| 13 | 5 55 | 6 20 | 13 8 | − 6 | 19 10 | − 3 23 | + 20 | 16 18 |
| 15 | 8 37 | 10 20 | 12 13 | − 7 | 21 34 | − 5 22 | − 34 | 15 41 |
| 16 | 10 10 | 11 55 | 10 58 | +31 | 22 31 | − 5 28 | − 46 | 16 17 |
| 17 | 12 2 | 13 53 | 11 10 | +21 | 24 28 | − 5 28 | − 46 | 16 38 |
| 18 | 9 24 | 10 24 | 11 3 | +28 | 21 25 | − 5 29 | − 47 | 14 49 |
| 20 | 8 30 | 9 18 | 12 38 | +12 | 21 44 | − 5 29 | − 47 | 16 12 |
| | | | | Mean | | | | 78 15 57.5 |
| 12 | 234 16 10 | 16 58 | 15 35 | − 7 | 32 2 | − 4 17 | + 52 | 144 28 15 |
| 13 | 18 53 | 20 5 | 13 8 | − 9 | 32 28 | − 4 17 | + 52 | 28 54 |
| 18 | 24 55 | 25 28 | 11 3 | −27 | 36 36 | − 6 56 | − 54 | 28 31 |
| | | | | Mean | | | | 144 28 33.3 |
| 2 | 132 39 28 | 40 15 | 13 28 | +11 | 53 31 | − 0 52 | − 32 | 42 53 27 |
| 3 | 40 56 | 41 2 | 13 34 | +16 | 54 49 | − 0 52 | − 32 | 53 51 |
| 11 | 39 11 | 39 40 | 14 13 | + 6 | 53 45 | + 0 41 | − 25 | 53 46 |
| 15 | 40 7 | 40 53 | 12 13 | + 9 | 52 52 | + 1 5 | + 16 | 53 44 |
| 16 | 41 32 | 42 5 | 10 58 | +20 | 53 6 | + 1 6 | + 7 | 53 46 |
| 18 | 40 40 | 41 35 | 11 3 | +20 | 52 31 | + 1 7 | + 6 | 52 50 |
| 19 | 40 16 | 40 50 | 11 22 | +14 | 52 9 | + 1 7 | + 6 | 53 17 |
| | | | | Mean | | | | 42 53 31.6 |
| 2 | 138 30 38 | 32 40 | 13 28 | +10 | 45 17 | − 0 16 | − 29 | 48 45 51.0 |
| 2 | 197 16 8 | 16 14 | 13 28 | −12 | 29 27 | + 6 45 | + 44 | 107 37 28 |
| 10 | 29 3 | 30 16 | 13 7 | − 8 | 42 39 | − 5 18 | + 52 | 37 19 |
| 11 | 28 26 | 28 22 | 14 13 | − 5 | 42 32 | − 5 20 | + 54 | 37 0 |
| 12 | 26 57 | 27 23 | 15 35 | −10 | 42 35 | − 5 20 | + 54 | 37 45 |
| 13 | 29 3 | 29 25 | 13 8 | −19 | 42 3 | − 5 20 | + 54 | 37 26 |
| 15 | 34 12 | 35 23 | 12 13 | + 1 | 47 2 | − 8 27 | − 64 | 37 53 |
| 16 | 35 58 | 36 52 | 10 58 | + 7 | 47 38 | − 8 38 | − 70 | 37 58 |
| 18 | 34 41 | 35 58 | 11 3 | + 5 | 46 28 | − 8 39 | − 71 | 36 33 |
| 20 | 32 46 | 34 18 | 12 38 | + 1 | 46 11 | − 8 39 | − 71 | 37 20 |
| | | | | Mean | | | | 107 37 24.4 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Corrected Mean. | Scale Variation. | Proper Motion. | Parallax *Co-efficient.* | Final Corrected Distance. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | $s$ | | | | $\sigma$ |
| **59** | 1 | .9381 | .9276 | 369 | —57 | 148 | .9731 | +189 | —.1024 | —0.787 | 96.8795 |
| | 2 | .9478 | .9312 | 364 | —57 | 148 | .9793 | +221 | —.1017 | — .767 | .8899 |
| (41) | 3 | .9334 | .9322 | 394 | —57 | 148 | .9756 | +162 | —.1017 | — .767 | .8803 |
| | 10 | .7559 | .7671 | 337 | —59 | 148 | .7985 | — 39 | +.0796 | — .695 | .8653 |
| | 11 | .7572 | .7653 | 323 | —59 | 148 | .7967 | — 69 | +.0800 | — .676 | .8611 |
| | 12 | .7542 | .7318 | 350 | —59 | 148 | .7812 | — 58 | +.0800 | — .676 | .8467 |
| | 13 | .7580 | .7381 | 388 | —59 | 148 | .7901 | — 12 | +.0800 | — .676 | .8602 |
| | 15 | .6890 | .6809 | 380 | +59 | 146 | .7379 | —101 | +.1266 | + .579 | .8618 |
| | 16 | .6440 | .6572 | 581 | +56 | 146 | .7232 | — 65 | +.1293 | + .446 | .8517 |
| | 17 | .6586 | .6644 | 482 | +56 | 147 | .7244 | — 69 | +.1293 | + .446 | .8525 |
| | 18 | .6513 | .6443 | 564 | +56 | 146 | .7188 | — 52 | +.1296 | + .433 | .8488 |
| | 19 | .6702 | .6610 | 471 | +56 | 148 | .7275 | — 32 | +.1296 | + .433 | .8595 |
| | 20 | .6762 | .6707 | 399 | +56 | 146 | .7279 | —120 | +.1296 | + .433 | .8511 |
| | | | | | | Mean | | | | | 96.8622 |
| **60** | 2 | .7962 | .7690 | 422 | —58 | 145 | .8276 | +222 | —.2024 | —0.968 | 97.6350 |
| | 13 | .4324 | .4264 | 473 | —60 | 146 | .4795 | — 13 | +.1597 | — .985 | .6253 |
| (51) | 15 | .3186 | .3134 | 338 | +59 | 146 | .3645 | —102 | +.2530 | + .998 | .6201 |
| | | | | | | Mean | | | | | 97.6268 |
| **61** | 1 | .3070 | .3036 | 397 | —63 | 122 | .3432 | +211 | —.0862 | —0.737 | 108.2686 |
| | 2 | .3178 | .3030 | 389 | —64 | 122 | .3473 | +246 | —.0856 | — .712 | .2772 |
| (40) | 3 | .3112 | .2954 | 423 | —64 | 122 | .3436 | +180 | —.0856 | — .712 | .2669 |
| | 5 | .2298 | .2492 | 408 | —62 | 120 | .2784 | + 48 | —.0031 | — .323 | .2760 |
| | 6 | .2046 | .2209 | 480 | —62 | 122 | .2591 | + 97 | —.0031 | — .323 | .2616 |
| | 7 | .2193 | .1991 | 442 | —61 | 120 | .2515 | +101 | —.0027 | — .295 | .2551 |
| | 9 | .1560 | .1612 | 454 | —65 | 126 | .2024 | — 48 | +.0658 | — .681 | .2547 |
| | 10 | .1578 | .1520 | 368 | —66 | 126 | .1900 | — 44 | +.0669 | — .633 | .2444 |
| | 11 | .1635 | .1619 | 356 | —66 | 126 | .1966 | — 77 | +.0673 | — .613 | .2483 |
| | 12 | .1466 | .1568 | 383 | —66 | 126 | .1883 | — 65 | +.0673 | — .613 | .2412 |
| | 13 | .1485 | .1453 | 415 | —66 | 126 | .1867 | — 14 | +.0673 | — .613 | .2447 |
| | 15 | .0917 | .0877 | 425 | +66 | 122 | .1433 | —113 | +.1064 | + .506 | .2449 |
| | 16 | .0790 | .0780 | 647 | +63 | 122 | .1540 | — 72 | +.1087 | + .367 | .2602 |
| | 17 | .0733 | .0785 | 537 | +63 | 122 | .1404 | — 77 | +.1087 | + .367 | .2461 |
| | 18 | .0579 | .0615 | 628 | +63 | 122 | .1333 | — 58 | +.1089 | + .354 | .2409 |
| | 19 | .0782 | .0768 | 524 | +63 | 122 | .1407 | — 35 | +.1089 | + .354 | .2506 |
| | 20 | .0894 | .0866 | 445 | +63 | 122 | .1433 | —134 | +.1089 | + .354 | .2433 |
| | | | | | | Mean | | | | | 108.2544 |
| **62** | 2 | .5976 | .6115 | 483 | —66 | 125 | .6504 | +265 | —.1918 | —0.977 | 111.4726 |
| | 3 | .5722 | .5680 | 504 | —66 | 124 | .6179 | +186 | —.1918 | — .977 | .4322 |
| (57) | 18 | .1430 | .1066 | 539 | +65 | 130 | .1899 | — 60 | +.2453 | + .886 | .4406 |
| | | | | | | Mean | | | | | 111.4485 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. *π* |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 1 | 202 13 14 | 14 32 | 12 2 | —16 | 25 39 | + 6 38 | + 43 | 112 32 45 |
| 2 | 11 48 | 13 5 | 13 28 | —14 | 25 40 | + 6 35 | + 46 | 33 32 |
| 3 | 12 44 | 14 37 | 13 34 | —20 | 26 55 | + 6 35 | + 46 | 33 53 |
| 10 | 25 8 | 25 22 | 13 7 | — 8 | 38 14 | — 5 10 | + 53 | 33 2 |
| 11 | 23 46 | 24 18 | 14 13 | — 6 | 38 9 | — 5 12 | + 54 | 32 45 |
| 12 | 21 55 | 23 7 | 15 35 | —11 | 37 55 | — 5 12 | + 54 | 33 13 |
| 13 | 24 20 | 25 4 | 13 8 | —19 | 37 53 | — 5 12 | + 54 | 33 24 |
| 15 | 29 20 | 30 35 | 12 13 | — 2 | 42 9 | — 8 15 | — 63 | 33 12 |
| 16 | 30 13 | 31 50 | 10 58 | + 2 | 42 2 | — 8 25 | — 68 | 32 44 |
| 17 | 32 40 | 33 57 | 11 10 | — 1 | 44 27 | — 8 25 | — 68 | 33 33 |
| 18 | 30 18 | 31 20 | 11 3 | 0 | 41 52 | — 8 26 | — 69 | 32 11 |
| 19 | 30 15 | 31 5 | 11 22 | — 2 | 42 00 | — 8 26 | — 69 | 33 8 |
| 20 | 28 45 | 29 52 | 12 38 | — 3 | 41 53 | — 8 26 | — 69 | 33 16 |
| | | | | Mean | | | | 112 33 7.5 |
| | | | | | | | | |
| 2 | 156 50 25 | 50 51 | 13 28 | + 2 | 4 8 | + 2 3 | — 9 | 67 7 8 |
| 13 | 53 37 | 54 41 | 13 8 | + 1 | 7 18 | — 1 37 | + 1 | 6 5 |
| 15 | 56 2 | 58 2 | 12 13 | +11 | 9 26 | — 2 34 | — 13 | 6 28 |
| | | | | Mean | | | | 67 6 33.7 |
| | | | | | | | | |
| 1 | 207 10 48 | 12 2 | 12 2 | —16 | 23 11 | + 6 12 | + 43 | 117 29 51 |
| 2 | 8 43 | 9 52 | 13 28 | —14 | 22 31 | + 6 9 | + 45 | 29 56 |
| 3 | 9 24 | 11 10 | 13 34 | —20 | 23 31 | + 6 9 | + 45 | 30 2 |
| 5 | 18 0 | 19 2 | 11 38 | —17 | 29 52 | + 0 13 | + 62 | 30 19 |
| 6 | 17 4 | 18 27 | 11 38 | —37 | 28 46 | + 0 13 | + 62 | 29 38 |
| 7 | 12 40 | 13 33 | 12 52 | —26 | 26 33 | + 0 12 | + 62 | 30 28 |
| 9 | 20 16 | 21 4 | 14 30 | —32 | 34 38 | — 4 46 | + 48 | 29 39 |
| 10 | 21 2 | 21 36 | 13 7 | — 8 | 34 18 | — 4 50 | + 52 | 29 26 |
| 11 | 19 56 | 20 56 | 14 13 | — 6 | 34 33 | — 4 52 | + 53 | 29 29 |
| 12 | 18 13 | 18 35 | 15 35 | —11 | 33 48 | — 4 52 | + 53 | 29 26 |
| 13 | 20 33 | 21 8 | 13 8 | —19 | 33 39 | — 4 52 | + 53 | 29 30 |
| 15 | 25 25 | 26 33 | 12 13 | — 3 | 38 9 | — 7 42 | — 60 | 29 46 |
| 16 | 26 32 | 28 16 | 10 58 | — 3 | 38 19 | — 7 52 | — 63 | 29 35 |
| 17 | 28 15 | 29 31 | 11 10 | — 6 | 39 57 | — 7 52 | — 63 | 29 37 |
| 18 | 26 20 | 26 53 | 11 3 | — 6 | 37 40 | — 7 53 | — 63 | 28 34 |
| 19 | 26 15 | 26 40 | 11 22 | — 3 | 37 47 | — 7 53 | — 63 | 29 30 |
| 20 | 24 26 | 25 40 | 12 38 | — 3 | 37 38 | — 7 53 | — 63 | 29 36 |
| | | | | Mean | | | | 117 29 40.1 |
| | | | | | | | | |
| 2 | 165 20 35 | 21 26 | 13 28 | — 2 | 34 27 | + 2 42 | + 1 | 75 38 9 |
| 3 | 21 48 | 22 25 | 13 34 | — 4 | 35 37 | + 2 42 | + 1 | 38 25 |
| 18 | 30 0 | 30 27 | 11 3 | +29 | 41 45 | — 3 28 | — 30 | 37 16 |
| | | | | Mean | | | | 75 37 56.7 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Concluded.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. *s* | Scale Variation. | Proper Motion. | Parallax *Coefficient.* | Final Corrected Distance. σ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **63** | 2 | .7541 | .7438 | 470 | —65 | 133 | .7946 | +250 | —.1809 | —0.967 | 109.6263 |
| | 11 | .4323 | .4440 | 389 | —67 | 133 | .4757 | — 78 | +.1426 | — .946 | .5984 |
| (48) | 13 | .4072 | .4136 | 524 | —67 | 126 | .4607 | — 14 | +.1426 | — .946 | .5898 |
| | 15 | .3026 | .2808 | 411 | +66 | 124 | .3438 | —114 | +.2259 | + .920 | .5701 |
| | 16 | .2991 | .3042 | 555 | +64 | 128 | .3683 | — 73 | +.2307 | + .837 | .6024 |
| | 17 | .2860 | .2935 | 488 | +64 | 128 | .3498 | — 78 | +.2307 | + .837 | .5834 |
| | 18 | .2766 | .2810 | 550 | +63 | 126 | .3447 | — 59 | +.2312 | + .829 | .5806 |
| | 19 | .3023 | .2725 | 483 | +63 | 126 | .3466 | — 36 | +.2312 | + .829 | .5848 |
| | 20 | .3147 | .2970 | 425 | +63 | 134 | .3600 | —136 | +.2312 | + .829 | .5882 |
| | | | | | | Mean | | | | | 109.5916 |
| **64** | 1 | .1776 | .1780 | 535 | —70 | 123 | .2260 | +234 | —.2010 | —0.965 | 120.0360 |
| | 2 | .1922 | .1778 | 520 | —71 | 123 | .2316 | +273 | —.1996 | — .974 | .0468 |
| (46) | 3 | .1634 | .1586 | 602 | —71 | 123 | .2157 | +200 | —.1996 | — .974 | .0236 |
| | 4 | .0126 | .9952 | 575 | —73 | 123 | .0558 | — 3 | —.0149 | — .971 | .0281 |
| | 5 | .0018 | .9997 | 558 | —69 | 123 | .0514 | + 53 | —.0072 | — .889 | .0381 |
| | 6 | .9536 | .9504 | 818 | —69 | 123 | .0286 | +107 | —.0072 | — .889 | .0207 |
| | 7 | .9913 | .0029 | 664 | —68 | 124 | .0585 | +111 | —.0064 | — .874 | .0520 |
| | 9 | .8060 | .8200 | 741 | —72 | 123 | .8816 | — 53 | +.1542 | — .981 | .0179 |
| | 10 | .8454 | .8412 | 457 | —73 | 123 | .8834 | — 49 | +.1566 | — .985 | .0225 |
| | 11 | .8628 | .8512 | 427 | —73 | 123 | .8941 | — 86 | +.1575 | — .984 | .0304 |
| | 12 | .8466 | .8533 | 492 | —73 | 123 | .8936 | — 72 | +.1575 | — .984 | .0313 |
| | 13 | .8351 | .8323 | 584 | —73 | 123 | .8865 | — 15 | +.1575 | — .984 | .0299 |
| | 15 | .7124 | .7110 | 422 | +73 | 123 | .7629 | —125 | +.2495 | + .989 | .0126 |
| | 17 | .6883 | .6890 | 477 | +70 | 124 | .7451 | — 85 | +.2548 | + .935 | .0034 |
| | 19 | .6955 | .6875 | 481 | +70 | 123 | .7484 | — 39 | +.2553 | + .929 | .0117 |
| | 20 | .6944 | .6862 | 434 | +70 | 126 | .7428 | —149 | +.2553 | + .929 | .9951 |
| | | | | | | Mean | | | | | 120.0250 |
| **65** | 2 | .0835 | .0878 | 479 | —76 | 34 | .1161 | +294 | —.0945 | —0.743 | 129.0415 |
| | 15 | .8134 | .8004 | 506 | +78 | 46 | .8567 | —135 | +.1179 | + .547 | 128.9681 |
| (50) | 18 | .7827 | .7731 | 749 | +75 | 43 | .8515 | — 69 | +.1206 | + .398 | .9703 |
| | 20 | .8129 | .8114 | 532 | +75 | 43 | .8641 | —160 | +.1206 | + .398 | .9738 |
| | | | | | | Mean | | | | | 128.9884 |
| **66** | 2 | .9326 | .9067 | 523 | —72 | 122 | .9659 | +277 | —.1821 | —0.970 | 121.7990 |
| | 11 | .6092 | .6052 | 433 | —75 | 123 | .6443 | — 87 | +.1437 | — .950 | .7671 |
| (49) | 13 | .6028 | .5993 | 585 | —75 | 122 | .6532 | — 16 | +.1437 | — .950 | .7831 |
| | 18 | .4338 | .4378 | 610 | +70 | 128 | .5056 | — 65 | +.2329 | + .836 | .7427 |
| | | | | | | Mean | | | | | 121.7730 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Concluded.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. *p* | Proper Motion. | Parallax *Coefficient.* | Final Corrected Angle. π |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ′ ″ | ′ ″ | | ° ′ ″ |
| 2 | 171 47 50 | 48 36 | 13 28 | − 5 | 1 36 | + 3 25 | + 8 | 82 6 4 |
| 11 | 54 45 | 55 13 | 14 13 | − 2 | 9 10 | − 2 42 | + 19 | 6 4 |
| 13 | 54 32 | 55 23 | 13 8 | − 2 | 8 4 | − 2 42 | + 19 | 5 53 |
| 15 | 57 35 | 59 8 | 12 13 | + 8 | 10 43 | − 4 17 | − 29 | 5 57 |
| 16 | 58 45 | 00 32 | 10 58 | +30 | 10 6 | − 4 23 | − 37 | 5 1 |
| 17 | 172 0 50 | 1 45 | 11 10 | +19 | 12 47 | − 4 23 | − 37 | 6 6 |
| 18 | 171 58 36 | 59 25 | 11 3 | +28 | 10 32 | − 4 23 | − 38 | 5 5 |
| 19 | 58 36 | 59 6 | 11 22 | +17 | 10 30 | − 4 23 | − 38 | 5 52 |
| 20 | 57 8 | 58 32 | 12 38 | +10 | 10 38 | − 4 23 | − 38 | 6 15 |
| | | | | Mean | | | | 82 5 48.6 |
| 1 | 159 29 58 | 30 42 | 12 2 | + 1 | 42 23 | + 1 57 | − 7 | 69 44 31 |
| 2 | 27 58 | 28 33 | 13 28 | + 1 | 41 45 | + 1 56 | − 4 | 44 40 |
| 3 | 28 30 | 29 42 | 13 34 | 0 | 42 40 | + 1 56 | − 4 | 44 41 |
| 4 | 30 58 | 31 25 | 12 39 | 0 | 43 51 | + 0 9 | + 10 | 43 29 |
| 5 | 32 37 | 32 45 | 11 38 | 0 | 44 19 | + 0 4 | + 23 | 44 23 |
| 6 | 31 30 | 33 2 | 11 38 | − 6 | 43 48 | + 0 4 | + 23 | 44 17 |
| 7 | 27 32 | 27 55 | 12 52 | − 8 | 40 28 | + 0 4 | + 25 | 44 2 |
| 9 | 31 23 | 31 55 | 14 30 | − 4 | 46 5 | − 1 30 | − 1 | 44 5 |
| 10 | 32 38 | 33 35 | 13 7 | + 1 | 46 15 | − 1 32 | + 2 | 44 23 |
| 11 | 31 37 | 32 12 | 14 13 | + 1 | 46 8 | − 1 32 | + 4 | 44 6 |
| 12 | 29 26 | 30 7 | 15 35 | + 2 | 45 23 | − 1 32 | + 4 | 44 3 |
| 13 | 31 28 | 32 32 | 13 8 | + 1 | 45 9 | − 1 32 | + 4 | 44 2 |
| 15 | 34 5 | 35 40 | 12 13 | +11 | 47 16 | − 2 26 | − 13 | 44 26 |
| 17 | 37 0 | 37 53 | 11 10 | +23 | 49 0 | − 2 29 | − 21 | 44 18 |
| 19 | 34 50 | 35 2 | 11 22 | +20 | 46 38 | − 2 29 | − 22 | 44 0 |
| 20 | 33 28 | 34 33 | 12 38 | +13 | 46 52 | − 2 29 | − 22 | 44 29 |
| | | | | Mean | | | | 69 44 14.7 |
| 2 | 204 24 48 | 25 48 | 13 28 | −14 | 38 32 | + 5 3 | + 36 | 114 44 48 |
| 15 | 39 12 | 40 48 | 12 13 | − 3 | 52 10 | − 6 20 | − 49 | 45 13 |
| 18 | 40 5 | 41 10 | 11 3 | − 2 | 51 39 | − 6 28 | − 52 | 44 2 |
| 20 | 38 30 | 39 10 | 12 38 | − 3 | 51 25 | − 6 29 | − 52 | 44 51 |
| | | | | Mean | | | | 114 44 43.5 |
| 2 | 171 6 10 | 7 7 | 13 28 | − 5 | 20 1 | + 3 1 | + 7 | 81 24 4 |
| 11 | 11 43 | 12 37 | 14 13 | − 2 | 26 21 | − 2 23 | + 16 | 23 33 |
| 13 | 12 10 | 12 34 | 13 8 | − 7 | 25 23 | − 2 23 | + 16 | 23 30 |
| 18 | 15 34 | 16 12 | 11 3 | +28 | 27 24 | − 3 52 | − 33 | 22 30 |
| | | | | | | | | 81 23 24.2 |

## Table VII.—For Proper Motion.

(See Paragraphs 11–12 and 17–18.)

| Star No. | In Distance. | | In Position Angle. | | |
|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_5$ | $S_6$ | $S_7$ |
| 1 | —.2384 | —.0035 | +.9712 | .007 43 | +.007 216 |
| 2 | —.9977 | —.0000 | +.0681 | .009 17 | +.000 624 |
| 3 | —.9997 | —.0000 | —.0237 | .008 75 | —.000 207 |
| 4 | —.9968 | —.0000 | —.0794 | .009 03 | —.000 717 |
| 5 | —.7484 | —.0029 | +.6632 | .012 95 | +.008 588 |
| 6 | —.9997 | —.0000 | —.0228 | .010 53 | —.000 240 |
| 7 | —.9979 | —.0000 | +.0649 | .012 29 | +.000 798 |
| 8 | —.3231 | —.0073 | +.9464 | .016 36 | +.015 483 |
| 9 | —.8917 | —.0009 | —.4526 | .008 72 | —.003 947 |
| 10 | +.1802 | —.0049 | +.9836 | .010 09 | +.009 925 |
| 11 | +.1589 | —.0066 | +.9873 | .013 48 | +.013 309 |
| 12 | —.0319 | —.0093 | +.9995 | .018 63 | +.018 621 |
| 13 | +.3395 | —.0045 | +.9406 | .010 17 | +.009 566 |
| 14 | —.4216 | —.0118 | +.9068 | .028 84 | +.026 152 |
| 15 | —.9606 | —.0007 | —.2780 | .019 16 | —.005 326 |
| 16 | —.9419 | —.0019 | +.3360 | .033 01 | +.011 091 |
| 17 | +.3379 | —.0054 | +.9412 | .012 13 | +.011 417 |
| 18 | +.2877 | —.0065 | +.9577 | .014 30 | +.013 695 |
| 19 | —.7295 | —.0018 | —.6840 | .007 76 | —.005 308 |
| 20 | +.4677 | —.0053 | +.8838 | .013 56 | +.011 984 |
| 21 | —.9264 | —.0032 | —.3767 | .044 91 | —.016 918 |
| 22 | +.5569 | —.0031 | +.8306 | .009 04 | +.007 509 |
| 23 | +.5665 | —.0038 | +.8240 | .011 20 | +.009 229 |
| 24 | +.1855 | —.0568 | +.9827 | .117 38 | +.115 349 |
| 25 | | | | | |
| 26 | | | | | |
| 27 | —.5863 | —.0085 | —.8100 | .026 06 | —.021 109 |
| 28 | —.6038 | —.0028 | —.7971 | .008 95 | —.007 134 |
| 29 | +.7608 | —.0058 | +.6488 | .027 76 | +.018 011 |
| 30 | +.9269 | —.0039 | +.3753 | .054 36 | +.020 401 |
| 31 | —.4932 | —.0063 | —.8699 | .016 70 | —.014 527 |
| 32 | —.5183 | —.0048 | —.8552 | .013 00 | —.011 118 |
| 33 | +.8631 | —.0037 | +.5049 | .028 72 | +.014 501 |
| 34 | —.0903 | —.0144 | —.9959 | .028 99 | —.028 871 |
| 35 | +.3090 | —.0200 | —.9510 | .044 16 | —.041 996 |
| 36 | +.8577 | —.0059 | —.5141 | .044 64 | —.022 941 |
| 37 | —.1433 | —.0103 | —.9897 | .020 95 | —.020 734 |
| 38 | —.4283 | —.0036 | —.9036 | .008 91 | —.008 051 |
| 39 | +.7852 | —.0017 | +.6192 | .008 79 | +.005 443 |
| 40 | —.3641 | —.0045 | —.9314 | .010 39 | —.009 677 |

TABLE VII.—FOR PROPER MOTION. (*Concluded.*)

(See Paragraphs 11–12 and 17–18.)

| Star No. | In Distance. | | In Position Angle. | | |
|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_5$ | $S_6$ | $S_7$ |
| 41 | +.3234 | —.0132 | —.9463 | .029 42 | —.027 840 |
| 42 | +.8099 | —.0014 | +.5866 | .008 12 | +.004 763 |
| 43 | —.0424 | —.0077 | —.9991 | .015 35 | —.015 336 |
| 44 | +.1342 | —.0086 | —.9909 | .017 50 | —.017 341 |
| 45 | +.8777 | —.0011 | +.4792 | .009 43 | +.004 519 |
| 46 | +.8362 | —.0034 | —.5484 | .022 47 | —.012 323 |
| 47 | —.3107 | —.0035 | —.9505 | .007 66 | —.007 281 |
| 48 | +.5812 | —.0065 | —.8137 | .019 69 | —.016 022 |
| 49 | +.4478 | —.0069 | —.8941 | .017 30 | —.015 468 |
| 50 | +.5301 | —.0061 | —.8479 | .017 02 | —.014 431 |
| 51 | +.0343 | —.0047 | —.9994 | .009 35 | —.009 344 |
| 52 | +.6442 | —.0038 | —.7648 | .013 11 | —.010 027 |
| 53 | +.8692 | —.0016 | —.4943 | .013 18 | —.006 515 |
| 54 | +.8926 | —.0013 | —.4508 | .012 94 | —.005 833 |
| 55 | —.0531 | —.0037 | —.9986 | .007 43 | —.007 420 |
| 56 | +.9887 | —.0001 | +.1500 | .008 53 | +.001 280 |
| 57 | +.9988 | —.0000 | +.0482 | .009 29 | +.000 448 |
| 58 | +.5565 | —.0039 | —.8309 | .011 15 | —.009 265 |
| 59 | +.4832 | —.0040 | —.8755 | .010 32 | —.009 035 |
| 60 | +.9632 | —.0004 | —.2689 | .010 24 | —.002 754 |
| 61 | +.4063 | —.0039 | —.9137 | .009 24 | —.008 443 |
| 62 | +.9128 | —.0007 | —.4084 | .008 97 | —.003 663 |
| 63 | +.8604 | —.0012 | —.5096 | .009 13 | —.004 653 |
| 64 | +.9498 | —.0004 | —.3129 | .008 33 | —.002 606 |
| 65 | +.4494 | —.0031 | —.8933 | .007 75 | —.006 923 |
| 66 | +.8669 | —.0010 | —.4984 | .008 21 | —.004 092 |

## Table VIII.—For Parallax.

(See Paragraphs 14 and 22.)

| Star No. | In Distance. | | In Position Angle. | |
|---|---|---|---|---|
| | $S_3$ | $S_4$ | $S_8$ | $S_9$ |
| 1 | +.080 | +.825 | — 52.6 | — 4.6 |
| 2 | +.941 | +.330 | — 14.6 | + 51.4 |
| 3 | +.957 | +.259 | — 8.3 | + 50.7 |
| 4 | +.962 | +.215 | — 5.0 | + 53.2 |
| 5 | +.613 | +.726 | — 71.1 | + 38.2 |
| 6 | +.957 | +.260 | — 10.0 | + 61.1 |
| 7 | +.941 | +.328 | — 19.3 | + 68.9 |
| 8 | +.165 | +.829 | —114 6 | — 1.3 |
| 9 | +.918 | —.106 | + 19.1 | + 52.8 |
| 10 | —.320 | +.718 | — 67.6 | — 30.8 |
| 11 | —.301 | +.727 | — 90.9 | — 39.7 |
| 12 | —.121 | +.790 | —131.3 | — 35.0 |
| 13 | —.466 | +.641 | — 63.3 | — 39.5 |
| 14 | +.265 | +.825 | —197.3 | + 15 9 |
| 15 | +.958 | +.049 | + 17.0 | +116.8 |
| 16 | +.847 | +.524 | —112.7 | +156.0 |
| 17 | —.464 | +.642 | — 75.5 | — 47.0 |
| 18 | —.419 | +.668 | — 91.4 | — 51.8 |
| 19 | +.799 | —.332 | + 31.0 | + 43.4 |
| 20 | —.579 | +.561 | — 77.0 | — 61.1 |
| 21 | +.940 | —.037 | + 73.1 | +273.8 |
| 22 | —.656 | +.494 | — 47.1 | — 44.3 |
| 23 | —.665 | +.487 | — 57.7 | — 55.4 |
| 24 | —.325 | +.716 | —779.8 | —372.7 |
| 25 | | | | |
| 26 | | | | |
| 27 | +.681 | —.470 | +131.6 | +130.8 |
| 28 | +.696 | —.455 | + 44 1 | + 45.6 |
| 29 | —.823 | +.296 | —102.8 | —158.3 |
| 30 | —.940 | +.036 | — 85.8 | —331.6 |
| 31 | +.602 | —.543 | + 93.0 | + 76.9 |
| 32 | +.623 | —.524 | + 70.6 | + 61.4 |
| 33 | —.899 | +.155 | — 74.0 | —172.3 |
| 34 | +.237 | —.753 | +199.8 | + 73.8 |
| 35 | —.151 | —.829 | +309.6 | + 5.4 |
| 36 | —.740 | —.640 | +203.1 | —173.8 |
| 37 | +.286 | —.734 | +142.3 | + 59.3 |
| 38 | +.545 | —.587 | + 52.3 | + 38.4 |
| 39 | —.842 | +.266 | — 30.5 | — 50.9 |
| 40 | +.488 | —.627 | + 63.7 | + 41.5 |

TABLE VIII.—FOR PARALLAX. (*Concluded.*)

(See Paragraphs 14 and 22.)

| Star No. | In Distance. | | In Position Angle. | |
|---|---|---|---|---|
| | $S_3$ | $S_4$ | $S_8$ | $S_9$ |
| 41 | —.165 | —.829 | +206 0 | + 2.0 |
| 42 | —.861 | +.234 | — 26.1 | — 47.6 |
| 43 | +.192 | —.769 | +107.0 | + 34.9 |
| 44 | +.022 | —.812 | +124.3 | + 21.8 |
| 45 | —.909 | +.131 | — 22.5 | — 56.8 |
| 46 | —.714 | —.660 | +107.2 | — 83.1 |
| 47 | +.440 | —.656 | + 48.5 | + 28.5 |
| 48 | —.431 | —.797 | +125.1 | — 33.3 |
| 49 | —.292 | —.823 | +117.1 | — 13.2 |
| 50 | —.377 | —.810 | +111.3 | — 22.6 |
| 51 | +.118 | —.790 | + 65.9 | + 17.4 |
| 52 | —.498 | —.776 | + 79.7 | — 28.2 |
| 53 | —.754 | —.627 | + 58.4 | — 52.6 |
| 54 | —.783 | —.600 | + 53.8 | — 54.6 |
| 55 | +.202 | —.765 | + 51.7 | + 17.4 |
| 56 | —.965 | —.157 | + 0.4 | — 51.1 |
| 57 | —.959 | —.240 | + 7.2 | — 54.3 |
| 58 | —.405 | —.804 | + 71.9 | — 16.9 |
| 59 | —.328 | —.818 | + 68.9 | — 10.3 |
| 60 | —.877 | —.477 | + 30.3 | — 51.1 |
| 61 | —.249 | —.827 | + 63.4 | — 4.4 |
| 62 | —.808 | —.572 | + 34.8 | — 39.6 |
| 63 | —.743 | —.637 | + 41.4 | — 35.7 |
| 64 | —.858 | —.508 | + 27.1 | — 40.2 |
| 65 | —.293 | —.823 | + 52.5 | — 5.9 |
| 66 | —.751 | — 630 | + 36.6 | — 32.6 |

## Table IX.—Mean Results.

| Star No. | Distance. | Position Angle. | α′—α | δ′—δ | No. of Plates. | Durchmusterung. | |
|---|---|---|---|---|---|---|---|
| | | | | | | No. | Mag. |
| | ″ | ° ′ ″ | ″ | ″ | | ° | |
| 1 | 3771.42 | 307 44 19.4 | —3824.94 | +2291.19 | 10 | 38.4318 | 7.2 |
| 2 | 3055.07 | 235 25 23.3 | —3176.65 | —1745.70 | 6 | 37.4154 | 9.1 |
| 3 | 3202.47 | 230 9 10.8 | —3101.33 | —2063.32 | 5 | 37.4155 | 9.3 |
| 4 | 3103.85 | 226 58 31.0 | —2861.47 | —2127.48 | 2 | 37.4157 | 9.3 |
| 5 | 2163.15 | 273 6 36.6 | —2746.93 | + 108.47 | 19 | 38.4325 | 6.0 |
| 6 | 2660.10 | 230 12 33.1 | —2581.61 | —1710.30 | 19 | 37.4159 | 7.5 |
| 7 | 2279.03 | 235 15 9.0 | —2368.76 | —1305.58 | 2 | 37.4161 | 9.5 |
| 8 | 1712.84 | 302 42 34.5 | —1838.55 | + 921.62 | 6 | 38.4331 | 9.3 |
| 9 | 3213.79 | 204 35 20.2 | —1681.35 | —2925.69 | 6 | 37.4166 | 9.1 |
| 10 | 2775.08 | 332 1 31.7 | —1670.41 | +2447.56 | 6 | 38.4332 | 9.2 |
| 11 | 2078.41 | 330 48 8.3 | —1297.85 | +1812.35 | 3 | 38.4333 | 9.4 |
| 12 | 1503.97 | 319 53 21.3 | —1237.16 | +1148.44 | 3 | 38.4334 | 9 5 |
| 13 | 2754.25 | 341 24 38.4 | —1127.39 | +2609.07 | 17 | 38.4335 | 9.0 |
| 14 | 971.48 | 296 47 43.5 | —1104.18 | + 436.52 | 11 | 38.4336 | 8.8 |
| 15 | 1462.27 | 215 20 57.0 | —1070.60 | —1194.04 | 8 | 37.4170 | 8.5 |
| 16 | 848.59 | 251 12 59.6 | —1020.22 | — 274.47 | 8 | 37.4171 | 9.4 |
| 17 | 2308 80 | 341 20 48.0 | — 946.63 | +2186.47 | 6 | [38.4338] | [9.4] |
| 18 | 1958.83 | 338 22 5.9 | — 924.37 | +1819.88 | 9 | 38.4337 | 9.0 |
| 19 | 3610.25 | 188 17 34.5 | — 653.13 | —3573.00 | 4 | 37.4172 | 8.3 |
| 20 | 2066.13 | 349 29 58.9 | — 482.39 | +2031.26 | 12 | 38.4339 | 8.9 |
| 21 | 623.86 | 209 16 22.4 | — 386.98 | — 544.37 | 7 | 37.4173 | 8.8 |
| 22 | 3100.22 | 355 24 41.4 | — 319.06 | +3090.17 | 7 | 38.4340 | 9.1 |
| 23 | 2500.62 | 356 4 29.8 | — 219.69 | +2494.70 | 19 | 38.4341 | 8.2 |
| 24 | 238.68 | 333 13 7.5 | — 136.82 | + 213.06 | 2 | 38.4342 | 9.5 |
| 25 | | **61[1] Cygni** | | | | 38.4343 | 5.0 |
| 26 | 19.39 | *61[2] Cygni* | | | 19 | 38.4344 | 5.3 |
| 27 | 1074.60 | 177 15 24.0 | + 65.11 | —1073.38 | 10 | 37.4175 | 9.0 |
| 28 | 3130.15 | 178 34 1.3 | + 98.35 | —3129.18 | 6 | 37.4176 | 8.7 |
| 29 | 1008.91 | 11 4 37.0 | + 247.35 | + 990.04 | 3 | 38.4348 | 9.5 |
| 30 | 515.04 | 29 38 16.0 | + 324.32 | + 447.54 | 1 | 38.4349 | 9.4 |
| 31 | 1677.09 | 170 56 2.0 | + 333.84 | —1656.26 | 1 | 37.4177 | 9.5 |
| 32 | 2155.55 | 172 40 30.0 | + 346.56 | —2138.10 | 19 | 37.4178 | 7.5 |
| 33 | 975.29 | 21 15 9.1 | + 450.96 | + 908.72 | 7 | 38.4350 | 9.5 |
| 34 | 966.32 | 146 39 17.0 | + 673.17 | — 807.78 | 3 | 37. | |
| 35 | 634.19 | 123 8 22.5 | + 674.16 | — 347.24 | 2 | 37.4179 | 8.6 |
| 36 | 627.41 | 82 19 26.8 | + 790.67 | + 83.07 | 8 | 38.4351 | 9.5 |
| 37 | 1336.94 | 149 37 6.6 | + 855.80 | —1154.21 | 18 | 37.4180 | 7.7 |
| 38 | 3143.57 | 166 49 5.1 | + 900.87 | —3061.70 | 9 | 37.4181 | 9.0 |
| 39 | 3185.45 | 13 17 8.6 | + 941.74 | +3099.16 | 14 | 38.4353 | 8.4 |
| 40 | 2696.96 | 162 49 15.6 | +1002.82 | —2577.83 | 7 | 37.4182 | 9.4 |

TABLE X.—CATALOGUE OF STARS ABOUT 61[1] CYGNI.

| Star No. | A.G. Lund. | Right Ascension, 1873. | Precession, *J* | Sec. Var., *K* | Declination, 1873. | Precession, *L* | Sec. Var., *M* |
|---|---|---|---|---|---|---|---|
| | | h m s | s | s | ° ′ ″ | ″ | ″ |
| 1 | | 20 56 57.333 | +2.3031 | +0.0041 | 38 45 44.59 | +13.991 | +0.235 |
| 2 | | 57 40.552 | 2.3357 | .0041 | 37 38 27.70 | 14.036 | .237 |
| 3 | | 57 45.574 | 2.3384 | .0041 | 37 33 10.08 | 14.041 | .237 |
| 4 | | 58 1.564 | 2.3396 | .0041 | 37 32 5.92 | 14.058 | .237 |
| 5 | | 58 9.200 | 2.3235 | .0042 | 38 09 21.87 | 14.066 | .236 |
| 6 | | 20 58 20.222 | +2.3375 | +0.0041 | 37 39 3.10 | +14.077 | +0.237 |
| 7 | | 58 34.412 | 2.3353 | .0042 | 37 45 47.82 | 14.092 | .236 |
| 8 | | 59 9.759 | 2.3206 | .0042 | 38 22 55.02 | 14.129 | .234 |
| 9 | | 59 20.239 | 2.3496 | .0042 | 37 18 47.71 | 14.140 | .237 |
| 10 | | 59 20.968 | 2.3097 | .0043 | 38 48 20.96 | 14.140 | .232 |
| 11 | | 20 59 45.806 | +2.3161 | +0.0043 | 38 37 45.75 | +14.166 | +0.233 |
| 12 | | 59 49.852 | 2.3211 | .0043 | 38 26 41.84 | 14.170 | .233 |
| 13 | | 59 57.170 | 2.3107 | .0043 | 38 51 2.47 | 14.178 | .232 |
| 14 | | 59 58.717 | 2.3270 | .0043 | 38 14 49.92 | 14.179 | .234 |
| 15 | | 21 00 0.956 | 2.3391 | .0042 | 37 47 39.36 | 14.181 | .235 |
| 16 | | 21 00 4.314 | +2.3324 | +0.0043 | 38 02 58.93 | +14.185 | +0.234 |
| 17 | | 00 9.220 | 2.3145 | .0043 | 38 43 59.87 | 14.190 | .233 |
| 18 | | 00 10.704 | 2.3172 | .0044 | 38 37 53.28 | 14.192 | .233 |
| 19 | | 00 28.787 | 2.3578 | .0043 | 37 08 0.40 | 14.210 | .237 |
| 20 | | 00 40.170 | 2.3172 | .0044 | 38 41 24.66 | 14.222 | .232 |
| 21 | | 21 00 46.530 | +2.3369 | +0.0044 | 37 58 29.03 | +14.229 | +0.234 |
| 22 | | 00 51.058 | 2.3099 | .0044 | 38 59 3.57 | 14.233 | .231 |
| 23 | | 00 57.683 | 2.3149 | .0044 | 38 49 8.10 | 14.240 | .232 |
| 24 | | 01 3.208 | 2.3321 | .0044 | 38 11 6.46 | 14 246 | .233 |
| 25 | | **21 01 12.329** | **2.3343** | **.0044** | **38 07 33.40** | **14.260** | **.233** |
| 26 | | | See | *Contribu* | *tion* No. 13. | | |
| 27 | | 01 16.670 | +2.3422 | +0.0044 | 37 49 40.02 | +14.259 | +0.234 |
| 28 | | 01 18.886 | 2.3572 | .0044 | 37 15 24.22 | 14.262 | .235 |
| 29 | | 01 28.819 | 2.3276 | .0044 | 38 24 3.44 | 14.272 | .232 |
| 30 | | 01 33.950 | 2.3321 | .0044 | 38 15 0.94 | 14.277 | .233 |
| 31 | | 21 01 34.585 | +2.3387 | +0.0044 | 37 39 57.14 | +14.278 | +0.234 |
| 32 | | 01 35.433 | 2.3511 | .0044 | 37 31 55.30 | 14.279 | .235 |
| 33 | | 01 42.393 | 2.3290 | .0044 | 38 22 42.12 | 14.286 | .232 |
| 34 | | 01 57.207 | 2.3425 | .0044 | 37 54 5.62 | 14.301 | .234 |
| 35 | | 01 57.273 | 2.3392 | .0044 | 38 01 46.16 | 14.301 | .233 |
| 36 | | 21 02 5.040 | +2.3364 | +0.0044 | 38 08 56.47 | +14.309 | +0.233 |
| 37 | | 02 9.382 | 2.3458 | .0044 | 37 48 19.19 | 14.313 | .234 |
| 38 | | 02 12.387 | 2.3597 | .0044 | 37 16 31.70 | 14.316 | .235 |
| 39 | | 02 15.112 | 2.3147 | .0045 | 38 59 12.56 | 14.319 | .230 |
| 40 | | 02 19.184 | 2.3565 | .0044 | 37 24 35.57 | 14.324 | .234 |

## Table IX.—Mean Results. (*Concluded.*)

| Star No. | Distance. | Position Angle. | α′—α | δ′—δ | No. of Plates. | Durchmusterung. No. | Durchmusterung. Mag. |
|---|---|---|---|---|---|---|---|
| | ″ | ° ′ ″ | ″ | ″ | | ° | |
| 41 | 952.00 | 122 36 30.0 | +1017.45 | — 514.25 | 2 | 37.4183 | 9 5 |
| 42 | 3448.83 | 15 37 11.8 | +1195.67 | +3319.79 | 5 | 38.4356 | 8.9 |
| 43 | 1824.90 | 143 50 53.3 | +1360.90 | —1475.72 | 12 | 37.4185 | 9.0 |
| 44 | 1600.46 | 133 45 6.3 | +1463.45 | —1109.29 | 6 | 37.4186 | 9.5 |
| 45 | 2971.02 | 22 53 48.0 | +1484.97 | +2734.35 | 2 | 38.4357 | 9.3 |
| 46 | 1246.52 | 84 39 5.0 | +1578.37 | + 113.27 | 1 | 38.4358 | 9.5 |
| 47 | 3657.35 | 159 32 17.0 | +1604.53 | —3429.64 | 3 | 37.4187 | 9.0 |
| 48 | 1422.69 | 105 53 10.6 | +1736.87 | — 392.98 | 19 | 37.4189 | 7.9 |
| 49 | 1618.91 | 114 46 4.0 | +1863.84 | — 682.32 | 1 | 37.4191 | 9.4 |
| 50 | 1645.44 | 109 24 10.7 | +1968.78 | — 551.20 | 15 | 37.4192 | 9.0 |
| 51 | 2995.55 | 139 41 7.0 | +2442.53 | —2291.17 | 1 | 37.4195 | 9.5 |
| 52 | 2136.94 | 101 21 31.4 | +2658.96 | — 429.20 | 10 | 37.4197 | 9.1 |
| 53 | 2125.57 | 81 5 52.2 | +2672.78 | + 320.52 | 16 | 38.4362 | 7.8 |
| 54 | 2164.54 | 78 15 57.5 | +2698.53 | + 431.63 | 13 | 38.4363 | 9.1 |
| 55 | 3771.13 | 144 28 33.3 | +2753.46 | —3078.19 | 3 | 37.4198 | 8.7 |
| 56 | 3283.52 | 42 53 31.6 | +2867.24 | +2396.00 | 7 | 38.4364 | 9.0 |
| 57 | 3014.80 | 48 45 51.0 | +2903.97 | +1977.36 | 1 | 38.4365 | 9.3 |
| 58 | 2513.28 | 107 37 24.4 | +3036.08 | — 771.78 | 9 | 37.4201 | 9.3 |
| 59 | 2713.34 | 112 33 7.5 | +3172.80 | —1052.51 | 13 | 37.4202 | 8.8 |
| 60 | 2734.76 | 67 6 33.7 | +3215.61 | +1051.59 | 3 | 38.4367 | 9.0 |
| 61 | 3032.47 | 117 29 40.1 | +3401.30 | —1413.65 | 17 | 37.4203 | 8.3 |
| 62 | 3121.94 | 75 37 56.7 | +3855.71 | + 757.20 | 3 | 38.4369 | 9.3 |
| 63 | 3069.92 | 82 5 48.6 | +387[illegible].48 | + 404.48 | 9 | 38.4370 | 9.0 |
| 64 | 3362.19 | 69 44 14.7 | +4027.23 | +1145.36 | 16 | 38.4372 | 7.8 |
| 65 | 3613.27 | 114 44 43.5 | +4147.41 | —1532.77 | 4 | 37.4209 | 8.4 |
| 66 | 3411.15 | 81 23 24.2 | +4295.50 | + 488.97 | 4 | 38.4375 | 8.4 |

TABLE X.—CATALOGUE OF STARS ABOUT 61[1] CYGNI. (*Concluded.*)

| Star No. | A.G. Lund. | Right Ascension, 1873. | Precession, *J* | Sec. Var., *K* | Declination, 1873. | Precession, *L* | Sec. Var., *M* |
|---|---|---|---|---|---|---|---|
| | | h m s | s | | ° ′ ″ | ″ | |
| 41 | | 21 02 20.159 | +2.3415 | +0.0045 | 37 58 59.15 | +14.325 | +0.233 |
| 42 | | 02 32.040 | 2.3140 | .0045 | 39 2 53.19 | 14.336 | .230 |
| 43 | | 02 43.056 | 2.3498 | .0045 | 37 42 57.68 | 14.348 | .234 |
| 44 | | 02 49.892 | 2.3476 | .0045 | 37 49 4.11 | 14.355 | .233 |
| 45 | | 02 51.327 | 2.3194 | .0045 | 38 53 7.75 | 14.356 | .230 |
| 46 | | 21 02 57.554 | +2.3391 | +0.0045 | 38 9 26.67 | +14.362 | +0.232 |
| 47 | | 02 59.298 | 2.3648 | .0045 | 37 10 23.76 | 14.364 | .235 |
| 48 | | 03 8.120 | 2.3434 | .0045 | 38 1 0.42 | 14.373 | .232 |
| 49 | | 03 16.585 | 2.3459 | .0045 | 37 56 11.08 | 14.382 | .232 |
| 50 | | 03 23.581 | 2.3453 | .0045 | 37 58 22.20 | 14.389 | .232 |
| 51 | | 21 03 55.164 | +2.3595 | +0.0045 | 37 29 22.23 | +14.421 | +0.233 |
| 52 | | 04 9.593 | 2.3470 | .0046 | 38 0 24.20 | 14.435 | .231 |
| 53 | | 04 10.514 | 2.3415 | .0046 | 38 12 53.92 | 14.436 | .231 |
| 54 | | 04 12.231 | 2.3409 | .0046 | 38 14 45.03 | 14.438 | .231 |
| 55 | | 04 15.893 | 2.3662 | .0045 | 37 16 15.21 | 14.442 | .233 |
| 56 | | 21 04 23.478 | +2.3272 | +0.0046 | 38 47 29.40 | +14.450 | +0.229 |
| 57 | | 04 25.927 | 2.3302 | .0046 | 38 40 30.76 | 14.452 | .230 |
| 58 | | 04 34.734 | 2.3508 | .0046 | 37 54 41.62 | 14.461 | .232 |
| 59 | | 04 43.849 | 2.3532 | .0046 | 37 50 0.89 | 14.470 | .232 |
| 60 | | 04 46.703 | 2.3382 | .0046 | 38 25 4.99 | 14.473 | .230 |
| 61 | | 21 04 59.082 | +2.3567 | +0.0046 | 37 43 59.75 | +14.486 | +0.231 |
| 62 | | 05 29.376 | 2.3427 | .0047 | 38 20 10.60 | 14.516 | .230 |
| 63 | | 05 30.428 | 2.3454 | .0047 | 38 14 17.88 | 14.517 | .230 |
| 64 | | 05 40.811 | 2.3406 | .0048 | 38 26 38.76 | 14.527 | .229 |
| 65 | | 05 48.823 | 2.3603 | .0047 | 37 42 0.63 | 14.536 | .231 |
| 66 | | 05 58.696 | 2.3463 | .0048 | 38 15 42.37 | 14.546 | .229 |

## Table XI.—Limiting Values of Parallax Coefficients for $\Pi = +0.''3597$.

### In Distance.

Use Parallax Coefficient $S_3\,P_3 + S_4\,P_4$ as the argument in the body of table.

| | *d* .0000 | *d* .0010 | *d* .0020 | *d* .0030 | *d* .0040 | *d* .0050 | *d* .0060 | *d* .0070 | *d* .0080 | *d* .0090 | *d* .0100 | *d* .0110 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *d* .0000 | .0000 | .0740 | .1519 | .2297 | .3076 | .3855 | .4634 | .5412 | .6191 | .6970 | .7749 | .8528 |
| 1 | .0039 | .0818 | .1596 | .2375 | .3154 | .3933 | .4712 | .5490 | .6269 | .7048 | .7827 | .8605 |
| 2 | .0117 | .0896 | .1674 | .2453 | .3232 | .4011 | .4789 | .5568 | .6347 | .7126 | .7905 | .8683 |
| 3 | .0195 | .0973 | .1752 | .2531 | .3310 | .4089 | .4867 | .5646 | .6425 | .7204 | .7982 | .8761 |
| 4 | .0273 | .1051 | .1830 | .2609 | .3388 | .4166 | .4945 | .5724 | .6503 | .7282 | .8060 | .8839 |
| 5 | .0350 | .1129 | .1908 | .2687 | .3466 | .4244 | .5023 | .5802 | .6581 | .7359 | .8138 | .8917 |
| 6 | .0428 | .1207 | .1986 | .2765 | .3543 | .4322 | .5101 | .5880 | .6658 | .7437 | .8216 | .8995 |
| 7 | .0506 | .1285 | .2064 | .2843 | .3621 | .4400 | .5179 | .5958 | .6736 | .7515 | .8294 | .9073 |
| 8 | .0584 | .1363 | .2142 | .2920 | .3699 | .4478 | .5257 | .6035 | .6814 | .7593 | .8372 | .9151 |
| .0009 | .0662 | .1441 | .2219 | .2998 | .3777 | .4556 | .5335 | .6113 | .6892 | .7671 | .8450 | .9228 |
| | .0740 | .1519 | .2297 | .3076 | .3855 | .4634 | .5412 | .6191 | .6970 | .7749 | .8528 | .9306 |

### In Position–Angle.

Use Parallax Coefficient $S_8\,P_3 + S_9\,P_4$ as the argument in the body of table.

| | 00″ | 10″ | 20″ | 30″ | 40″ | 50″ | 60″ | 70″ | 80″ | 90″ | 100″ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.″ | 0.0 | 26.4 | 54.2 | 82.0 | 109.8 | 137.6 | 165.4 | 193.2 | 221.0 | 248.8 | 276.6 |
| 1. | 1.4 | 29.2 | 57.0 | 84.8 | 112.6 | 140.4 | 168.2 | 196.0 | 223.8 | 251.6 | 279.4 |
| 2. | 4.2 | 32.0 | 59.8 | 87.6 | 115.4 | 143.2 | 171.0 | 198.8 | 226.6 | 254.4 | 282.2 |
| 3. | 7.0 | 34.8 | 62.6 | 90.4 | 118.2 | 146.0 | 173.8 | 201.6 | 229.4 | 257.2 | 285.0 |
| 4. | 9.7 | 37.5 | 65.3 | 93.1 | 120.9 | 148.7 | 176.5 | 204.3 | 232.1 | 259.9 | 287.7 |
| 5. | 12.5 | 40.3 | 68.1 | 95.9 | 123.7 | 151.5 | 179.3 | 207.1 | 234.9 | 262.7 | 290.5 |
| 6. | 15.3 | 43.1 | 70.9 | 98.7 | 126.5 | 154.3 | 182.1 | 209.9 | 237.7 | 265.5 | 293.3 |
| 7. | 18.1 | 45.9 | 73.7 | 101.5 | 129.3 | 157.1 | 184.9 | 212.7 | 240.5 | 268.3 | 296.1 |
| 8. | 20.9 | 48.7 | 76.5 | 104.3 | 132.1 | 159.9 | 187.7 | 215.5 | 243.3 | 271.1 | 298.9 |
| 9. | 23.6 | 51.4 | 79.2 | 107.0 | 134.8 | 162.6 | 190.4 | 218.2 | 246.0 | 273.8 | 301.6 |
| | 26.4 | 54.2 | 82.0 | 109.8 | 137.6 | 165.4 | 193.2 | 221.0 | 248.8 | 276.6 | 304.4 |

## The Position of $61^2$ Cygni.

**26.** When we correct the measured coördinates of $61^2$ *Cygni* with respect to $61^1$ *Cygni*, it is, of course, necessary to take into account the very considerable proper motion of the measured star as well as of the central star.

On account of the shortness of time over which the RUTHERFURD plates extend, a value of the relative motion deduced from them alone would have very small weight. On the other hand, the mean of the measured distances and of the measured angles is entitled to great weight as representing the true value of the distance and angle of these stars at the mean of the dates of observation, 1873.546. I have, accordingly, with the latter as a basis, deduced trigonometrically a set of formulæ which represent the motion of either of these stars relative to the other; assuming the motion of each to be uniform and on the arc of a great circle. In these formulæ have then been substituted constants derived from the proper motion of each star separately, as determined from meridian observations in the manner used in my "Declinations and Proper Motions of Fifty-six Stars,"* to which reference is made for an explanation of the method.

**27.** For $61^1$ *Cygni* I have used AUWERS' values as previously quoted on page 62; but for $61^2$ *Cygni* the results given here have been derived from the data of Table XII.

$$61^1 \textit{ Cygni } \rho = 5.''20521 \quad \chi = 51°38'42'' \quad t = 1807.$$
$$61^2 \textit{ Cygni } \rho = 5.\ \ 15192 \quad \chi = 53\ \ 33\ \ 47 \quad t = 1858.$$

By the usual formulæ† these become:

$$61^1 \textit{ Cygni } \rho_0 = 5.''20521 \quad \chi_0 = 51°42'13'' \quad 1873.546.$$
$$61^2 \textit{ Cygni } \rho_0' = 5.\ \ 15192 \quad \chi_0' = 53\ \ 34\ \ 37 \quad 1873.546.$$

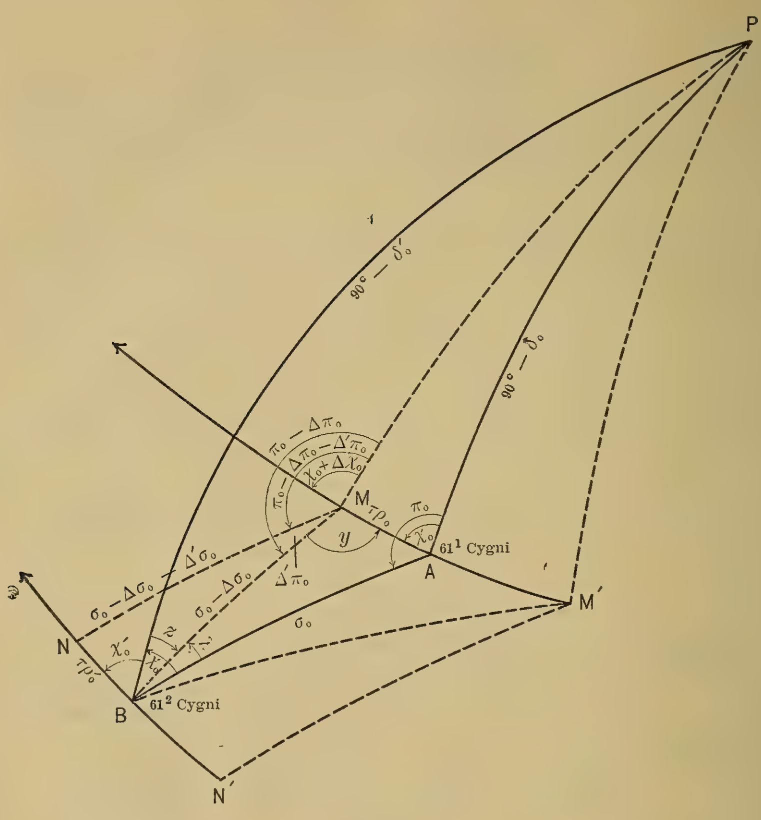
We have also:

$$61^1 \textit{ Cygni } \quad \delta_0 = 38°7'35''$$

and from the RUTHERFURD measures:

For $61^2$ *Cygni*, relative to $61^1$, $\sigma_0 = 19.''3823$ $\pi_0 = 114°41'30''$ at 1873.546.

* *Contribution from the Observatory of Columbia College, New York.*—No. 8.
† Chauvenet: Manual of Spherical and Practical Astronomy, Vol. I, §380.




$AB = \sigma_0 =$ True distance at 1873.546 from the mean of all the measured distances.

$MN =$ Distance measured on plate of the date, $t$, corrected except for proper motion.

$\rho_0$, $\rho_0' =$ The proper motions of $61^1$ and $61^2$ *Cygni* at the epoch 1873.546.

$AM$, $BN =$ Arcs traveled over in the time $\tau = t - 1873.546$.

$\Delta\sigma_0 =$ The change in $\sigma_0$ due to the proper motion of only $61^1$ from $A$ to $M$.

$\Delta'\sigma_0 =$ The change in $(\sigma_0 - \Delta\sigma_0)$ due to the proper motion of only $61^2$ from $B$ to $N$.

$PAB = \pi_0 =$ True angle at 1873.546 from the mean of all the measured angles.

$PMN =$ Position-angle measured on plate of the date, $t$, corrected except for proper motion.

$\chi_0$, $\chi_0' =$ The position-angles of the proper motion of $61^1$ and $61^2$ at 1873.546.

$PBA = \lambda_0'$, also $y, z, \lambda$ are auxiliary angles having the significance shown above.

$\Delta\pi_0 =$ The change in $\pi_0$ due to the proper motion of only $61^1$ from $A$ to $M$.

$\Delta'\pi_0 =$ The change in $(\pi_0 - \Delta\pi_0)$ due to the proper motion of $61^2$ from $B$ to $N$.

**28.** Let the angles and arcs have the significance attached to them in the figure; where $P$ is the Pole; $PA$ and $PB$ hour-circles through *61*[1] and *61*[2] respectively at 1873.546, and $M'M$ and $N'N$ the paths of proper motion. Then, as the arc $AB$ joining *61*[1] and *61*[2] is the mean of all the measures of distance, it may be assumed as the true distance at the mean date of observation. In like manner $PAB$ is assumed as the true position-angle at the same date. The problem before us is to (1) determine the distance $MN$ at the end of the interval $\tau$ years; (2) determine the angle $PMN$ at the end of the same interval. In both these cases evidently we regard the only cause of motion of the stars to be that known as proper motion, *i.e.*, uniform motion on the arc of a great circle.

Let all angles count from the hour circle positively towards the east, *i.e.*, counter-clockwise in the figure; or else from the arc $AB$, but always likewise positive when counter-clockwise, as shown by the direction of the arrows in the figure.

**29.** Let us first suppose that *61*[2] remains motionless while *61*[1] advances from $A$ to $M$ during the time $\tau$; then the change in distance is given by the formula:

$$\begin{aligned}\Delta\sigma_0 = {} & (\tau\rho_0)\cos(\pi_0-\chi_0) \\ & + (\tau\rho_0)^2\left\{-\frac{1}{2\sigma_0}\sin^2(\pi_0-\chi_0)\right\} \\ & + (\tau\rho_0)^3\left\{-\frac{1}{2\sigma_0^2}\sin^2(\pi_0-\chi_0)\cos(\pi_0-\chi_0)\right\} \\ & + (\tau\rho_0)^4\left\{\frac{1}{2\sigma_0^3}\left[\tfrac{1}{4}\sin^4(\pi_0-\chi_0)-\sin^2(\pi_0-\chi_0)\cos^2(\pi_0-\chi_0)\right]\right\}.\end{aligned}$$

When the proper constants have been substituted in this we have:

$$\Delta\sigma_0 = [9.657224](\tau\rho_0)+[8.311234_n](\tau\rho_0)^2+[6.68105_n](\tau\rho_0)^3+[3.6310_n](\tau\rho_0)^4.$$

Thus is obtained the auxiliary distance $BM$ agreeing of course with the formula of paragraph 11, as far as terms in $\tau^2$.

**30.** Now during the same interval of time $\tau$, suppose *61*[1] to remain still and *61*[2] to be in motion. Then the change of distance is given by the formula:

$$\begin{aligned}\Delta'\sigma_0 = {} & (\tau\rho_0')\cos(\chi_0'-z) \\ & + (\tau\rho_0')^2\left\{-\frac{1}{2(\sigma_0-\Delta\sigma_0)}\sin^2(\chi_0'-z)\right\} \\ & + (\tau\rho_0')^3\left\{-\frac{1}{2(\sigma_0-\Delta\sigma_0)^2}\sin^2(\chi_0'-z)\cos(\chi_0'-z)\right\} \\ & + (\tau\rho_0')^4\left\{\frac{1}{2(\sigma_0-\Delta\sigma_0)^3}\left[\tfrac{1}{4}\sin^4(\chi_0'-z)-\sin^2(\chi_0'-z)\cos^2(\chi_0'-z)\right]\right\}\end{aligned}$$

which may be computed for each plate separately after $\Delta\sigma_0$ has been computed by the preceding formula; and where the value of $z$ is obtained from the following relations :*

$$z = \lambda - \lambda_0'.$$

$$\lambda_0' = \overline{180^\circ} - \pi_0 - \sigma_0 \sin \pi_0 \tan \delta_0$$

$$\cot \lambda = \frac{1}{\tau\rho_0} \cdot \frac{\sigma_0}{\sin(\pi_0 - \chi_0)} - \cot(\pi_0 - \chi_0).$$

By substitution of the constants for these stars these become :

$$\lambda_0' = 65^\circ 18' 16''.5$$

$$\cot \lambda_0 = 21.75560 \frac{1}{\tau\rho_0} - 0.509789$$

hence

$$z = \lambda - 65^\circ 18' 16''.5$$

which may be computed for each plate.

Thus the variation in distance due solely to the proper motions of $61^1$ and $61^2$ *Cygni* in the assumed direction at the assumed rate may be expressed by

$$\Delta\sigma_0 + \Delta'\sigma_0$$

as computed for each value of $\tau$, and printed in columns nine and ten of Table XIII. This quantity is additive to the observed distance on each plate to reduce to the mean epoch.

**31.** By the formula of paragraph 17 may be computed values of $K$ or $\Delta\chi_0$ applicable to the new mean epoch adopted, thus :

$$\Delta\chi_0 = [9.7895]\, \tau\rho$$

where the number in brackets is a logarithm as usual.

We also have, as in paragraph 30,

$$\cot \Delta'\pi_0 = \frac{1}{\tau\rho_0'} \cdot \frac{\sigma - \Delta\sigma_0}{\sin(\chi_0' - z)} - \cot(\chi_0' - z)$$

and

$$\cot y = \frac{1}{\sigma_0} \cdot \frac{\tau\rho_0}{\sin(\pi_0 - \chi_0)} - \cot(\pi_0 - \chi_0)$$

* Jordan : *Handbuch der Vermessungskunde*, 4te Auflage. Bd. III, § 359, 342.

whence is obtained by substitution of the constants and from the figure:

$$\Delta\pi_0 = \quad 62^\circ 59' 17'' + (y - \Delta\chi_0) \qquad \text{before epoch,}$$
$$= -117^\circ\ 0' 43'' + (y - \Delta\chi_0) \qquad \text{after epoch,}$$

and thus the total change of angle is

$$\Delta\pi_0 + \Delta'\pi_0$$

additive to the observed position-angle. These quantities are printed in columns seven and eight of Table XIII.

When these corrections for proper motion have been applied to the preceding columns of Table XIII we get in the next-to-the-last column of the Table the distance and angle of *61*[2] good for 1873.546 corrected for all known motions of either star, except for difference of parallax if there be any such difference. This oint will be considered in the following *Contribution*, No. 13.

## Table XII.—Proper Motion of $61^2$ *Cygni.*

| Authority. | Date of Observation. $t$ | Epoch of Catalogue, $T$ | No. of Obs. $n$ | Position at Epoch of Catalogue. | Reduction to 1875+Syst. Correction. $A'$ | Reduced Position. $B$ | Wgt. | C.—O. $R$ |
|---|---|---|---|---|---|---|---|---|
| | | | | **Right Ascension.** | | | | |
| | | | | $20^h+$ | | $21^h\ 1^m+$ | | |
| | | | | m s | m s | s | | s |
| Br. 2745 | 1753.8 | 1755 | 2 | 55 57.41 | +5 21.767 | 19.177 | 0.3 | —.031 |
| Pi. xx:476 | 1806.2 | 1800 | 17 | 57 57.80 | +3 21.497 | 19.297 | 0.3 | —.089 |
| Abo 482 | 1828. | 1830 | 62 | 59 18.34 | +2 0.805 | 19.145 | 4.0 | +.089 |
| Pond 946 | 1830. | 1830 | 16 | 59 18.73 | +2 0.737 | 19.467 | 1.0 | —.230 |
| Tay. 9785 | 1835. | 1835 | 5 | 59 32.24 | +1 47.368 | 19.608 | 0.4 | —.365 |
| 12 $Yr_1$ 1887 | 1839. | 1840 | 30 | 59 45.14 | +1 34.086 | 19.226 | 3.0 | +.022 |
| 12 $Yr_2$ 1887 | 1845. | 1845 | 40 | 59 58.61 | +1 20.598 | 19.208 | 3.0 | +.047 |
| 6 Yr. 1358 | 1850.8 | 1850 | 45 | 60 12.11 | +1 7.153 | 19.263 | 3.0 | —.001 |
| $Rad_1$ 5107 | 1853.0 | 1845 | 19 | 59 58.76 | +1 20.550 | 19.310 | 3.0 | —.046 |
| Yarn. 9477 | 1854.8 | 1860 | 23 | 60 37.08 | +0 42.174 | 19.254 | 2.0 | +.012 |
| $Rad_2$ 2059 | 1856.4 | 1860 | 11 | 60 38.93 | +0 40.377 | 19.307 | 2.0 | —.039 |
| 7 Yr. 1743 | 1856.9 | 1860 | 48 | 60 38.95 | +0 40.308 | 19.258 | 3.0 | +.011 |
| Quet. 9276 | 1861.6 | 1865 | 18 | 60 51.11 | +0 28.134 | 19.244 | 3.0 | +.031 |
| N. 7 Yr. 2394 | 1864.0 | 1864 | 17 | 60 49.70 | +0 29.569 | 19.269 | 3.0 | +.009 |
| Poulk. | 1866.2 | 1865 | 27 | 60 52.448 | +0 26.839 | 19.287 | 8.0 | —.007 |
| 9 Yr. 1976 | 1872.3 | 1872 | 13 | 61 11.185 | +0 8.091 | 19.276 | 3.0 | +.011 |
| Romb. 4784 | 1877.9 | 1875 | 7 | 61 19.37 | +0 0.002 | 19.372 | 4.0 | —.078 |
| 10 Yr. 3532 | 1883.6 | 1880 | 14 | 61 32.656 | —0 13.394 | 19.262 | 3.0 | +.039 |
| Green. Yearly | 1893.7 | 1893 | 10 | 62 7.565 | —0 48.294 | 19.271 | 2.4 | +.042 |
| | | | | m s | | | | |
| Results. | 1858.58 | 1875 | 424 | 61 19.291 | | | 51.4 | |
| | | | | **Declination.** | | | | |
| | | | | 37°+ | | 38°7′+ | | |
| | | | | ′ ″ | ′ ″ | ″ | | ″ |
| Br. 2745 | 1753.8 | 1755 | 1 | 33 43.9 | +34 13.76 | 57.66 | 0.2 | —0.78 |
| Pi. xx:476 | 1805.8 | 1800 | 13 | 46 34.0 | +21 26.49 | 60.49 | 0.3 | —2.21 |
| Abo 482 | 1828. | 1830 | 33 | 55 4.7 | +12 54.11 | 58.81 | 4.0 | +0.07 |
| Tay. 9785 | 1835. | 1835 | 9 | 56 30.47 | +11 29.19 | 59.66 | 0.5 | —0.59 |
| 12 $Yr_1$ 1887 | 1839. | 1840 | 31 | 57 55.71 | +10 3.00 | 58.71 | 3.0 | +0.47 |
| 12 $Yr_2$ 1887 | 1844. | 1845 | 36 | 59 22.02 | + 8 36.89 | 58.91 | 3.0 | +0.40 |
| 6 Yr. 1358 | 1851.2 | 1850 | 35 | 60 48.67 | + 7 10.90 | 59.57 | 3.0 | —0.06 |
| $Rad_1$ 5107 | 1853.2 | 1845 | 18 | 59 23.2 | + 8 36.32 | 59.52 | 3.0 | +0.04 |
| Yarn. 9477 | 1854.0 | 1860 | 113 | 63 22.6 | + 4 37.25 | 59.85 | 3.0 | —0.27 |
| 7 Yr. 1743 | 1857.0 | 1860 | 44 | 63 40.53 | + 4 19.02 | 59.55 | 3.0 | +0.11 |
| $Rad_2$ 2059 | 1858.8 | 1860 | 10 | 63 41.8 | + 4 18.51 | 60.31 | 2.0 | —0.60 |
| N. 7 Yr. 2394 | 1864.2 | 1864 | 19 | 64 49.69 | + 3 9.90 | 59.59 | 3.0 | +0.27 |
| 9 Yr. 1976 | 1871.9 | 1872 | 14 | 67 8.90 | + 0 51.16 | 60.06 | 3.0 | .00 |
| Romb. 4784 | 1877.9 | 1875 | 7 | 68 0.7 | + 0 0.02 | 60.72 | 4.0 | —0.50 |
| 10 Yr. 3532 | 1883.6 | 1880 | 15 | 69 26.61 | — 1 26.54 | 60.07 | 3.0 | +0.31 |
| Green. Yearly | 1893.7 | 1893 | 10 | 73 12.43 | — 5 11.81 | 60.62 | 2.4 | +0.03 |
| | | | | ′ ″ | | | | |
| Results. | 1857.69 | 1875 | 408 | 68 0.150 | | | 40.4 | |

Probably an error of 5″ in Quetelet's declination, hence it has been discarded.

TABLE XIII.—POSITION OF $61^2$ *Cygni.*

| Plate. | Observed Dist. | | Corrections for | | Corrected Mean. | Scale Variation. | Distance at Date of each Plate. | Correction for Proper Motion of | | Distance at | Parallax Co-efficient. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | East. | West. | Refr. | Scale. | $s$ | $v'$ | $28''.0124(s+v')$ | $61^1$ *Cygni* | $61^2$ *Cygni* | 1873.546 | |
| | | | | | | | $''$ | $''$ | $''$ | $''$ | |
| 1 | 0.6843 | 0.6716 | 3 | + 5 | 0.6788 | +1 | 19.0176 | −5.2484 | +5.4774 | 19.2466 | −0.767 |
| 2 | .6900 | .6866 | 3 | 0 | .6886 | +2 | .2949 | −5.2191 | +5.4468 | .5226 | − .745 |
| 3 | .6968 | .6846 | 3 | 0 | .6910 | +1 | .3594 | −5.2191 | +5.4468 | .5871 | − .745 |
| 4 | .6918 | .6916 | 3 | 0 | .6920 | 0 | .3846 | −1.6956 | +1.7739 | .4629 | − .572 |
| 5 | .6877 | .6865 | 3 | 0 | .6874 | 0 | .2557 | −1.5652 | +1.6381 | .3286 | − .369 |
| 6 | .6834 | .7012 | 3 | − 2 | .6924 | +1 | .3986 | −1.5652 | +1.6381 | .4715 | − .369 |
| 7 | .6968 | .6864 | 3 | + 3 | .6922 | +1 | .3930 | −1.5505 | +1.6229 | .4654 | − .341 |
| 8 | .6934 | .6935 | 3 | 0 | .6937 | −1 | .4294 | +0.7173 | −0.7583 | .3884 | − .715 |
| 9 | .6852 | .6910 | 3 | 0 | .6883 | 0 | .2809 | +0.7173 | −0.7583 | .2399 | − .715 |
| 10 | .6951 | .6940 | 2 | 0 | .6947 | 0 | .4602 | +0.7448 | −0.7877 | .4173 | − .670 |
| 11 | .7023 | .7016 | 2 | + 1 | .7023 | 0 | .6731 | +0.7546 | −0.7981 | .6296 | − .650 |
| 12 | .6955 | .6951 | 3 | + 1 | .6958 | 0 | .4910 | +0.7546 | −0.7981 | .4475 | − .650 |
| 13 | .6963 | .6992 | 3 | + 1 | .6982 | 0 | .5583 | +0.7546 | −0.7981 | .5148 | − .650 |
| 15 | .6966 | .6987 | 3 | − 6 | .6974 | −1 | .5330 | +1.5946 | −1.7030 | .4246 | + .550 |
| 16 | .6839 | .7047 | 4 | 0 | .6947 | 0 | .4602 | +1.6312 | −1.7433 | .3481 | + .415 |
| 17 | .6935 | .6958 | 3 | + 3 | .6953 | 0 | .4770 | +1.6312 | −1.7433 | .3649 | + .415 |
| 18 | .6774 | .6957 | 4 | + 3 | .6873 | 0 | .2529 | +1.6348 | −1.7471 | .1406 | + .401 |
| 19 | .6868 | .6846 | 4 | 0 | .6861 | 0 | .2193 | +1.6348 | −1.7471 | .1070 | + .401 |
| 20 | .6905 | .6889 | 3 | +10 | .6910 | −1 | .3538 | +1.6348 | −1.7471 | 19.2415 | +0.401 |
| | | | | | Means | | 19.3823 | | | 19.3868 | |

TABLE XIII, *Concluded*.—POSITION OF $61^2$ *Cygni*.

| Plate. | Observed Position Angle | | Zero Correction plus precession, etc. | Refrac. | Corrected Mean Angle at Date of each Plate. $p$ | Correction for Proper Motion of | | Angle at | Parallax *Coefficient.* |
|---|---|---|---|---|---|---|---|---|---|
| | East. | West. | | | | $61^1$ *Cygni* | $61^2$ *Cygni* | 1873·546 | |
| | ° ′ ″ | ° ′ ″ | ′ ″ | ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | |
| 1 | 203 25 46 | 203 43 17 | 12 2 | —16 | 113 46 30 | +18 31 4 | —17 53 47 | 114 23 47 | +6354 |
| 2 | 204 6 26 | 203 7 26 | 13 28 | —14 | 51 10 | +18 27 0 | —17 49 51 | 28 19 | +6732 |
| 3 | 203 20 11 | 203 31 18 | 13 34 | —20 | 39 5 | +18 27 0 | —17 49 51 | 16 14 | +6732 |
| 4 | 203 44 56 | 203 47 23 | 12 39 | —18 | 57 56 | + 7 58 50 | — 7 44 37 | 12 9 | +8536 |
| 5 | 203 30 8 | 204 48 33 | 11 38 | —17 | 114 18 4 | + 7 28 2 | — 7 14 49 | 31 17 | +9464 |
| 6 | 204 45 51 | 204 36 21 | 11 38 | —39 | 49 52 | + 7 28 2 | — 7 14 49 | 63 5 | +9464 |
| 7 | 203 30 28 | 204 1 21 | 12 52 | —26 | 1 42 | + 7 24 31 | — 7 11 24 | 14 49 | +9533 |
| 8 | 204 15 3 | 204 9 3 | 13 3 | —20 | 24 32 | — 4 42 11 | + 4 35 26 | 17 47 | +7149 |
| 9 | 205 21 46 | 203 56 36 | 14 30 | —33 | 52 38 | — 4 42 11 | + 4 35 26 | 45 53 | +7149 |
| 10 | 204 41 33 | 205 2 20 | 13 7 | — 8 | 115 4 34 | — 4 54 37 | + 4 46 55 | 56 52 | +7689 |
| 11 | 204 3 57 | 205 29 54 | 14 13 | — 6 | 0 32 | — 4 59 5 | + 4 51 16 | 52 43 | +7889 |
| 12 | 204 49 18 | 204 22 36 | 15 35 | —11 | 114 51 32 | — 4 59 5 | + 4 51 16 | 43 43 | +7889 |
| 13 | 204 34 43 | 203 57 12 | 13 8 | —19 | 29 11 | — 4 59 5 | + 4 51 16 | 21 22 | +7889 |
| 15 | 204 54 37 | 205 7 44 | 12 13 | — 4 | 115 13 0 | —13 8 31 | +12 49 0 | 53 29 | —9045 |
| 16 | 204 58 47 | 204 47 40 | 10 58 | — 1 | 3 42 | —13 37 52 | +13 17 42 | 43 32 | —9677 |
| 17 | 206 5 42 | 205 55 25 | 11 10 | — 2 | 116 9 37 | —13 37 52 | +13 17 42 | 109 27 | —9677 |
| 18 | 204 39 30 | 204 36 40 | 11 3 | — 2 | 114 48 17 | —13 40 49 | +13 20 34 | 28 2 | —9715 |
| 19 | 204 55 18 | 204 58 48 | 11 22 | — 3 | 115 8 20 | —13 40 49 | +13 20 34 | 48 5 | —9715 |
| 20 | 205 11 40 | 205 39 0 | 12 38 | — 2 | 38 10 | —13 40 49 | +13 20 34 | 114 77 55 | —9715 |
| | | | Means | | 114 41 30 | | | 114 41 30 | |

## IV.—*The Parallax of 61[1] Cygni, deduced from the Rutherfurd Photographic Measures.*

By Herman S. Davis.

Read May 3d, 1897.

**32.** For the purpose of determining the parallax of *61[1] Cygni* the measures of both distance and position-angle have been used as recorded in the preceding catalogue of sixty-five stars. The method adopted for getting the parallax from the measures of distance is the same as has been used in previous investigations at this Observatory.* Briefly stated this consists of correcting the observed distances for refraction, aberration, errors of the scale, proper motion of 61[1] *Cygni*, etc. These distances so corrected may be obtained from Table V by taking the sums of the quantities in columns eight, nine and ten. These sums are printed in columns two and three of Table XVI.

**33.** Then particular pairs of comparison stars were so chosen that their components should be as nearly as possible equally distant from 61[1] *Cygni* and differing 180° in position-angle. Table XIV contains a catalogue of these stars with memorandum of some other observers who have used the same stars for determining the parallax of 61 *Cygni*.

In the equations of condition of Table XVII have been introduced an unknown $y$ varying with the time, as a correction of the assumed proper motion; and another unknown $x$, as the correction of the assumed mean of the distances. The coefficients of the parallax have been obtained as follows: Using the symbols of paragraph 14, the quantities of column eleven, Table V are

$$S_3 P_3 + S_4 P_4.$$

Denoting by primed letters all symbols belonging to the *less distant* of the two comparison stars of each pair, we have as the coefficient of the parallax

$$(S_3 P_3 + S_4 P_4) - (S_3' P_3 + S_4' P_4)$$

when the absolute term of the equations is the *difference* of the distance of the comparison stars from 61[1] *Cygni*, after these dif-

* *The Parallax of $\mu$ and $\theta$ Cassiopeiæ*, by Harold Jacoby.
*The Parallax of $\eta$ Cassiopeiæ*, by Herman S. Davis.

ferences have been corrected by their proportional part of the variation of distance. This variation is deduced from the deviation of the *sum* of the distances on the various plates from the mean of all the plates. See Table XVI, columns four to seven inclusive.

Equations of condition thus formed are in Table XVII. At the foot of each page of this table will be found the normal equations, the deduced values of the unknowns, with their probable errors and the probable error of one equation of unit weight.

Eight different stars combined in five pairs were used for the determination of the parallax by measures of distance.

**34.** Whereas heretofore only measures of distance were used for parallax, in the present research measures of angle have also been used. For it has been recently shown* in the case of eight stars among the *Pleiades* whose average distance is 2160″, ranging from 631″ to 3160″, that the displacement on the arc of a great circle by reason of the probable error of observation is but little larger in measures of angle than of distance. This research on the measures of 61[1] *Cygni* has shown in addition that, for the seven stars whose measurement of position-angle I have used, the probable error for one plate of unit weight is $\pm 0''.149$ in angle, whereas for the eight stars used in distance it is $\pm 0''.191$. The average distance of these stars is only 1956″, ranging from 1075″ to 2754″. This fully justifies the use of position-angle for parallax determination from the Rutherfurd photographic plates in the present and in future reductions.

**35.** In the use of measures of position-angle the seven stars were selected irrespective of distance but as equally distributed in angle as possible.

Several methods of reduction suggested themselves, but the following was adopted. The observed angles were corrected as described in paragraphs 16–21. The "reduced angles," obtained from adding together columns six and seven of Table VI and the "variation" of paragraph 21, are printed in Table XVIII.

If $x'$ and $y'$ be introduced for error of the adopted mean of the angles and of proper motion respectively, and the parallax coefficient

$$S_8 P_3 + S_9 P_4$$

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* *On the Permanence of the Rutherfurd Photographic Plates*, by Harold Jacoby. Page 282.

from column eight, Table VI, be used, the equations of condition can be formed as in Table XVIII. The solution of these equations is given at the bottom of each page; where also will be found the probable errors of the unknowns; likewise the probable error of one equation of unit weight expressed as change of position-angle and also as reduced to the arc of a great circle by aid of the

$$\text{"Factor"} = 28''.0124 \cdot \sigma \cdot \sin 1'' = [6.1329]\, \sigma$$

**36.** The values of parallax given by the measures of distance of the various pairs of stars are collected in the first part of Table XV, with their weights, $p$, deduced from the least-square solution, and the corresponding probable errors, $r_\pi$. As the stars 5 and 6 enter respectively into each of two pairs, the "combining weights" of those pairs, $(p)$, were used in computing the mean of the five determinations. The $(r_\pi)$ is the probable error of the parallax when $(p)$ is regarded as the weight. Hence

$$\text{Parallax} = +0''.3999 \pm 0''.0230.$$

In the second part of Table XV are given the values of parallax deduced from the measures of position-angle, with their probable errors $r_\pi$. Hence

$$\text{Parallax} = +0''.3326 \pm 0''.0189.$$

When these two values are combined with weights which are the reciprocals of the squares of their respective probable errors there results the

$$\text{Mean relative parallax of } 61^1\ \textit{Cygni} = +0''.360 \pm 0''.0146$$

TABLE XIV.—COMPARISON STARS.

| Comp. Star. No. | Approximate position referred to $61^1$ *Cygni*. Distance. | Angle. | Durchmusterung. Number. | Mag. | Remarks. |
|---|---|---|---|---|---|
| 64 | 3362″ | 69°.74 | 38°:4372 | 7.8 | |
| 6 | 2660 | 230.21 | 37:4159 | 7.5 | |
| 39 | 3185 | 13.29 | 38:4353 | 8.4 | |
| 5 | 2163 | 273.11 | 38:4325 | 6.0 | Johnson. |
| 53 | 2126 | 81.10 | 38:4362 | 7.8 | |
| 54 | 2165 | 78.27 | 38:4363 | 9.1 | |
| 48 | 1423 | 105.89 | 37:4189 | 7.9 | Johnson : [Pritchard] : Wilsing. |
| 14 | 971 | 296.79 | 38:4336 | 8.8 | [Pritchard]. |
| 37 | 1337 | 149.62 | 37:4180 | 7.7 | [Pritchard]. |
| 27 | 1075 | 177.26 | 37:4175 | 9.0 | Johnson : [Pritchard]. |
| 48 | 1423 | 105.89 | 37:4189 | 7.9 | |
| 43 | 1825 | 143.85 | 37:4185 | 9.0 | |
| 32 | 2156 | 172.68 | 37:4178 | 7.5 | |
| 23 | 2501 | 356.08 | 38:4341 | 8.2 | |
| 13 | 2754 | 341.41 | 38:4335 | 9.0 | |

TABLE XV.—RESULTS.

FROM MEASURES OF DISTANCE.

| Comp. Stars. | Relative Parallax of $61^1$ *Cygni* | Weights. $p$ | Weights. $(p)$ | Probable Error. $r_1$ | Probable Error. $r_\pi$ | Probable Error. $(r_\pi)$ | Relative Weights. $\frac{1}{(r_\pi)^2}$ |
|---|---|---|---|---|---|---|---|
| | $''$ | | | | $''$ | $''$ | |
| 64– 6 | +0.5211 | 26.2675 | 17.5117 | ±0.1641 | ±0.0373 | ±0.0457 | 479.3 |
| 39– 6 | +0.4497 | 19.8822 | 13.2548 | .2562 | .0429 | .0525 | 362.7 |
| 5–53 | +0.3733 | 22.8220 | 15.2147 | ± .2020 | ±0.0400 | ±0.0490 | 416.3 |
| 54– 5 | +0.2431 | 21.8784 | 14.5856 | .1576 | .0409 | .0500 | 399.2 |
| 48–14 | +0.3888 | 8.4314 | 8.4314 | ± .1840 | ±0.0658 | ±0.0658 | 230.7 |
| **Results** | + **0.3999** | | 68.9982 | ±0.1912 | ± **0.0230** | | **1888.2** |

FROM MEASURES OF POSITION-ANGLE.

| Comp. Stars. | Relative Parallax of $61^1$ *Cygni* | Weights. $p$ | Weights. $\sigma^2$ | Probable Error. $(r_1)$ | Probable Error. $r_1$ | Probable Error. $r_\pi$ | Relative Weight. $\frac{1}{r_\pi^2}$ |
|---|---|---|---|---|---|---|---|
| | $''$ | | | $''$ | $''$ | $''$ | |
| 37 | +0.3028 | 196 129.40 | 2278. | ±15.70 | ±0.1018 | ±0.0354 | 796.9 |
| 27 | +0.3779 | 157 834.62 | 1471. | 29.27 | .1525 | .0395 | 641.2 |
| 48 | +0.2794 | 110 142.84 | 2580. | 25.49 | .1758 | .0473 | 447.5 |
| 43 | +0.3299 | 79 259.74 | 4245. | 18.52 | .1638 | .0557 | 322.0 |
| 32 | +0.3442 | 63 960.30 | 5921. | 12.37 | .1293 | .0620 | 259.9 |
| 23 | +0.3334 | 44 572.46 | 7968. | 12.33 | .1496 | .0743 | 181.0 |
| 13 | +0.4401 | 36 689.52 | 9667. | ±12.32 | ±0.1646 | ±0.0819 | 149.0 |
| **Results** | + **0.3326** | 688 588.88 | | | ±0.1488 | ± **0.0189** | **2797.5** |

TABLE XVI.—OBSERVATIONAL DATA.

COMPARISON STARS 64 AND 6.

| Plate No. | Corrected Distance. | | Sum of Distances | Mean *minus* Sum | Difference of Distances | Scale Corr. | Corrected Difference |
|---|---|---|---|---|---|---|---|
| | Star 64 | Star 6 | | | | | |
| 1 | 120.0484 | 94.9562 | 215.0046 | —.0152 | 25.0922 | —.0018 | 25.0904 |
| 2 | .0593 | .9648 | .0241 | —.0347 | .0945 | —.0041 | .0904 |
| 3 | .0361 | .9600 | 214.9961 | —.0067 | .0761 | —.0008 | .0753 |
| 4 | .0406 | .9519 | .9925 | —.0031 | .0887 | —.0004 | .0883 |
| 5 | .0495 | .9559 | 215.0054 | —.0160 | .0936 | —.0019 | .0917 |
| 6 | .0321 | .9487 | 214.9808 | +.0086 | .0834 | +.0010 | .0844 |
| 7 | .0632 | .9609 | 215.0241 | —.0347 | .1023 | —.0041 | .0982 |
| 8 | | | | | | | |
| 9 | .0305 | .9480 | 214.9785 | +.0109 | .0825 | +.0013 | .0838 |
| 10 | .0351 | .9526 | .9877 | +.0017 | .0825 | +.0002 | .0827 |
| 11 | .0430 | .9487 | .9917 | —.0023 | .0943 | —.0003 | .0940 |
| 12 | .0439 | .9499 | .9938 | —.0044 | .0940 | —.0005 | .0935 |
| 13 | .0425 | .9357 | .9782 | +.0112 | .1068 | +.0013 | .1081 |
| 15 | 119.9999 | .9668 | .9667 | +.0227 | .0331 | +.0027 | .0358 |
| 16 | | | | | | | |
| 17 | .9914 | .9781 | .9695 | +.0199 | .0133 | +.0023 | .0156 |
| 18 | | | | | | | |
| 19 | .9998 | .9805 | .9803 | +.0091 | .0193 | +.0011 | .0204 |
| 20 | .9832 | .9701 | .9533 | +.0361 | .0131 | +.0042 | .0173 |
| | Adopted mean, 214.9894 | | | | Assumed value, 25.0730 | | |

## Table XVII.—Parallax Equations.

### Comparison Stars 64 and 6.

| Plate. | | | | | Residuals. Scale. | Arc. |
|---|---|---|---|---|---|---|
| 1 | 1.00$x$ | —1.14$y$ | —1.84Π | +1.74 = 0 | +0.46 | +0″.13 |
| 2 | 1.00 | —1.13 | —1.87 | +1.74 = 0 | +0.39 | + .11 |
| 3 | 1.00 | —1.13 | —1.87 | +0.23 = 0 | —1.12 | — .31 |
| 4 | 1.00 | —0.08 | —1.94 | +1.53 = 0 | —0.23 | — .06 |
| 5 | 1.00 | —0.04 | —1.85 | +1.87 = 0 | +0.27 | + .08 |
| 6 | 1.00 | —0.04 | —1.85 | +1.14 = 0 | —0.46 | — .13 |
| 7 | 1.00 | —0.04 | —1.83 | +2.52 = 0 | +0.96 | + .27 |
| 9 | 1.00 | +0.88 | —1.90 | +1.08 = 0 | —0.86 | — .24 |
| 10 | 1.00 | +0.89 | —1.93 | +0.97 = 0 | —1.03 | — .29 |
| 11 | 1.00 | +0.90 | —1.93 | +2.10 = 0 | +0.10 | + .03 |
| 12 | 1.00 | +0.90 | —1.93 | +2.05 = 0 | +0.05 | + .01 |
| 13 | 1.00 | +0.90 | —1.93 | +3.51 = 0 | +1.51 | + .42 |
| 15 | 1.00 | +1.42 | +1.99 | —3.72 = 0 | +1.42 | + .40 |
| 17 | 1.00 | +1.45 | +1.94 | —5.74 = 0 | —0.69 | — .19 |
| 19 | 1.00 | +1.45 | +1.93 | —5.26 = 0 | —0.23 | — .06 |
| 20 | 1.00 | +1.45 | +1.93 | —5.57 = 0 | —0.54 | — .15 |
| | | | | | $[vv] = 9.81$ | |

### Normal Equations.

$$+16.0000x + 6.6400y - 14.8800\Pi + 0.1900 = 0$$
$$+16.1850 + 9.3353 - 25.1545 = 0$$
$$+58.0200 - 78.1820 = 0$$

### Solution.

| In units of 2d dec. place of scale. | In Arc. |
|---|---|
| $\Pi = +1.8602 \pm 0.1143$ | $\Pi = +0''.5211 \pm 0''.0320$ |
| $y = -0.2695 \pm 0.2073$ | $y = -0\ .0755 \pm 0\ .0581$ |
| $x = +1.8299 \pm 0.2276$ | $x = +0\ .5126 \pm 0\ .0638$ |

Probable error of one equation = (Scale) $\pm 0''.5859$ = (Arc.) $\pm 0''.1641$

TABLE XVI.—OBSERVATIONAL DATA.

COMPARISON STARS 39 AND 6.

| Plate No. | Corrected Distance. | | Sum of Distances | Mean *minus* Sum | Difference of Distances | Scale Corr. | Corrected Difference |
|---|---|---|---|---|---|---|---|
| | Star 39 | Star 6 | | | | | |
| 1 | 113.7446 | 94.9562 | 208.7008 | —.0261 | 18.7884 | —.0023 | 18.7861 |
| 2 | .7430 | .9648 | .7078 | —.0331 | .7782 | —.0030 | .7752 |
| 3 | .7364 | .9600 | .6964 | —.0217 | .7764 | —.0020 | .7744 |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | .7575 | .9487 | .7062 | —.0315 | .8088 | —.0028 | .8060 |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | .7218 | .9480 | .6698 | +.0049 | .7738 | +.0004 | .7742 |
| 10 | .7204 | .9526 | .6730 | +.0017 | .7678 | +.0002 | .7680 |
| 11 | .7166 | .9487 | .6653 | +.0094 | .7679 | +.0008 | .7687 |
| 12 | | | | | | | |
| 13 | .7230 | .9357 | .6587 | +.0160 | .7873 | +.0014 | .7887 |
| 15 | .7000 | .9668 | .6668 | +.0079 | .7332 | +.0007 | .7339 |
| 16 | .6976 | .9552 | .6528 | +.0219 | .7424 | +.0020 | .7444 |
| 17 | .6843 | .9781 | .6624 | +.0123 | .7062 | +.0011 | .7073 |
| 18 | .6968 | .9650 | .6618 | +.0129 | .7318 | +.0012 | .7330 |
| 19 | .6970 | .9805 | .6775 | —.0028 | .7165 | —.0003 | .7162 |
| 20 | .6766 | .9701 | .6467 | +.0280 | .7065 | +.0025 | .7090 |

Adopted mean, 208.6747 Assumed value, 18.7560

## TABLE XVII.—PARALLAX EQUATIONS.

### COMPARISON STARS 39 AND 6

| Plate. | | | | | Residuals Scale. | Residuals Arc. |
|---|---|---|---|---|---|---|
| 1 | 1.00$x$ | —1.14$y$ | —1.30Π | +3.01 = 0 | +0.52 | +″.15 |
| 2 | 1.00 | —1.13 | —1.37 | +1.92 = 0 | —0.68 | — .19 |
| 3 | 1.00 | —1.13 | —1.37 | +1.84 = 0 | —0.76 | — .21 |
| 6 | 1.00 | —0.04 | —1.76 | +5.00 = 0 | +2.10 | + .59 |
| 9 | 1.00 | +0.88 | —1.43 | +1.82 = 0 | —0.29 | — .08 |
| 10 | 1.00 | +0.89 | —1.52 | +1.20 = 0 | —1.05 | — .29 |
| 11 | 1.00 | +0.90 | —1.55 | +1.27 0 | —1.03 | — .29 |
| 13 | 1.00 | +0.90 | —1.55 | +3.27 = 0 | +0.97 | + .27 |
| 15 | 1.00 | +1.42 | +1.73 | —2.21 = 0 | +0.92 | + .26 |
| 16 | 1.00 | +1.45 | +1.81 | —1.16 = 0 | +2.09 | + .59 |
| 17 | 1.00 | +1.45 | +1.81 | —4.87 = 0 | —1.61 | — .45 |
| 18 | 1.00 | +1.45 | +1.81 | —2.30 = 0 | +0.96 | + .27 |
| 19 | 1.00 | +1.45 | +1.81 | —3.98 = 0 | —0.72 | — .20 |
| 20 | 1.00 | +1.45 | +1.81 | —4.70 = 0 | —1.44 | — .40 |

$[vv] = 20.23$

### Normal Equations.

$$+14.0000x + 8.8000y - 1.0700\Pi + 0.1100 = 0$$
$$+19.5704 \quad +14.8265 \quad -28.9273 = 0$$
$$+37.0751 \quad -63.9392 = 0$$

### Solution.

| In units of 2d dec. place of scale. | In Arc. |
|---|---|
| $\Pi = +1.6054 \pm 0.2051$ | $\Pi = +0''.4497 \pm 0''.0575$ |
| $y = +0.2941 \pm 0.3330$ | $y = +0\ .0821 \pm 0\ .0933$ |
| $x = -0.0694 \pm 0.3291$ | $x = -0\ .0194 \pm 0\ .0922$ |

| | Scale. | Arc. |
|---|---|---|
| Probable error of one equation | $= \pm 0.9145$ | $= \pm 0''.2562$ |

TABLE XVI.—OBSERVATIONAL DATA.

COMPARISON STARS 5 AND 53.

| Plate No. | Corrected Distance. | | Sum of Distances | Mean *minus* Sum | Difference of Distances | Scale Corr. | Corrected Difference |
|---|---|---|---|---|---|---|---|
| | Star 5 | Star 53 | | | | | |
| 1 | 77.2195 | 75.9023 | 153.1218 | —.0225 | 1.3172 | —.0002 | 1.3170 |
| 2 | .2144 | .9034 | .1178 | —.0185 | .3110 | —.0002 | .3108 |
| 3 | .2131 | .8892 | .1023 | —.0030 | .3239 | —.0000 | .3239 |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | .2135 | .8975 | .1110 | —.0117 | .3160 | —.0001 | .3159 |
| 7 | .2180 | .9198 | .1378 | —.0385 | .2982 | —.0003 | .2979 |
| 8 | | | | | | | |
| 9 | .2093 | .8921 | .1014 | —.0021 | .3172 | —.0000 | .3172 |
| 10 | .2058 | .8913 | .0971 | +.0022 | .3145 | +.0000 | .3145 |
| 11 | .2092 | .8894 | .0986 | +.0007 | .3198 | +.0000 | .3198 |
| 12 | .2103 | .8845 | .0948 | +.0045 | .3258 | +.0000 | .3258 |
| 13 | .2093 | .8958 | .1051 | —.0058 | .3135 | —.0001 | .3134 |
| 15 | .2244 | .8536 | .0780 | +.0213 | .3708 | +.0002 | .3710 |
| 16 | .2169 | .8650 | .0819 | +.0174 | .3519 | +.0002 | .3521 |
| 17 | .2201 | .8707 | .0908 | +.0085 | .3494 | +.0001 | .3495 |
| 18 | .2254 | .8513 | .0767 | +.0226 | .3741 | +.0002 | .3743 |
| 19 | .2317 | .8559 | .0876 | +.0117 | .3758 | +.0001 | .3759 |
| 20 | .2199 | .8646 | .0845 | +.0148 | .3553 | +.0001 | .3554 |

Adopted mean, 153.0993 Assumed value, 1.3330

## Table XVII.—Parallax Equations.

### Comparison Stars 5 and 53.

| Plate. | | | | | Residuals. Scale. | Arc. |
|---|---|---|---|---|---|---|
| 1 | 1.00$x$ | —1.14$y$ | +1.90$\Pi$ | —1.60 = 0 | +0.41 | +0″.11 |
| 2 | 1.00 | —1.13 | +1.90 | —2.22 = 0 | —0.21 | — .06 |
| 3 | 1.00 | —1.13 | +1.90 | —0.91 = 0 | +1.10 | + .31 |
| 6 | 1.00 | —0.04 | +1.47 | —1.71 = 0 | —0.41 | — .11 |
| 7 | 1.00 | —0.04 | +1.42 | —3.51 = 0 | —2.28 | — .64 |
| 9 | 1.00 | +0.88 | +1.88 | —1.58 = 0 | +0.16 | + .04 |
| 10 | 1.00 | +0.89 | +1.85 | —1.85 = 0 | —0.15 | — .04 |
| 11 | 1.00 | +0.90 | +1.83 | —1.32 = 0 | +0.35 | + .10 |
| 12 | 1.00 | +0.90 | +1.83 | —0.72 = 0 | +0.95 | + .27 |
| 13 | 1.00 | +0.90 | +1.83 | —1.96 = 0 | —0.29 | — .08 |
| 15 | 1.00 | +1.42 | —1.75 | +3.80 = 0 | +0.64 | + .18 |
| 16 | 1.00 | +1.45 | —1.57 | +1.91 = 0 | —1.02 | — .29 |
| 17 | 1.00 | +1.45 | —1.57 | +1.65 = 0 | —1.28 | — .36 |
| 18 | 1.00 | +1.45 | —1.55 | +4.13 = 0 | +1.22 | + .34 |
| 19 | 1.00 | +1.45 | —1.55 | +4.29 = 0 | +1.38 | + .39 |
| 20 | 1.00 | +1.45 | —1.55 | +2.24 = 0 | —0.67 | — .19 |
| | | | | | $[vv]$ = 14.87 | |

### Normal Equations.

$$+16.0000x + 9.6600y + 8.2700\Pi + 0.6400 = 0$$
$$+20.3820 - 12.1142 + 24.9478 = 0$$
$$+47.2107 - 58.9600 = 0$$

### Solution.

| In units of 2d dec. place of scale. | In Arc. |
|---|---|
| $\Pi = +1.3326 \pm 0.1510$ | $\Pi = +0''.3733 \pm 0''.0423$ |
| $y = -0.1213 \pm 0.2593$ | $y = -0\ .0340 \pm 0\ .0726$ |
| $x = -0.6556 \pm 0.2826$ | $x = -0\ .1836 \pm 0\ .0792$ |

Probable error of one equation = (Scale) $\pm 0.7211$ = (Arc) $\pm 0''.2020$

## Table XVI.—Observational Data.

### Companion Stars 54 and 5.

| Plate No. | Corrected Distance | | Sum of Distances | Mean *minus* Sum | Difference of Distances | Scale Corr. | Corrected Difference |
|---|---|---|---|---|---|---|---|
| | Star 54 | Star 5 | | | | | |
| 1 | 77.3081 | 77.2195 | 154.5276 | —.0383 | 0.0886 | 0 | 0.0886 |
| 2 | .3106 | .2144 | .5250 | —.0357 | .0962 | 0 | .0962 |
| 3 | .2969 | .2131 | .5100 | —.0207 | .0838 | 0 | .0838 |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | .2808 | .2093 | .4901 | —.0008 | .0715 | 0 | .0715 |
| 10 | .2803 | .2058 | .4861 | +.0032 | .0745 | 0 | .0745 |
| 11 | .2740 | .2092 | .4832 | +.0061 | .0648 | 0 | .0648 |
| 12 | .2661 | .2103 | .4764 | +.0129 | .0558 | 0 | .0558 |
| 13 | .2799 | .2093 | .4892 | +.0001 | .0706 | 0 | .0706 |
| 15 | .2449 | .2244 | .4693 | +.0200 | .0205 | 0 | .0205 |
| 16 | .2605 | .2169 | .4774 | +.0119 | .0436 | 0 | .0436 |
| 17 | .2620 | .2201 | .4821 | +.0072 | .0419 | 0 | .0419 |
| 18 | .2507 | .2254 | .4761 | +.0132 | .0253 | 0 | .0253 |
| 19 | | | | | | | |
| 20 | .2474 | .2199 | .4673 | +.0220 | .0275 | 0 | 0.0275 |

Adopted mean, 154.4893 — Assumed value, 0.0590

## TABLE XVII.—PARALLAX EQUATIONS.

### COMPARISON STARS 54 AND 5.

| Plate. | | | | | Residuals. Scale. | Arc. |
|---|---|---|---|---|---|---|
| 1 | 1.00$x$ | —1.14$y$ | —1.91Π | +2.96 = 0 | —0.10 | —0″.03 |
| 2 | 1.00 | —1.13 | —1.90 | +3.72 = 0 | +0.68 | + .19 |
| 3 | 1.00 | —1.13 | —1.90 | +2.48 = 0 | —0.56 | — .16 |
| 9 | 1.00 | +0.88 | —1.89 | +1.25 = 0 | +0.34 | + .10 |
| 10 | 1.00 | +0.89 | —1.86 | +1.55 = 0 | +0.68 | + .19 |
| 11 | 1.00 | +0.90 | —1.84 | +0.58 = 0 | —0.27 | — .08 |
| 12 | 1.00 | +0.90 | —1.84 | —0.32 = 0 | —1.17 | — .33 |
| 13 | 1.00 | +0.90 | —1.84 | +1.16 = 0 | +0.31 | + .09 |
| 15 | 1.00 | +1.42 | +1.77 | —3.85 = 0 | —1.01 | — .28 |
| 16 | 1.00 | +1.45 | +1.59 | —1.54 = 0 | +1.17 | + .33 |
| 17 | 1.00 | +1.45 | +1.59 | —1.71 = 0 | +1.00 | + .28 |
| 18 | 1.00 | +1.45 | +1.57 | —3.37 = 0 | —0.68 | — .19 |
| 20 | 1.00 | +1.45 | +1.57 | —3.15 = 0 | —0.46 | — .13 |
| | | | | | [$vv$] = 6.96 | |

### Normal Equations.

$$+13.0000x + 8.2900y - 6.8900\Pi - 0.2400 = 0$$
$$+18.2763 + 9.8622 - 26.2564 = 0$$
$$+41.1755 - 47.5103 = 0$$

### Solution.

| In units of 2d dec. place of scale. | In Arc. |
|---|---|
| Π = +0.8680 ±0.1203 | Π = +0″.2431 ±0″.0337 |
| $y$ = +1.0570 ±0.2044 | $y$ = +0 .2961 ±0 .0573 |
| $x$ = —0.1955 ±0.2369 | $x$ = —0 .0548 ±0 .0664 |

Probable error of one equation = ±0.5626 (Scale) = ±0″.1576 (Arc).

## Table XVI.—Observational Data.

### Comparison Stars 48 and 14.

| Plate No. | Corrected Distance | | Sum of Distances | Mean *minus* Sum | Difference of Distances | Scale Corr. | Corrected Difference |
|---|---|---|---|---|---|---|---|
| | Star 48 | Star 14 | | | | | |
| 1 | | | | | | | |
| 2 | 50.8127 | 34.6771 | 85.4898 | —.0210 | 16.1356 | —.0039 | 16.1317 |
| 3 | .8164 | .6853 | .5017 | —.0329 | .1311 | —.0062 | .1249 |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | .7984 | .6690 | .4674 | +.0014 | .1294 | +.0003 | .1297 |
| 11 | .7972 | .6765 | .4737 | —.0049 | .1207 | —.0009 | .1198 |
| 12 | .7955 | .6742 | .4697 | —.0009 | .1213 | —.0002 | .1211 |
| 13 | .7971 | .6601 | .4572 | +.0116 | .1370 | +.0022 | .1392 |
| 15 | .7785 | .6805 | .4590 | +.0098 | .0980 | +.0018 | .0998 |
| 16 | .7762 | .6744 | .4506 | +.0182 | .1018 | +.0034 | .1052 |
| 17 | | | | | | | |
| 18 | .7742 | .6928 | .4670 | +.0018 | .0814 | +.0003 | .0817 |
| 19 | .7680 | .6859 | .4539 | +.0149 | .0821 | +.0028 | .0849 |
| 20 | .7829 | .6834 | .4663 | +.0025 | .0995 | +.0005 | .1000 |
| | Adopted mean, 85.4688 | | | | Assumed value, 16.1130 | | |

## TABLE XVII.—PARALLAX EQUATIONS.

### COMPARISON STARS 48 AND 14.

| Plate. | | | | | Residuals. Scale. | Residuals. Arc. |
|---|---|---|---|---|---|---|
| 2 | 1.00$x$ | —1.13$y$ | —1.55$\Pi$ | +1.87 = 0 | +0.32 | +0″.09 |
| 3 | 1.00 | —1.13 | —1.55 | +1.19 = 0 | —0.36 | — .10 |
| 10 | 1.00 | +0.89 | —1.42 | +1.67 = 0 | +0.23 | + .06 |
| 11 | 1.00 | +0.90 | —1.38 | +0.68 = 0 | —0.71 | — .20 |
| 12 | 1.00 | +0.90 | —1.38 | +0.81 = 0 | —0.58 | — .16 |
| 13 | 1.00 | +0.90 | —1.38 | +2.62 = 0 | +1.23 | + .34 |
| 15 | 1.00 | +1.42 | +1.19 | —1.32 = 0 | +0.84 | + .24 |
| 16 | 1.00 | +1.45 | +0.93 | —0.78 = 0 | +1.02 | + .29 |
| 18 | 1.00 | +1.45 | +0.90 | —3.13 = 0 | —1.37 | — .38 |
| 19 | 1.00 | +1.45 | +0.90 | —2.81 = 0 | —1.05 | — .30 |
| 20 | 1.00 | +1.45 | +0.90 | —1.30 = 0 | +0.46 | + .13 |
| | | | | | $[vv] = 7.58$ | |

Normal Equations.

$$+11.0000x + 8.5500y - 3.8400\Pi - 0.5000 = 0$$
$$+16.2023 \quad + 5.4665 \quad -11.7759 = 0$$
$$+17.2456 \quad -21.5984 = 0$$

Solution.

| In units of 2d dec. place of scale. | In Arc. |
|---|---|
| $\Pi = +1.3880 \pm 0.2261$ | $\Pi = +0''.3888 \pm 0''.0634$ |
| $y = -0.0359 \pm 0.2918$ | $y = -0\ .0101 \pm 0\ .0818$ |
| $x = +0.5579 \pm 0.3485$ | $x = +0\ .1563 \pm 0\ .0976$ |

| | Scale. | Arc. |
|---|---|---|
| Probable error of one equation | $\pm 0.6568 =$ | $\pm 0''.1840$ |

## TABLE XVIII.—PARALLAX EQUATIONS.

### POSITION-ANGLE. STAR 37.

| Plate. | Reduced Angle. | | | | | Residuals in arc of great circle. |
|---|---|---|---|---|---|---|
| 2 | 149°35′56″ | 1.00$x'$ | —1.13$y'$ | +146.Π | —54″ = 0 | —″.11 |
| 3 | 36 28 | 1.00 | —1.13 | +146. | —22 = 0 | + .10 |
| 4 | 35 37 | 1.00 | —0.08 | +152. | —73 = 0 | — .25 |
| 5 | 36 10 | 1.00 | —0.04 | +145. | —40 = 0 | — .05 |
| 6 | 36 55 | 1.00 | —0.04 | +145. | + 5 = 0 | + .24 |
| 7 | 36 28 | 1.00 | —0.04 | +143. | —22 = 0 | + .07 |
| 8 | 36 53 | 1.00 | +0.88 | +148. | + 3 = 0 | + .21 |
| 9 | 36 28 | 1.00 | +0.88 | +148. | —22 = 0 | + .05 |
| 10 | 36 19 | 1.00 | +0.89 | +151. | —31 = 0 | — .00 |
| 11 | 36 22 | 1.00 | +0.90 | +151. | —28 = 0 | + .02 |
| 12 | 36 3 | 1.00 | +0.90 | +151. | —47 = 0 | — .10 |
| 13 | 35 52 | 1.00 | +0.90 | +151. | —58 = 0 | — .18 |
| 15 | 38 5 | 1.00 | +1.42 | —156. | +75 = 0 | + .07 |
| 16 | 37 38 | 1.00 | +1.45 | —152. | +48 = 0 | — .10 |
| 17 | 38 18 | 1.00 | +1.45 | —152. | +88 = 0 | + .16 |
| 18 | 37 16 | 1.00 | +1.45 | —151. | +26 = 0 | — .24 |
| 19 | 37 58 | 1.00 | +1.45 | —151. | +68 = 0 | + .03 |
| 20 | 38 2 | 1.00 | +1.45 | —151. | +72 = 0 | + .06 |

149 36 50 = Adopted Mean.

Normal Equations.

$$+18.00x' + 11.56y' + 864.00\Pi - 12.00 = 0$$
$$+19.86 - 876.04 + 474.39 = 0$$
$$+402194.00 - 115427.00 = 0$$

Solution.

| | | |
|---|---|---|
| $\Pi = + 0''.3028 \pm 0''.0355$ | $[vv]$ | $= 8127.$ |
| $y' = - 3\ .9189 \pm 6\ .039$ | $\sigma$ | $= 1336''.94$ |
| $x' = - 11\ .3531 \pm 6\ .368$ | Factor | $= .00648$ |

In Angle. Arc of great circle.

Probable error of one equation $= \pm 15''.70 = \pm 0''.1018$

## TABLE XVIII.—PARALLAX EQUATIONS.

### POSITION-ANGLE. STAR 27.

| Plate. | Reduced Angle. | | | | | Residuals in arc of great circle. |
|---|---|---|---|---|---|---|
| 2 | 177° 14′ 9″ | 1.00$x'$ | —1.13$y'$ | +183.Π | — 59.″=0 | +″.03 |
| 3 | 13 57 | 1.00 | —1.13 | +183. | — 71. =0 | — .03 |
| 10 | 14 59 | 1.00 | +0.89 | +178. | — 9. =0 | + .21 |
| 11 | 15 3 | 1.00 | +0.90 | +176. | — 5. =0 | + .23 |
| 12 | 14 10 | 1.00 | +0.90 | +176. | — 58. =0 | — .05 |
| 13 | 13 4 | 1.00 | +0.90 | +176. | —124. =0 | — .39 |
| 15 | 16 11 | 1.00 | +1.42 | —169. | + 63. =0 | — .12 |
| 16 | 16 11 | 1.00 | +1.45 | —151. | + 63. =0 | — .08 |
| 18 | 17 20 | 1.00 | +1.45 | —149. | +132. =0 | + .28 |
| 20 | 16 14 | 1.00 | +1.45 | —149. | + 66. =0 | — .07 |

177 15 8.0 = Adopted Mean.

#### Normal Equations.

$$+10.00x' + 7.10y' + 454.00\Pi - 2.00 = 0$$
$$+14.10 - 670.99 + 438.50 = 0$$
$$+287354.00 - 107966.00 = 0$$

#### Solution.

| | | |
|---|---|---|
| $\Pi = +\,0''.3797 \pm 0''.0737$ | $[vv]$ | $= 13187.$ |
| $y' = -\,7\ .1257 \pm 12\ .65$ | $\sigma$ | $= 1074''.60$ |
| $x' = -11\ .8966 \pm 14\ .69$ | Factor | $= .00521$ |

In Angle. Arc of great circle.

Probable error of one equation $= \pm 29''.27 = \pm 0''.1525$

## Table XVIII.—Parallax Equations.

### Position-Angle. Star 48.

| Plate. | Reduced Angle. | | | | | Residuals in arc of great circle. |
|---|---|---|---|---|---|---|
| 1 | 105°52′58″ | 1.00$x'$ | —1.14$y'$ | + 68.Π | — 3″ = .0 | +″.03 |
| 2 | 52 0 | 1.00 | —1.13 | + 74. | —61 = .0 | — .35 |
| 3 | 53 23 | 1.00 | —1.13 | + 74. | +22 = .0 | + .22 |
| 4 | 51 32 | 1.00 | —0.08 | +102. | —89 = .0 | — .48 |
| 5 | 53 43 | 1.00 | —0.04 | +119. | +42 = .0 | + .46 |
| 6 | 53 9 | 1.00 | —0.04 | +119. | + 8 = .0 | + .22 |
| 7 | 52 48 | 1.00 | —0.04 | +121. | —13 = .0 | + .08 |
| 8 | 52 55 | 1.00 | +0.88 | + 80. | — 6 = .0 | + .06 |
| 9 | 53 3 | 1.00 | +0.88 | + 80. | + 2 = .0 | + .12 |
| 10 | 52 19 | 1.00 | +0.89 | + 89. | —42 = .0 | — .16 |
| 11 | 52 42 | 1.00 | +0.90 | + 92. | —19 = .0 | — .00 |
| 12 | 52 36 | 1.00 | +0.90 | + 92. | —25 = .0 | — .04 |
| 13 | 52 8 | 1.00 | +0.90 | + 92. | —53 = .0 | — .24 |
| 15 | 53 38 | 1.00 | +1.42 | —110. | +37 = .0 | + .00 |
| 16 | 54 4 | 1.00 | +1.45 | —121. | +63 = .0 | + .16 |
| 17 | 54 12 | 1.00 | +1.45 | —121. | +71 = .0 | + .22 |
| 18 | 52 32 | 1.00 | +1.45 | —122. | —29 = .0 | — .47 |
| 19 | 53 55 | 1.00 | +1.45 | —122. | +54 = .0 | + .10 |
| 20 | 53 51 | 1.00 | +1.45 | —122. | +50 = .0 | + .07 |

105 53 1.0 = Adopted Mean.

Normal Equations.

$$+19.00x' + 10.42y' + 484.00\Pi + 9.00 = 0$$
$$+21.16 - 836.67 + 280.52 = 0$$
$$+201090.00 - 50207.00 = 0$$

Solution.

$\Pi = +0''.2794 \pm 0''.0766$ $\quad [vv] = 22847.$

$y' = +2\ .0965 \pm 8\ .487$ $\quad \sigma = 1422''.69$

$x' = -8\ .7418 \pm 8\ .453$ $\quad$ Factor = .00690

| | In Angle. | Arc of great circle. |
|---|---|---|
| Probable error of one equation | = ±25″.49 | = ±0″.1758 |

## Table XVIII.—Parallax Equations.

### Position-Angle. Star 43.

| Plate. | Reduced Angle. | | | | | Residuals in arc of great circle. |
|---|---|---|---|---|---|---|
| 1 | 143°50′ 1″ | $1.00x'$ | $-1.14y'$ | $+101.\Pi$ | $-48.''=0$ | $-''.01$ |
| 2 | 49 42 | 1.00 | $-1.13$ | $+104.$ | $-67. = 0$ | $-$ .17 |
| 3 | 50 22 | 1.00 | $-1.13$ | $+104.$ | $-27. = 0$ | $+$ .18 |
| 10 | 50 28 | 1.00 | $+0.89$ | $+108.$ | $-21. = 0$ | $+$ .07 |
| 11 | 50 19 | 1.00 | $+0.90$ | $+109.$ | $-30. = 0$ | $-$ .01 |
| 12 | 50 16 | 1.00 | $+0.90$ | $+109.$ | $-33. = 0$ | $-$ .03 |
| 13 | 50 17 | 1.00 | $+0.90$ | $+109.$ | $-32. = 0$ | $-$ .02 |
| 15 | 52 5 | 1.00 | $+1.42$ | $-114.$ | $+76. = 0$ | $+$ .23 |
| 16 | 51 23 | 1.00 | $+1.45$ | $-113.$ | $+34. = 0$ | $-$ .14 |
| 18 | 51 43 | 1.00 | $+1.45$ | $-112.$ | $+54. = 0$ | $+$ .04 |
| 19 | 52 19 | 1.00 | $+1.45$ | $-112.$ | $+90. = 0$ | $+$ .36 |
| 20 | 50 41 | 1.00 | $+1.45$ | $-112.$ | $-8. = 0$ | $-$ .51 |

143 50 49.0 = Adopted Mean.

Normal Equations.

$$+12.00x' + 7.41y' + 181.00\Pi - 12.00 = 0$$
$$+17.50 - 772.69 + 411.17 = 0$$
$$+142537.00 - 54985.00 = 0$$

Solution.

$\Pi = +0''.3299 \pm 0''.0658$ $\quad [vv] = 6788.$

$y' = -9\ .8126 \pm 6\ .845$ $\quad \sigma = 1824''.90$

$x' = +2\ .0830 \pm 7\ .280$ $\quad$ Factor = .00885

In Angle. Arc of great circle.

Probable error of one equation $= \pm 18''.52 = \pm 0''.1638$

## TABLE XVIII.—PARALLAX EQUATIONS.

### POSITION-ANGLE. STAR 32.

| Plate. | Reduced Angle. | | | | | Residuals in arc of great circle. |
|---|---|---|---|---|---|---|
| 1 | 172°39′49″ | 1.00$x'$ | —1.14$y'$ | +93.Π | —30.″=0 | +0″.08 |
| 2 | 39 51 | 1.00 | —1.13 | +93. | —28. =0 | + .10 |
| 3 | 39 55 | 1.00 | —1.13 | +93. | —24. =0 | + .14 |
| 4 | 39 12 | 1.00 | —0.08 | +87. | —67. =0 | — .43 |
| 5 | 39 41 | 1.00 | —0.04 | +75. | —38. =0 | — .18 |
| 6 | 39 51 | 1.00 | —0.04 | +75. | —28. =0 | — .07 |
| 7 | 40 2 | 1.00 | —0.04 | +73. | —17. =0 | + .03 |
| 8 | 40 11 | 1.00 | +0.88 | +92. | — 8. =0 | + .10 |
| 9 | 40 1 | 1.00 | +0.88 | +92. | —18. =0 | — .00 |
| 10 | 39 59 | 1.00 | +0.89 | +91. | —20. =0 | — .03 |
| 11 | 40 5 | 1.00 | +0.90 | +90. | —14. =0 | + .03 |
| 12 | 40 18 | 1.00 | +0.90 | +90. | — 1. =0 | + .17 |
| 13 | 40 4 | 1.00 | +0.90 | +90. | —15. =0 | + .02 |
| 15 | 41 6 | 1.00 | +1.42 | —88. | +47. =0 | — .02 |
| 16 | 40 47 | 1.00 | +1.45 | —80. | +28. =0 | — .19 |
| 17 | 41 17 | 1.00 | +1.45 | —80. | +58. =0 | + .12 |
| 18 | 41 36 | 1.00 | +1.45 | —79. | +77. =0 | + .32 |
| 19 | 41 19 | 1.00 | +1.45 | —79. | +60. =0 | + .14 |
| 20 | 40 34 | 1.00 | +1.45 | —79. | +15. =0 | — .33 |

172°40 19.0 = Adopted Mean.

Normal Equations.

$$+19.00x' + 10.42y' + 649.00\Pi - 23.00 = 0$$
$$+21.16 \quad - \quad 546.78 \quad + \quad 445.80 = 0$$
$$+138871.00 \quad - 49582.00 = 0$$

Solution.

$\Pi = +0''.3442 \pm 0''.0489$ $\quad [vv] = 5382.$

$y' = -9\ .5621 \pm 4\ .251$ $\quad \sigma = 2155.''55$

$x' = -5\ .3013 \pm 4\ .638$ $\quad$ Factor = .01045

| | In Angle. | Arc of great circle. |
|---|---|---|
| Probable error of one equation | = ±12.″37 | = ±0.″1293 |

## TABLE XVIII.—PARALLAX EQUATIONS.

### POSITION-ANGLE. STAR 23.

| Plate. | Reduced Angle. | | | | | Residuals in arc of great circle. |
|---|---|---|---|---|---|---|
| 1 | 356°4′49″ | 1.00$x$ | —1.14$y$ | —79.Π | + 8.″=0 | —0″.08 |
| 2 | 5 12 | 1.00 | —1.13 | —79. | +31. =0 | + .20 |
| 3 | 4 49 | 1.00 | —1.13 | —79. | + 8. =0 | — .08 |
| 4 | 5 20 | 1.00 | —0.08 | —73. | +39. =0 | + .31 |
| 5 | 4 14 | 1.00 | —0.04 | —62. | —27. =0 | — .45 |
| 6 | 4 40 | 1.00 | —0.04 | —62. | — 1. =0 | — .13 |
| 7 | 5 7 | 1.00 | —0.04 | —60. | +26. =0 | + .20 |
| 8 | 4 50 | 1.00 | +0.88 | —78. | + 9. =0 | — .08 |
| 9 | 4 57 | 1.00 | +0.88 | —78. | +16. =0 | + .00 |
| 10 | 5 0 | 1.00 | +0.89 | —77. | +19. =0 | + .04 |
| 11 | 4 42 | 1.00 | +0.90 | —76. | + 1. =0 | — .17 |
| 12 | 4 58 | 1.00 | +0.90 | —76. | +17. =0 | + .02 |
| 13 | 5 11 | 1.00 | +0.90 | —76. | +30. =0 | + .18 |
| 15 | 4 1 | 1.00 | +1.42 | +73. | —40. =0 | — .07 |
| 16 | 4 13 | 1.00 | +1.45 | +66. | —28. =0 | + .05 |
| 17 | 3 59 | 1.00 | +1.45 | +66. | —42. =0 | — .12 |
| 18 | 4 24 | 1.00 | +1.45 | +65. | —17. =0 | + .18 |
| 19 | 3 40 | 1.00 | +1.45 | +65. | —61. =0 | — .36 |
| 20 | 4 39 | 1.00 | +1.45 | +65. | — 2. =0 | + .36 |

356 4 41.0 = Adopted Mean.

### Normal Equations.

$$+19.00x' + 10.42y' - 555.00\Pi - 14.00 = 0$$
$$+21.16 + 448.60 - 248.42 = 0$$
$$+97481.00 - 26185.00 = 0$$

### Solution.

$\Pi = +\ 0''.3334 \pm 0''.0584$ $[vv] = 5349.$

$y' = -\ 0\ .6676 \pm 4\ .237$ $\sigma = 2500''.62$

$x' = +10\ .8423 \pm 4\ .652$ Factor $= .01213$

In Angle. Arc of great circle.

Probable error of one equation $= \pm 12''.33 = \pm 0''.1496$

## Table XVIII.—Parallax Equations.

### Position-Angle. Star 13.

| Plate. | Reduced Angle. | | | | | | Residuals in arc of great circle. |
|---|---|---|---|---|---|---|---|
| 1 | 341°25′ 9″ | 1.00$x$ | —1.14$y$ | —73.Π | +23.″ | = 0 | +0″.11 |
| 2 | 24 30 | 1.00 | —1.13 | —73. | —16. | = 0 | — .41 |
| 3 | 25 10 | 1.00 | —1.13 | —73. | +24. | = 0 | + .12 |
| 4 | 25 40 | 1.00 | —0.08 | —72. | +54. | = 0 | + .46 |
| 5 | 25 0 | 1.00 | —0.04 | —66. | +14. | = 0 | — .04 |
| 6 | 24 55 | 1.00 | —0.04 | —66. | + 9. | = 0 | — .11 |
| 7 | 25 6 | 1.00 | —0.04 | —65. | +20. | = 0 | + .05 |
| 10 | 25 14 | 1.00 | +0.89 | —74. | +28. | = 0 | + .04 |
| 11 | 25 13 | 1.00 | +0.90 | —74. | +27. | = 0 | + .02 |
| 12 | 24 59 | 1.00 | +0.90 | —74. | +13. | = 0 | — .16 |
| 13 | 25 4 | 1.00 | +0.90 | —74. | +18. | = 0 | — .10 |
| 15 | 23 54 | 1.00 | +1.42 | +74. | —52. | = 0 | — .20 |
| 16 | 24 13 | 1.00 | +1.45 | +69. | —33. | = 0 | + .03 |
| 17 | 24 19 | 1.00 | +1.45 | +69. | —27. | = 0 | + .11 |
| 18 | 24 47 | 1.00 | +1.45 | +69. | + 1. | = 0 | + .48 |
| 19 | 23 52 | 1.00 | +1.45 | +69. | —54. | = 0 | — .26 |
| 20 | 23 59 | 1.00 | +1.45 | +69. | —47. | = 0 | — .16 |

341 24 46.0 = Adopted Mean.

### Normal Equations.

$$+17.00x' + 8.66y' - 365.00\Pi + 2.00 = 0$$
$$+19.62 \quad + 601.51 \quad - 270.02 = 0$$
$$+85293.00 \quad -30221.00 = 0$$

### Solution.

$\Pi = +\ 0''.4401 \pm 0''.0643$ $\qquad [vv] = 4672.$

$y' = -\ 4\ .9631 \pm 4\ .591$ $\qquad \sigma = 2754''.25$

$x' = +11\ .8592 \pm 4\ .582$ $\qquad$ Factor = .01336

In Angle. Arc of great circle.

Probable error of one equation = $\pm 12''.32 = \pm 0''.1646$

## The Parallax of $61^2$ Cygni.

**37.** If the coefficients for parallax of $61^2$ *Cygni* be computed by the formulæ of paragraphs 14 and 22, we have:

$$S_3 = -0.296 \qquad S_8 = +9777.$$
$$S_4 = -0.822 \qquad S_9 = -1120.$$

With these, and the values of $P_3$ and $P_4$ of paragraph 14, have been obtained the quantities printed in the last column of Table XIII.

**38.** The measured distances duly corrected for proper motions of both stars are given in the last-but-one column of Table XIII. Table XIX contains the equations of condition of the form:

$$x + (t - 1873.546)y + (S_3P_3 + S_4P_4)\,\Pi + \sigma - \sigma_0' = 0$$

from which are derived the values of the unknowns given on the same page.

**39.** In column nine of Table XIII are given in like manner the corrected position-angles from which the equations of condition of Table XX have been formed after the manner of paragraph 35. They are of the form

$$x' + (t - 1873.546)y' + \sigma\cdot\sin 1''\cdot (S_8P_3 + S_9P_4)\,\Pi + \sigma\cdot\sin 1''\cdot (\pi - \pi_0') = 0.$$

The resulting values of the unknowns will be found on the same page.

**40.** In both these cases, however, we cannot assume the parallax of the reference star to be *nil*. Its value has been shown to be $+0.''360 \pm ''.015$. The mean by weight of the values of parallax of *61*¹ with respect to *61*² obtained from distance and from angle is $+0''.072 \pm ''.028$, wherefore the concluded value of the

$$\text{Parallax of } 61^2 \text{ Cygni} = 0''.288 \pm ''.031$$

referred indirectly to all the comparison stars given in Table XIV.

### TABLE XIX.—PARALLAX EQUATIONS IN DISTANCE.

### COMPARISON STAR, *$61^1$ Cygni.*

| Plate. | | | | | $v$. |
|---|---|---|---|---|---|
| 1 | $1.00x$ | $-1.69y$ | $-0.77\Pi$ | $-0''.140=0$ | $-0''.248$ |
| 2 | 1.00 | $-1.68$ | $-0.74$ | $+\ .136=0$ | $+\ .032$ |
| 3 | 1.00 | $-1.68$ | $-0.74$ | $+\ .200=0$ | $+\ .096$ |
| 4 | 1.00 | $-0.63$ | $-0.57$ | $+\ .076=0$ | $+\ .022$ |
| 5 | 1.00 | $-0.59$ | $-0.37$ | $-\ .058=0$ | $-\ .085$ |
| 6 | 1.00 | $-0.59$ | $-0.37$ | $+\ .085=0$ | $+\ .058$ |
| 7 | 1.00 | $-0.58$ | $-0.34$ | $+\ .078=0$ | $+\ .055$ |
| 8 | 1.00 | $+0.33$ | $-0.71$ | $+\ .001=0$ | $-\ .045$ |
| 9 | 1.00 | $+0.33$ | $-0.71$ | $-\ .147=0$ | $-\ .193$ |
| 10 | 1.00 | $+0.34$ | $-0.67$ | $+\ .030=0$ | $-\ .010$ |
| 11 | 1.00 | $+0.35$ | $-0.65$ | $+\ .243=0$ | $+\ .205$ |
| 12 | 1.00 | $+0.35$ | $-0.65$ | $+\ .061=0$ | $+\ .023$ |
| 13 | 1.00 | $+0.35$ | $-0.65$ | $+\ .128=0$ | $+\ .090$ |
| 15 | 1.00 | $+0.87$ | $+0.55$ | $+\ .038=0$ | $+\ .168$ |
| 16 | 1.00 | $+0.90$ | $+0.42$ | $-\ .039=0$ | $+\ .075$ |
| 17 | 1.00 | $+0.90$ | $+0.42$ | $-\ .022=0$ | $+\ .092$ |
| 18 | 1.00 | $+0.91$ | $+0.40$ | $-\ .246=0$ | $-\ .134$ |
| 19 | 1.00 | $+0.91$ | $+0.40$ | $-\ .280=0$ | $-\ .168$ |
| 20 | 1.00 | $+0.91$ | $+0.40$ | $-\ .146=0$ | $-\ .033$ |

Normal Equations.

$$+19.000\,000x + 0.010\,000y - 5.350\,000\Pi - 0''.002\,000 = 0$$
$$+15.492\,500 \quad +5.728\,200 \quad -0\ .957\,070 = 0$$
$$+6.262\,300 \quad -0\ .691\,430 = 0$$

Solution.

| | Weights. |
|---|---|
| $x = +0''.0362 \pm 0''.0249$ | 12.08 |
| $y = +0\ .0272 \pm 0\ .0295$ | 8.59 |
| $\Pi = +0\ .1282 \pm 0\ .0533$ | 2.64 |

Probable error of one equation $= \pm 0''.0865$. $[vv] = 0.2634$

## TABLE XX.—PARALLAX EQUATIONS IN ANGLE.

### COMPARISON STAR, *61[1] Cygni.*

| Plate. | | | | | *v.* |
|---|---|---|---|---|---|
| 1 | $1.00x'$ | $-1.69y'$ | $+0.597\Pi$ | $-''.100=0$ | $+''.005$ |
| 2 | 1.00 | $-1.68$ | $+ .633$ | $- .074=0$ | $+ .033$ |
| 3 | 1.00 | $-1.68$ | $+ .633$ | $- .142=0$ | $+ .065$ |
| 4 | 1.00 | $-0.63$ | $+ .802$ | $- .165=0$ | $- .103$ |
| 5 | 1.00 | $-0.59$ | $+ .890$ | $- .058=0$ | $+ .006$ |
| 6 | 1.00 | $-0.59$ | $+ .890$ | $+ .122=0$ | $+ .186$ |
| 7 | 1.00 | $-0.58$ | $+ .896$ | $- .150=0$ | $- .086$ |
| 8 | 1.00 | $+0.33$ | $+ .672$ | $- .134=0$ | $- .128$ |
| 9 | 1.00 | $+0.33$ | $+ .672$ | $+ .025=0$ | $+ .031$ |
| 10 | 1.00 | $+0.34$ | $+ .723$ | $+ .087=0$ | $+ .095$ |
| 11 | 1.00 | $+0.35$ | $+ .742$ | $+ .063=0$ | $+ .072$ |
| 12 | 1.00 | $+0.35$ | $+ .742$ | $+ .013=0$ | $+ .022$ |
| 13 | 1.00 | $+0.35$ | $+ .742$ | $- .113=0$ | $- .104$ |
| 15 | 1.00 | $+0.87$ | $- .850$ | $+ .068=0$ | $- .031$ |
| 16 | 1.00 | $+0.90$ | $- .910$ | $+ .012=0$ | $- .092$ |
| 17 | 1.00 | $+0.90$ | $- .910$ | $+ .383=0$ | $+ .279$ |
| 18 | 1.00 | $+0.91$ | $- .913$ | $- .076=0$ | $- .181$ |
| 19 | 1.00 | $+0.91$ | $- .913$ | $+ .037=0$ | $- .068$ |
| 20 | 1.00 | $+0.91$ | $- .913$ | $+ .205=0$ | $+ .100$ |

Normal Equations.

$$+19.000\,000x + 0.010\,000y + 4.225\,000\Pi + 0''.003\,000 = 0$$
$$+15.492\,500 - 8.612\,500 + 1\ .231\,450 = 0$$
$$+12.145\,003 - 1\ .012\,807 = 0$$

Solution.

| | Weights. |
|---|---|
| $x' = -0''.0115 \pm ''.0200$ | 16.57 |
| $y' = -0\ .0510 \pm\ .0273 = -0^{\circ}.151 \pm 0^{\circ}.081$ | 8.87 |
| $\Pi = +0\ .0512 \pm\ .0321$ | 6.42 |

Probable error of one equation $= \pm 0''.0813$ $[vv] = 0.2326$

Incidentally it should be noticed that the assumed annual change in distance of *61*$^2$ from *61*$^1$ was $-0''.128$, the negative sign being used to indicate separation. From the value of $y$ in Table XIX the correction to this is $0''.027$. Thus the Rutherfurd plates for an interval of only 2.6 years give:

Annual increase of distance $= 0''.101 \pm ''.030$.

In like manner, the assumed increase of position-angle being $0^\circ.370$ and Table XX, giving as a correction a further increase of $0^\circ.151$, there results:

Annual increase of angle $= 0^\circ.521 \pm ^\circ.081$.

But what is of greater significance, there is also a difference of parallax:

$$(61^1 \text{ Cygni} - 61^2 \text{ Cygni}) = +0''.072 \pm ''.028$$

**41.** This result is so surprising and yet the difference of parallax obtained from angles and from distances is so accordant within the limits of their respective probable errors that I have deemed it advisable to use the very excellent series of measures of the distance of these two stars given by Wilsing in *Sitzungsberichten* der Königl. Preuss. Akademie der Wissenschaften*, 1893, Bd. 40, to see what value of the difference of parallax, if any, might be deduced from them.

**42.** Using Auwers' values of the right ascension and declination of $61^1$ *Cygni* for 1875.0 and his constants of precession we have:

$$\left.\begin{array}{l} \alpha = 21^h \ 2^m \ 0^s.6 \\ \delta = 38^\circ \ 12' \ 48''.6 \end{array}\right\} \text{for } 1891.0$$

I have taken $p = 114^\circ.692$ for 1873 with an annual variation of $0^\circ.50$ which gives $p = 123^\circ.5$ for 1891.0 quite accurately enough; as an error of a whole degree would, demonstrably, have no sensible effect upon the deduced value of parallax. Therefore:

$$S_3 = [9.9849] \sin 350^\circ.8 = -0.154$$
$$S_4 = [9\ 9181] \sin 271^\circ.3 = -0.828$$

With these and the values of $P_3$ and $P_4$ computed for each date of Wilsing's plates† were formed the parallax coefficients

$$S_3P_3 + S_4P_4$$

which are found in the equations of condition of Table XXI.

*Since given more fully in *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, Nr. 36, Bd. XI, 1897.

†*Sitzungsberichten*, etc., pages 883–4.

TABLE XXI.—WILSING'S MEASURES.

| No. | Date. | | Meas. Dist. | Equations of Condition. | Corrected Distance. | Distance *minus* Mean. $v$ |
|---|---|---|---|---|---|---|
| | | | ″ | ″ | ″ | ″ |
| 1 | 1890 Oct. | 14.43 | 21.04 | $1.x-0.22y$ —.82Π+.04=0 | 20.986 | +.004 |
| 2 | | 22.43 | 20.90 | 1 —0.19 —.79 —.10 | 20.847 | —.135 |
| 3 | Nov. | 5.32 | 20.89 | 1 —0.16 —.70 —.11=0 | 20.842 | —.140 |
| 4 | Dec. | 17.24 | 20.95 | 1 —0.04 —.21 —.05=0 | 20.935 | —.047 |
| 5 | 1891 Feb. | 4.29 | 20.99 | 1 +0.10 +.48 —.01=0 | 21.024 | +.042 |
| 6 | May | 5.48 | 21.04 | 1 +0.34 +.70 +.04=0 | 21.073 | +.091 |
| 7 | | 8.49 | 20.97 | 1 +0.35 +.68 —.03 | 21.001 | +.019 |
| 8 | | 11.46 | 21.04 | 1 +0.36 +.65 +.04 | 21.071 | +.089 |
| 9 | | 11.47 | 20.87 | 1 +0.36 +.65 —.13 | 20.901 | —.081 |
| 10 | | 12.47 | 20.81 | 1 +0.36 +.64 —.19 | 20.837 | —.145 |
| 11 | | 29.46 | 20.94 | 1 +0.40 +.46 —.06 | 20.947 | —.035 |
| 12 | June | 5.49 | 20.91 | 1 +0.42 +.37 —.09=0 | 20.907 | —.075 |
| 13 | | 16.44 | 20.85 | 1 +0.46 +.22 —.15 | 20.831 | —.151 |
| 14 | | 17.47 | 20.81 | 1 +0.46 +.21 —.19 | 20.790 | —.192 |
| 15 | | 17.49 | 20.76 | 1 +0.46 +.21 —.24 | 20.740 | —.242 |
| 16 | Aug. | 18.40 | 21.12 | 1 +0.63 —.60 +.12=0 | 21.017 | +.035 |
| 17 | | 18.41 | 21.11 | 1 +0.63 —.60 +.11 | 21.005 | +.023 |
| 18 | | 18.43 | 21.10 | 1 +0.63 —.60 +.10 | 20.995 | +.013 |
| 19 | | 22.42 | 21.01 | 1 +0.64 —.64 +.01 | 20.901 | —.081 |
| 20 | | 23.44 | 21.03 | 1 +0.64 —.65 +.03 | 20.920 | —.062 |
| 21 | | 27.41 | 21.06 | 1 +0.66 —.69 +.06 | 20.946 | —.036 |
| 22 | | 27.42 | 21.20 | 1 +0.66 —.69 +.20 | 21.086 | +.104 |
| 23 | | 28.45 | 21.04 | 1 +0.66 —.69 +.04 | 20.926 | —.056 |
| 24 | | 28.46 | 21.16 | 1 +0.66 —.69 +.16 | 21.046 | +.064 |
| 25 | | 29.38 | 21.02 | 1 +0.66 —.70 +.02 | 20.905 | —.077 |
| 26 | | 31.37 | 21.03 | 1 +0.67 —.72 +.03 | 20.912 | —.070 |
| 27 | | 31.39 | 21.06 | 1 +0.67 —.72 +.06 | 20.942 | —.040 |
| 28 | Sept. | 6.44 | 21.02 | 1 +0.69 —.76 +.02=0 | 20.896 | —.086 |
| 29 | | 6.45 | 21.12 | 1 +0.69 —.76 +.12 | 20.996 | +.014 |
| 30 | | 7.42 | 21.16 | 1 +0.69 —.77 +.16 | 21.036 | +.054 |
| 31 | | 7.43 | 21.16 | 1 +0.69 —.77 +.16 | 21.036 | +.054 |
| 32 | | 9.46 | 20.95 | 1 +0.69 —.78 —.05 | 20.825 | —.157 |
| 33 | | 11.38 | 20.97 | 1 +0.69 —.79 —.03 | 20.844 | —.138 |
| 34 | | 23.41 | 21.03 | 1 +0.72 —.83 +.03 | 20.898 | —.084 |
| 35 | | 23.43 | 21.14 | 1 +0.72 —.83 +.14 | 21.008 | +.026 |
| 36 | | 24.35 | 20.87 | 1 +0.72 —.83 —.13 | 20.738 | —.244 |
| 37 | | 24.36 | 21.22 | 1 +0.72 —.83 +.22 | 21.088 | +.106 |
| 38 | | 30.37 | 20.90 | 1 +0.75 —.84 —.10 | 20.764 | —.218 |
| 39 | | 30.38 | 21.04 | 1 +0.75 —.84 +.04 | 20.904 | —.078 |

TABLE XXI.—WILSING'S MEASURES, (*Continued*).

| No. | Date. | | Meas. Dist. | Equations of Condition. | Corrected Distance. | Distance *minus* Mean. $v$ |
|---|---|---|---|---|---|---|
| | | | ″ | ″ | ″ | ″ |
| 40 | 1891 Oct. | 1.37 | 21.00 | $1.x + 0.75y - .84\Pi + .00 = 0$ | 20.864 | —.118 |
| 41 | | 1.37 | 21.07 | 1 +0.75 —.84 +.07 | 20.934 | —.048 |
| 42 | | 6.35 | 21.01 | 1 +0.77 —.84 +.01 | 20.873 | —.109 |
| 43 | | 6.37 | 21.13 | 1 +0.77 —.84 +.13 | 20.993 | +.011 |
| 44 | | 9.36 | 21.32 | 1 +0.78 —.84 +.32 | 21.182 | +.200 |
| 45 | | 10.30 | 21.31 | 1 +0.78 —.84 +.31 | 21.172 | +.190 |
| 46 | | 20.43 | 21.13 | 1 +0.80 —.80 +.13 | 20.994 | +.012 |
| 47 | | 23.42 | 21.21 | 1 +0.81 —.79 +.21 | 21.074 | +.092 |
| 48 | | 23.43 | 21.08 | 1 +0.81 —.79 +.08 | 20.944 | —.038 |
| 49 | | 28.36 | 21.10 | 1 +0.82 —.76 +.10 | 20.965 | —.017 |
| 50 | Oct. | 29.32 | 21.17 | 1 +0.82 —.75 +.17=0 | 21.036 | +.054 |
| 51 | Nov. | 3.32 | 21.13 | 1 +0.84 —.72 +.13 | 20.998 | +.016 |
| 52 | | 3.33 | 21.11 | 1 +0.84 —.72 +.11 | 20.978 | —.004 |
| 53 | | 5.41 | 21.06 | 1 +0.84 —.70 +.06 | 20.930 | —.052 |
| 54 | | 5.42 | 21.03 | 1 +0.84 —.70 +.03 | 20.900 | —.082 |
| 55 | | 19.30 | 21.34 | 1 +0.88 —.57 +.34 | 21.217 | +.235 |
| 56 | | 29.33 | 21.23 | 1 +0.91 —.46 +.23 | 21.115 | +.133 |
| 57 | | 29.34 | 21.41 | 1 +0.91 —.46 +.41 | 21.295 | +.313 |
| 58 | Dec. | 7.23 | 21.31 | 1 +0.93 —.35 +.31=0 | 21.202 | +.220 |
| 59 | | 11.33 | 21.25 | 1 +0.94 —.30 +.25 | 21.147 | +.165 |
| 60 | | 12.30 | 21.18 | 1 +0.95 —.29 +.18 | 21.077 | +.095 |
| 61 | | 12.31 | 21.26 | 1 +0.95 —.29 +.26 | 21.157 | +.175 |
| 62 | | 17.32 | 21.13 | 1 +0.96 —.21 +.13 | 21.033 | +.051 |
| 63 | | 17.33 | 21.07 | 1 +0.96 —.21 +.07 | 20.973 | —.009 |
| 64 | | 25.27 | 21.32 | 1 +0.98 —.10 +.32 | 21.230 | +.248 |
| 65 | | 25.29 | 21.11 | 1 +0.98 —.10 +.11 | 21.020 | +.038 |
| 66 | | 25.30 | 21.09 | 1 +0.98 —.10 +.09 | 21.000 | +.018 |
| 67 | 1892 Jan. | 7.24 | 21.07 | 1 +1.02 +.09 +.07=0 | 20.994 | +.012 |
| 68 | | 7.26 | 21.12 | 1 +1.02 +.09 +.12 | 21.044 | +.062 |
| 69 | | 17.29 | 21.14 | 1 +1.04 +.24 +.14 | 21.075 | +.093 |
| 70 | | 17.30 | 21.10 | 1 +1.04 +.24 +.10 | 21.035 | +.053 |
| 71 | | 20.25 | 21.26 | 1 +1.05 +.28 +.26 | 21.198 | +.216 |
| 72 | | 20.27 | 21.18 | 1 +1.05 +.28 +.18 | 21.118 | +.136 |
| 73 | | 20.28 | 21.09 | 1 +1.05 +.28 +.09 | 21.028 | +.046 |
| 74 | May | 8.53 | 21.08 | 1 +1.35 +.67 +.08=0 | 21.028 | +.046 |
| 75 | | 11.52 | 21.08 | 1 +1.36 +.64 +.08 | 21.024 | +.042 |
| 76 | | 11.53 | 21.07 | 1 +1.36 +.64 +.07 | 21.014 | +.032 |
| 77 | | 26.54 | 21.05 | 1 +1.40 +.48 +.05 | 20.977 | —.005 |
| 78 | | 26.56 | 21.10 | 1 +1.40 +.48 +.10 | 21.027 | +.045 |
| 79 | June | 8.49 | 21.05 | 1 +1.43 +.32 +.05=0 | 20.960 | —.022 |
| 80 | | 8.51 | 21.07 | 1 +1.43 +.32 +.07 | 20.980 | —.002 |
| 81 | | 17.55 | 21.17 | 1 +1.46 +.20 +.17 | 21.068 | +.086 |
| 82 | | 28.48 | 21.16 | 1 +1.49 +.04 +.16 | 21.041 | +.059 |

TABLE XXI.—WILSING'S MEASURES, (*Concluded*).

| No. | Date. | Meas. Dist. | Equations of Condition. | Cor-rected Distance. | Distance *minus* Mean. *v* |
|---|---|---|---|---|---|
| | | ″ | ″ | ″ | ″ |
| 83 | 1892 Dec. 22.36 | 21.12 | 1.*x* +1.97*y* —.13Π +.12=0 | 20.947 | —.035 |
| 84 | 1893 Jan. 7.24 | 21.16 | 1 +2.02 +.10 +.16 | 21.003 | +.021 |
| 85 | 7.28 | 21.12 | 1 +2.02 +.10 +.12 | 20.963 | —.019 |
| 86 | 11.25 | 21.15 | 1 +2.03 +.16 +.15 | 20.997 | +.015 |
| 87 | 28.26 | 21.10 | 1 +2.08 +.40 +.10 | 20.964 | —.018 |
| 88 | Feb. 4.26 | 21.19 | 1 +2.10 +.49 +.19 | 21.060 | +.078 |
| 89 | Mar. 23.61 | 20.98 | 1 +2.23 +.83 —.02=0 | 20.869 | —.113 |
| 90 | 23.64 | 21.00 | 1 +2.23 +.83 .00 | 20.889 | —.093 |
| 91 | 27.62 | 21.06 | 1 +2.24 +.84 +.06 | 20.949 | —.033 |
| 92 | Apr. 6.57 | 20.95 | 1 +2.27 +.84 —.05=0 | 20.837 | —.145 |
| 93 | 18.59 | 21.02 | 1 +2.30 +.80 +.02 | 20.900 | —.082 |
| 94 | 21.50 | 21.05 | 1 +2.31 +.79 +.05 | 20.929 | —.053 |
| 95 | May 9.55 | 21.11 | 1 +2.36 +.66 +.11=0 | 20.974 | —.008 |
| 96 | 10.51 | 21.11 | 1 +2.36 +.65 +.11 | 20.973 | —.009 |
| 97 | 15.56 | 21.10 | 1 +2.37 +.60 +.10 | 20.958 | —.024 |
| 98 | 23.57 | 21.09 | 1 +2.39 +.52 +.09 | 20.939 | —.043 |
| 99 | June 1.50 | 21.12 | 1 +2.41 +.41 +.12=0 | 20.957 | —.025 |
| 100 | 7.49 | 21.15 | 1 +2.43 +.34 +.15 | 20.980 | —.002 |
| 101 | 14.49 | 21.16 | 1 +2.45 +.24 +.16 | 20.979 | —.003 |
| 102 | 24.44 | 21.13 | 1 +2.48 +.10 +.13 | 20.935 | —.047 |
| 103 | July 4.44 | 21.22 | 1 +2.51 —.04 +.22=0 | 21.009 | +.027 |
| 104 | 15.41 | 21.21 | 1 +2.54 —.19 +.21 | 20.984 | +.002 |
| 105 | Aug. 3.41 | 21.24 | 1 +2.59 —.44 +.24 | 20.988 | +.006 |
| 106 | Aug. 4.41 | 21.23 | 1 +2.59 —.46 +.23=0 | 20.977 | —.005 |
| 107 | 10.39 | 21.17 | 1 +2.61 —.52 +.17 | 20.909 | —.073 |
| 108 | 31.45 | 21.26 | 1 +2.67 —.72 +.26 | 20.977 | —.005 |
| 109 | Sept. 1.49 | 21.27 | 1 +2.67 —.73 +.27=0 | 20.986 | +.004 |
| 110 | 15.48 | 21.22 | 1 +2.71 —.81 +.22 | 20.926 | —.056 |

21.00 = Assumed Mean. $\Sigma vv$ = 1″.1032

Mean = 20.982

**43.** From these equations are obtained the following normal equations and values of the unknowns :

Normal Equations.

$$+110.0000x + 129.0300y - 19.1300\Pi + 10.3300 = 0$$
$$+215.2083 - 3.9695 + 15.7599 = 0$$
$$+39.4805 - 3.4429 = 0$$

Solution.

| | Weights. |
|---|---|
| $x = +0''.0180 \pm 0''.0014$ | 25.49 |
| $y = -0\ .0824 \pm 0\ .0093$ | 54.42 |
| $\Pi = +0\ .0876 \pm 0\ .0123$ | 30.81 |

Probable error of one equation $= \pm\, 0''.0684$

$[vv] = 1''.1006$

**44.** It will be noticed that this difference of parallax between *61*[1] and *61*[2] is in very close agreement with the $+ 0''.072 \pm .''028$ derived from the Rutherfurd measures. Its probable error and the sum of the squares of the residuals when compared with similar quantities* in Wilsing's determination of the parallax of 61[2] *Cygni* would indicate that it has as real an existence in the measures as his own values of the parallax of *61*[2] itself; while at the same time bearing testimony to the excellent quality of his measures.

**45.** Yet this difference of parallax does not preclude the possibility of orbital motion of either *61*[1] or *61*[2] about a dark companion, as has been suggested by Wilsing to account for the systematic irregularity of his measures—a suggestion which the outstanding residuals, after corrections for this difference of parallax have been applied to the measures, would in a degree confirm. And yet it is greatly to be regretted that points numbered 1, 2, 3, and 4 of his curve† are determined by only 4, 2, 2, and 2, exposures on 2, 1, 1, and 1 plates respectively, in contrast with the other points which are determined by the means of from 11 to 40 exposures; and that the most critical portion of the curve (that from January 15th, 1892, to January 13th, 1893) is determined by two points only, from 15 and 11 exposures on only 5 and 4 plates respectively. Moreover, for the reasons stated on page 160 of this paper, the testimony of the Pritchard measures, adduced by

* $[vv] = 2.691$; 2.390 and 1.681 on pages 109, 114 and 120 respectively, *Publicationen*, etc.

† *Sitzungsberichten*, etc., pages 884–5.

JACOBY* to corroborate WILSING, should be given no weight at the present time.

On the other hand, it is still an open question whether or not the parallaxes obtained from RUTHERFURD measures may not be affected by systematic errors, the nature and origin as well as existence of which are at present unknown. The case of $\beta$ *Cygni*† as well as Mrs. Davis' deduction of a similarly large parallax from the measures‡ of "Bradley 3077" give room for this suspicion. It is for this reason that the confirmation of difference of parallax by WILSING's measures is all the more instructive.

**46.** It should be stated in this connection also, that even if such orbital motion exist, its amplitude is so greatly diminished by this difference of parallax of the two stars as to reduce the sum of the squares of the residuals formed in means for the 22 groups of WILSING's Table on page 885§ from 0.1708 to 0.1052 or by nearly forty per cent.

In the following Table, are reproduced, in column two, these twenty-two mean residuals‡ and in column three are given also the mean of the residuals for the same plates from the last column of Table XXI, whereby to facilitate their comparison as to the effect produced by the introduction of the parallax into the equations.

I have also made a second solution of these 110 equations on the assumption that there might be a term whose coëfficient is||

$$\tan \zeta \cos (p - q)$$

to account for the unequal effect on the two stars of the atmospheric dispersion. The solution of the equations and the resulting residuals are not contradictory of WILSING's conclusions (from the similarity of the spectra of $61^1$ and $61^2$) that there is no reason for the introduction of this term. In column four are given, however, the means of the residuals resulting from this solution.

**Monthly Notices*, Vol. LIV, page 117. See also, *Vierteljahrsschrift*, for 1891, Vol. 26, p. 146.

† *Astronomical Journal*, No. 287: On the Probable Large Parallax of $\beta$ Cygni, by Harold Jacoby.

‡ Contribution from the Observatory of Columbia University, New York, No. 14.

§ *Sitzungsberichten*, etc.

|| *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, No 36, page 144.

¶ *Monthly Notices*, Vol. LV, page 123. But see also Vol. LVIII, page 83.

TABLE XXII.—WILSING'S MEASURES.

(See Paragraph 46.)

| No. of Point on Curve. | Mean of Residuals. Wilsing. | With Parallax. | With Paral. and Atmos. Dispersion. | Weight. Plates. | Expos. | Mean Date. |
|---|---|---|---|---|---|---|
| 1 | +.041″ | —.066″ | —.073″ | 2 | 4 | 1890 Oct. 18 |
| 2 | —.039 | —.140 | —.142 | 1 | 2 | Nov. 5 |
| 3 | +.001 | —.047 | —.084 | 1 | 2 | Dec. 17 |
| 4 | +.031 | +.042 | —.041 | 1 | 2 | 1891 Feb. 4 |
| 5 | —.039 | —.010 | +.052 | 6 | 12 | May 13 |
| 6 | —.179 | —.165 | —.145 | 4 | 8 | June 14 |
| 7 | +.071 | —.015 | —.003 | 12 | 24 | Aug. 25 |
| 8 | +.031 | —.063 | —.047 | 12 | 24 | Sept. 17 |
| 9 | +.111 | +.018 | +.026 | 10 | 19 | Oct. 13 |
| 10 | +.131 | +.077 | +.066 | 8 | 16 | Nov. 11 |
| 11 | +.151 | +.111 | +.069 | 9 | 17 | Dec. 17 |
| 12 | +.091 | +.088 | +.018 | 7 | 14 | 1892 Jan. 15 |
| 13 | —.009 | +.032 | +.043 | 5 | 15 | May 16 |
| 14 | +.011 | +.030 | +.038 | 4 | 11 | June 15 |
| 15 | —.009 | +.007 | —.061 | 6 | 40 | 1893 Jan. 13 |
| 16 | —.159 | —.080 | —.043 | 3 | 19 | Mar. 24 |
| 17 | —.169 | —.093 | —.054 | 3 | 24 | April 15 |
| 18 | —.089 | —.021 | —.014 | 4 | 34 | May 14 |
| 19 | —.049 | —.019 | +.004 | 4 | 32 | June 11 |
| 20 | +.021 | +.012 | +.026 | 3 | 24 | July 18 |
| 21 | +.011 | —.028 | —.002 | 3 | 25 | Aug. 15 |
| 22 | +.031 | —.026 | —.022 | 2 | 18 | Sept. 8 |

**47.** Several astronomers have investigated the parallax of these stars by measures with reference to the point mid-way between *61*¹ and *61*²; others with reference to either star independently of the other. In Table XXIII are gathered many of the results of such investigations where the stars were individually observed. When the same measures have been reduced in several different ways or by different persons, that result which is regarded as definitive has been printed in heavy type, the lightface type being used in other cases. The numbers in the last column refer to the list of reference books given on pages 159–160.

TABLE XXIII.—VARIOUS VALUES OF PARALLAX OF 61¹ CYGNI.

| Method. | Star of Comparison. | Parallax of 61¹ Cygni. | Probable error $r$ | Authority. | Ref. No. |
|---|---|---|---|---|---|
| $\delta$ | Absolute | $+0''.349$ | $\pm0''.080$ | Peters | 2 |
| $\Delta\delta$ | 38°4351 | .4654 | .0497 | Ball | 8 |
| $\Delta\delta$ | 38°4351 | .400 | .055 | Ramb. Ball | 15 |
| $a$ | Absolute (?) | .50 | .094 | Belopolsky | 10 |
| $\Delta a$ | | .21 | .03 | Flint | 16 |
| Photography | Ten Stars | .30 | .031 | Kapteyn | 17 |
| | | Distance. | | | |
| Photography | 37°4189 | [$+0''.4294$] | $\pm0''.0162$ | Pritchard | 12 |
| " | 38°4336 | [ .4414] | .0222 | Pritchard | 12 |
| " | 37°4175 | [ .4448] | .0212 | Pritchard | 12 |
| " | 38°4348 | [ .4193] | .0182 | Pritchard | 12 |
| Photography | 38°4372—37°4159 | .5211 | .0373 | Davis | 13 |
| " | 38°4353—37°4159 | .4497 | .0429 | Davis | 13 |
| " | 38°4325—38°4362 | .3733 | .0400 | Davis | 13 |
| " | 38°4363—38°4325 | .2431 | .0409 | Davis | 13 |
| " | 37°4189—38°4336 | .3888 | .0658 | Davis | 13 |
| Photography | 37°4189 | .405 | .026 | Wilsing | 14 |
| | | Position Angle. | | | |
| Photography | 37°4180 | $+0''.3028$ | $\pm0''.0354$ | Davis | 13 |
| " | 37°4175 | .3779 | .0395 | Davis | 13 |
| " | 37°4189 | .2794 | .0473 | Davis | 13 |
| " | 37°4185 | .3299 | .0557 | Davis | 13 |
| " | 37°4178 | .3442 | .0620 | Davis | 13 |
| " | 38°4341 | .3334 | .0743 | Davis | 13 |
| " | 38°4335 | .4401 | .0819 | Davis | 13 |

TABLE XXIII.—VARIOUS VALUES OF PARALLAX OF 61² CYGNI.

| Method. | Star of Comparison. | Parallax of 61² Cygni. | Probable error $r$ | Authority. | Ref. No. |
|---|---|---|---|---|---|
| $\Delta\delta$, Microm. | 38°4351 | +0″.4676 | ±0″.0321 | Ball | 9 |
| " | 38°4345 | .2698 | .0130 | A. Hall | 11 |
| " | 38°4345 | .3217 | .0213 | A. Hall | 11 |
| " | $\Delta\alpha = -63^s.5$, $\Delta\delta = -34''$ | .2005 | .0246 | A. Hall | 11 |
| $\Delta\alpha$ | Absolute (?) | .55 | .091 | Belopolsky | 10 |
| Photography | Ten Stars. | .36 | .034 | Kapteyn | 17 |
| | | Distance. | | | |
| Micrometer | 38°4345 | 0″.5092 | ±0″.0355 | O. Struve | 3 |
| " | " | .5179 | .0328 | Lamp's Struve | 6 |
| Micrometer | 38°4345 | .4365 | .0738 | Socoloff's Schweizer | 5 |
| " | " | .4885 | .0824 | Socoloff's Schweizer | 5 |
| " | " | .4388 | .0654 | Lamp's Socoloff's Schweizer | 6 |
| " | " | .5220 | .0770 | Lamp's Socoloff's Schweizer | 6 |
| " | " | .4594 | .0637 | Lamp's Schweizer | 6 |
| " | " | .4715 | .0684 | Lamp's Schweizer | 6 |
| Photography | 37°4189 | [ .4250] | .0176 | Pritchard | 12 |
| " | 38°4336 | [ .4508] | .0191 | Pritchard | 12 |
| " | 37°4175 | [ .4320] | .0190 | Pritchard | 12 |
| " | 38°4348 | [ .4303] | .0178 | Pritchard | 12 |
| Photography | 61¹ *Cygni* | .288 | .031 | Davis | 13 |
| Photography | 37°4189 | .357 | .017 | Wilsing | 14 |
| | | Position-Angle. | | | |
| Micrometer | 38°4345 | +0″.5008 | ±0″.0466 | O. Struve | 3 |
| " | " | .4913 | .0371 | Lamp's Struve | 6 |
| Micrometer | 38°4345 | .3761 | .0439 | Socoloff's Schweizer | 5 |
| " | " | .4926 | .0546 | Socoloff's Schweizer | 5 |
| " | " | .3925 | .0438 | Lamp's Socoloff's Schweizer | 6 |
| " | " | .4957 | .0512 | Lamp's Socoloff's Schweizer | 6 |
| " | " | .3818 | .0457 | Lamp's Schweizer | 6 |
| " | " | .4824 | .0517 | Lamp's Schweizer | 6 |

**48.** While there is some dependence of one result on another in those instances where the same star of comparison was used, yet, as the measures were made by independent observers and dissimilar methods, and show in themselves no indication of a parallax of the comparison-star, it is not improper to combine all these individual results into means by weights proportional to the reciprocal of the square of the probable error. Thus we have the mean of previous determinations of the

$$\text{Parallax of } 61^1 \text{ Cygni} = 0.''417 + 0''.0216$$

and, in like manner excluding my own determinations:

$$\text{Parallax of } 61^2 \text{ Cygni} = 0''.335 + 0''.0076$$

which give:

$$61^1 - 61^2 = +0.''082 \ \pm 0''.023 \quad [+0''.054 \pm 0''.010]$$

and if the Rutherfurd results be included as given in Table XXIII, this becomes:

$$61^1 - 61^2 = +0''.048 \pm 0''.014 \quad [+0''.035 \pm 0''.009]$$

The numbers placed in the brackets are what these values would have been had Pritchard's results not been discarded.

**49.** Let us now tabulate these differences of parallax of the two stars under consideration:

| | | | |
|---|---|---|---|
| Davis' Rutherfurd,—direct measures of distance | +0''.128 | +''.053 | |
| Davis' Rutherfurd,—direct measures of angles | + .051 | .032 | |
| Adopted Mean = | | + 0''.072 | ± ''.028 |
| Davis' Wilsing,—direct measures of distance | | + .088 | .012 |
| Wilsing's $(61^1 - 6) - (61^2 - 6)$* | | + .048 | .031 |
| Mean of all determinations† previous to Rutherfurd = | | + .082 | .013 |
| Mean of all determinations including Rutherfurd = | | + .048 | .014 |

The magnitude and accordance of these values when considered in connection with their respective probable errors leave little room for doubt as to the reality of the difference of parallax detected by the measures of the Rutherfurd plates, and discarding Pritchard's results in no respect lessens the force of the argument. So that if $61^1$ *Cygni* be really a binary system of which

**Publicationen des Astrophysikalischen Observatoriums zu Potsdam*: Nr. 36. page 148.

†As determined from Table XXIII on pages 155–6, using only the values in bold type.

one member is a dark body* it is nevertheless far removed from the influence of 61² *Cygni*, which would account for the as yet unproved† orbital motion of *61*¹ and *61*² around a centre of gravity common to the two. The probabilities in favor of the existence of such orbital motion, if they really have the *same* parallax, are fully as strong as are those against the juxtaposition in line of sight of two stars having so nearly the same large apparent motion, if they are really separated in space by the distance which this *difference* of parallax indicates.

This presents to us therefore one of those cases where the exceedingly strong probability against an event happening is perhaps overruled by its actual occurrence.

The evidence here presented as to a difference of parallax is at any rate of sufficient weight to demand a more extended series of photographic measures of the same degree of precision as WILSING's and extending over more than two years. Perhaps Prof. Wilsing would himself be willing to continue his series of plates. It is also highly desirable to reinforce the evidence of a variable proper motion of *61*¹ by independent methods, such as is afforded by the spectroscope, for example.

* *Publications of the Lick Observatory*, Vol. II, 1894. Page 122. BURNHAM records his inability to see at 1889.463 and 1889.502 a companion to either star, though using the 36-inch telescope with powers up to 1000.

† *Monthly Notices*, Vol. XXXV, page 323. *Ast. Nach.*, Vol. 132, pages 87 and 199. BURNHAM in *The Sideral Messenger*, Vol. X, page 1, and MANN, *ibid.* page 13.

**Reference Books.**—(See Table XXIII.)

(1.) Bessel—Astronomische Nachrichten, No. 365–6, and Vol. XVII.

(2.) Peters—Recherches sur la Parallaxe des Étoiles Fixes. Recueil de Mémoires présentés à l' Académie des Sciences par les Astronomes de Poulkova. Vol. I, page 136.

(3.) Struve — Nouvelle Détermination de la Parallaxe annuelle des Étoiles *a* Lyræ et 61 Cygni. Memoires de l' Académie Impériale des Sciences de St.-Pétersbourg, VII Série. Vol. I, No. 1, page 44.

(4.) Auwers—Untersuchungen über die Beobachtungen von Bessel und Schlüter am Königsberger Heliometer zur Bestimmung der Parallaxe von 61 Cygni. Abhandlungen der Academie zu Berlin, 1868: page 113.

(5.) Socoloff — Parallaxes des Étoiles observées par G. Schweizer. Annales de l' Observatoire de Moscou, Vol. VIII, 2, pages 89–90.

(6.) Lamp—Neue Berechnung der Parallaxe von 61 Cygni aus den Beobachtungen von Schweizer in Moskau 1863–1866, Kiel, 1883, pages 52–9.

(7.) Johnson — Introduction to the Observations with the Heliometer. Part II of Astronomical Observations made at the Radcliffe Observatory in the year 1853. Vol. XIV, page xxxix.

(8.) Ball—On a new Determination of the Parallax of the Preceding Star of 61 Cygni by the Method of Differences of Declination. Astronomical Observations and Researches made at Dunsink. Part III, page 27.

(9.) Ball—Further Researches on the Parallax of 61 Cygni. Astronomical Observations and Researches made at Dunsink. Part V, page 166.

(10.) Belopolsky—Astronomische Nachrichten, No. 2888.

These values of parallax are computed from discordances in right ascension between observations made six months apart on the transit instrument by Wagner at Poulkova in 1862–1870.

(11.) Hall—Observations for Stellar Parallax. Washington Observations for 1883, Appendix II, pages 54 and 67.

(12.) Pritchard—Researches in Stellar Parallax by the aid of Photography, from Observations made at the Oxford University Observatory, Oxford, 1889.

In the formation of Table XXIII, giving the various values of the parallax of 61 *Cygni* hitherto published, I have not placed Pritchard's values in bold type, because they cannot be regarded as trustworthy. They have been discarded in taking the means of the determinations for $61^1$ and $61^2$. I have examined the eight sets of normal equations given in the work on 61 *Cygni* (pages 17–63) and among the eight sets have not found one which is correct in every quantity. The set on page 30 first attracted my attention and so it may be used for illustration. As given there the quantities are :

$$\begin{aligned} -\ 1''.3140 &= +\ 88.0000\,x - 6.7889\,d\mu - 2.5442\,\pi \\ +\ 4\ \ .3827 &= -\ \ 6.7889 \qquad + 8.4762 \qquad + 9.7965 \\ +17\ \ .1716 &= -\ \ 2.5442 \qquad + 9.7965 \qquad +38.7724 \end{aligned}$$

These should be :

$$\begin{aligned} -\ 1''.2180 &= +\ 88.0000\,x - 6.7889\,d\mu - 0.9281\,\pi \\ +\ 4\ \ .3853 &= -\ \ 6.7889 \qquad + 8.4783 \qquad + 9.7854 \\ +17\ \ .1967 &= -\ \ 0.9281 \qquad + 9.7854 \qquad +38.7849 \end{aligned}$$

This criticism applies not only to the normals for 61 *Cygni* but for many of the other stars as well. No attempt has been made to verify all the numbers in each set of normals, nor indeed to extend the test to all sets of normals given in the book, but it can be stated that at least one number is wrong in each of the fourteen sets given on pages 17, 23, 30, 36, 47, 52, 58, 73, 75, 87, 104, 106, 107 and 113.

(13.) Davis—Contributions from the Observatory of Columbia University, New York, No. 13.

(14.) Wilsing—Untersuchungen über die Parallaxe und die Eigenbewegung von 61 Cygni nach Photographischen Aufnahmen. Publicationen des Astrophysikalischen Observatoriums zu Potsdam, No. 36, pages 152 and 148.

(15.) Rambaut—On the Effects of Atmospheric Dispersion on the Position of a Star. Monthly Notices, Vol. LV, page 123.

(16.) Flint—Research Work at the Washburn Observatory. The Astrophysical Journal, Vol. VI, page 420.

A preliminary announcement of results now in process of computation.

(17.) Kapteyn—Bestimmung von 250 Parallaxen. Astronomische Nachrichten, Bd. 145, S. 300.

## V.—*The Rutherfurd Photographic Measures of Thirty-four Stars near "Bradley 3077."*

BY HERMAN S. DAVIS.

Read May, 1897.

**1**. The methods of reduction employed in the formation of this catalogue are the same as have been described in my paper on *Sixty-five Stars near 61 Cygni*, except that no corrections for parallax were applied. The computations have been almost entirely performed by Mrs. Davis, who has also rendered considerable assistance in the computations connected with all my other papers on the *Rutherfurd Measures*.

In this presentation of results the Tables have been given numbers to correspond with the similar tables in the paper on *61 Cygni*, reference to which will make clear any matter not sufficiently intelligible from the captions to the various columns.

**2**. Nearly the mean date of observation, 1874.0, was selected as the epoch to which the observations were reduced. Thus we have:

$$\Delta p_{73} = -8'' + [0.919]\,A + [0.246_n]\,B + [0.167_n]\,C + [9.537]\,D$$
$$\Delta p_{74} = \;\;0 \;+ [0.919]\,A + [0.246_n]\,B + [0.167_n]\,C + [9.537]\,D$$

as the correction for precession, nutation and aberration in position-angle; and, for all years, to correct for aberration in distance:

$$\Delta s = \{[4.058]C + [4.416_n]D\}s$$

**3**. The logarithms of the Besselian day-numbers, taken from the *American Ephemeris*, are:

| Plates. | log $A$. | log $B$. | log $C$. | log $D$. |
|---|---|---|---|---|
| 1, 2, 3, | 9.786 | $0.808_n$ | 1.053 | 1.213 |
| 4, 5, 6, | 9.805 | $0.801_n$ | 0.958 | 1.253 |
| 7, 8, | 9.336 | $0.857_n$ | $0.776_n$ | $1.287_n$ |
| 9, 10, | 9.411 | $0.854_n$ | $0.418_n$ | $1.306_n$ |
| 11, 12. | 9.417 | $0.854_n$ | $0.364_n$ | $1.307_n$ |

**4.** ARGELANDER'S position and proper motion of this star as given in *Mittlere Positionen von 160 Sternen* have been adopted. For 1874.0 they are:

$$\alpha = 23^h\ 07^m\ 13^s.356 \qquad \mu = +0^s.24867$$
$$\delta = 56^\circ\ 28'\ 21''.95 \qquad \mu' = +0''.2685$$

From these are derived:

$$\rho = 2''.07765 = 0^d.07416 \qquad \chi = 82^\circ\ 34'\ 29''$$

The values of $P_1$, $P_2$, $P_5$, and $K$, depending hereon, are in Table VII on page 184; and $S_1$, $S_5$, $S_6$, and $S_7$, are in Table VIII.

**5.** For determining the correction for scale-variation, stars numbered 3, 9, 19, 20, 31 and 33 have been used. These are so distributed that

$$\Sigma s_s = 428^d.6222, \quad \Sigma \cos p = -0.01, \quad \text{and } \Sigma \sin p = -0.10$$

Therefore the

$$\text{Scale variation} = \frac{\Sigma s_s - (s_3 + s_9 + s_{19} + s_{20} + s_{31} + s_{33})}{\Sigma s_s}\, s.$$

This factor of $s$ will be found on page 184.

**6.** The correction for orientation variation on page 184 has been deduced in the same manner as described in paragraphs 19–21 of the paper on *61 Cygni*, except that Mrs. Davis has reduced the orientation to the mean of all the plates excluding that numbered six, regarding for very obvious reasons the mean of the remaining eleven as nearer the truth than the mean of the entire twelve. Thus the corrections actually applied reduces the orientation to the mean of the remaining eleven plates. The nine stars whose numbers are 8, 9, 10, 11, 14, 16, 17, 20 and 33 after correction for proper motion have been used as standards. They give:

$$\frac{\Sigma\sigma^2 S_8}{\Sigma\sigma^2} = +6.0 \quad \text{and} \quad \frac{\Sigma\sigma^2 S_9}{\Sigma\sigma^2} = -2.3$$

**7.** For calculating the difference of right ascension and of declination the following constants have been used:

$$\log P = 0.257799 \qquad \log R = 9.5094_n \qquad \log T = 4.5633_n$$
$$\log Q = 5.1221 \qquad \log S = 0.0458 \qquad \log U = 9.4870_n$$

Also, by paragraph 24 of *Catalogue of Sixty-five Stars near 61 Cygni*.

$$n = \sigma \sin \pi$$
$$m = \sigma \cos \pi$$
$$\alpha' - \alpha = Pn + Qnm + Rn^3 + Snm^2$$
$$\delta' - \delta = m + Tn^2 + Un^2m$$

TABLE I.—GENERAL DATA.—Observatory of L. M. Rutherfurd, New York.

Lat. = 40° 43′ 48″.5 Long. = $4^h55^m56^s.62$ W

| Plate. | Date. | Sidereal Time. | Hour Angle. | Barom. | Att. Therm. | Ext. Therm. | Tel. Therm. | Focus. | Zero. | $\zeta$ | $q$ | log $\kappa$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | h m s | h m s | | ° | ° | ° | | | ° | ° | |
| 1 | 1873 Nov. 14 | 1 54 3 | 2 46 53 | 30.132 | 29 | 28 | 30 | 8.0 | 58.60 | 31.09 | +102.42 | 6 4709 |
| 2 | Nov. 14 | 2 28 3 | 3 20 53 | 30.132 | 29 | 28 | 30 | 8.0 | 63.73 | 35.73 | + 94.30 | 6.4707 |
| 3 | Nov. 14 | 3 4 3 | 3 56 53 | 30.132 | 29 | 28 | 30 | 8.0 | 59.19 | 40.70 | + 86.73 | 6.4704 |
| 4 | Nov. 22 | 2 45 33 | 3 38 23 | 30.418 | 36 | 35 | 36 | 7.8 | 54.68 | 38.16 | + 90.51 | 6.4682 |
| 5 | Nov. 22 | 3 18 23 | 4 11 13 | 30.418 | 36 | 35 | 36 | 7.8 | 58.90 | 42.67 | + 83.92 | 6.4679 |
| 6 | Nov. 22 | 3 50 43 | 4 43 33 | 30.418 | 36 | 35 | 36 | 7.8 | 40.86 | 47.08 | + 77.89 | 6.4676 |
| 7 | 1874 June 1 | 19 7 7 | 19 59 54 | 29.984 | 60 | 55 | 60 | 7.7 | 54.11 | 41.15 | — 86.09 | 6.4437 |
| 8 | June 1 | 19 44 23 | 20 37 10 | 29.984 | 60 | 55 | 60 | 7.7 | 54.73 | 36.00 | — 93.86 | 6.4440 |
| 9 | June 12 | 18 27 27 | 19 20 14 | 29.950 | 71 | 69 | 70 | 7.64 | 54.15 | 46.57 | — 78.58 | 6.4305 |
| 10 | June 12 | 19 0 17 | 19 53 4 | 29.950 | 71 | 69 | 70 | 7.64 | 48.89 | 42.09 | — 84.75 | 6.4312 |
| 11 | June 13 | 18 59 43 | 19 52 30 | 30.300 | 59 | 57 | 60 | 7.7 | 54.21 | 42.16 | — 84.64 | 6.4466 |
| 12 | June 13 | 19 33 33 | 20 26 20 | 30.300 | 59 | 57 | 60 | 7.7 | 54.35 | 37.50 | — 91.51 | 6.4469 |

TABLE II.—CORRECTIONS FOR REFRACTION.

| Position Angle, $p$ | | $\frac{\sigma-s}{s}\times 10^3$ | $\pi-p$ | Position Angle, $p$ | | $\frac{\sigma-s}{s}\times 10^3$ | $\pi-p$ |
|---|---|---|---|---|---|---|---|
| PLATE 1. | | | | PLATE 2. | | | |
| | | | ″ | | | | ″ |
| 102° | 282° | +.410 | 0.0 | 94° | 274° | +.456 | 0.0 |
| 112 | 292 | .406 | — 3.9 | 104 | 284 | .451 | — 5.5 |
| 122 | 302 | .397 | — 7.2 | 114 | 294 | .438 | —10.4 |
| 132 | 312 | .383 | — 9.7 | 124 | 304 | .417 | —13.9 |
| 142 | 322 | .365 | —11.1 | 134 | 314 | .392 | —15.8 |
| 152 | 332 | .345 | —11.1 | 144 | 324 | .365 | —15.8 |
| 162 | 342 | .328 | — 9.7 | 154 | 334 | .339 | —13.9 |
| 172 | 352 | .314 | — 7.2 | 164 | 344 | .319 | —10.4 |
| 182 | 2 | .304 | — 3.9 | 174 | 354 | .306 | — 5.5 |
| 192 | 12 | .301 | 0.0 | 184 | 4 | .301 | 0.0 |
| 202 | 22 | .304 | + 3.9 | 194 | 14 | .306 | + 5.5 |
| 212 | 32 | .314 | + 7.2 | 204 | 24 | .319 | +10.4 |
| 222 | 42 | .328 | + 9.7 | 214 | 34 | .339 | +13.9 |
| 232 | 52 | .345 | +11.1 | 224 | 44 | .365 | +15.8 |
| 242 | 62 | .365 | +11.1 | 234 | 54 | .392 | +15.8 |
| 252 | 72 | .383 | + 9.7 | 244 | 64 | .417 | +13.9 |
| 262 | 82 | .397 | + 7.2 | 254 | 74 | .438 | +10.4 |
| 272 | 92 | .406 | + 3.9 | 264 | 84 | .451 | + 5.5 |
| 282 | 102 | .410 | 0.0 | 274 | 94 | .456 | 0.0 |
| PLATE 3. | | | | PLATE 4. | | | |
| | | | ′ | | | | ″ |
| 87° | 267° | +.521 | 0.0 | 91° | 271° | +.483 | 0.0 |
| 97 | 277 | .515 | — 7.8 | 101 | 281 | .477 | — 6.5 |
| 107 | 287 | .496 | —14.7 | 111 | 291 | .462 | —12.2 |
| 117 | 297 | .466 | —19.8 | 121 | 301 | .437 | —16.4 |
| 127 | 307 | .430 | —22.5 | 131 | 311 | .407 | —18.7 |
| 137 | 317 | .391 | —22.5 | 141 | 321 | .375 | —18.7 |
| 147 | 327 | .355 | —19.8 | 151 | 331 | .344 | —16.4 |
| 157 | 337 | .326 | —14.7 | 161 | 341 | .320 | —12.2 |
| 167 | 347 | .306 | — 7.8 | 171 | 351 | .305 | — 6.5 |
| 177 | 357 | .300 | 0.0 | 181 | 1 | .299 | 0.0 |
| 187 | 7 | .306 | + 7.8 | 191 | 11 | .305 | + 6.5 |
| 197 | 17 | .326 | +14.7 | 201 | 21 | .320 | +12.2 |
| 207 | 27 | .355 | +19.8 | 211 | 31 | .344 | +16.4 |
| 217 | 37 | .391 | +22.5 | 221 | 41 | .375 | +18.7 |
| 227 | 47 | .430 | +22.5 | 231 | 51 | .407 | +18.7 |
| 237 | 57 | .466 | +19.8 | 241 | 61 | .437 | +16.4 |
| 247 | 67 | .496 | +14.7 | 251 | 71 | .462 | +12.2 |
| 257 | 77 | .515 | + 7.8 | 261 | 81 | .477 | + 6.5 |
| 267 | 87 | .521 | 0.0 | 271 | 91 | .483 | 0.0 |

TABLE II.—CORRECTIONS FOR REFRACTION. (*Continued.*)

| Position Angle, $p$ | | $\frac{\sigma-s}{s}\times 10^3$ | $\pi-p$ | Position Angle, $p$ | | $\frac{\sigma-s}{s}\times 10^3$ | $\pi-p$ |
|---|---|---|---|---|---|---|---|
| PLATE 5. | | | | PLATE 6. | | | |
| 84° | 264° | +.552 | ″<br>0.0 | 78° | 258° | +.644 | ″<br>0.0 |
| 94 | 274 | .544 | — 8.9 | 88 | 268 | .634 | —12.2 |
| 104 | 284 | .523 | —16.8 | 98 | 278 | .603 | —22.8 |
| 114 | 294 | .489 | —22.6 | 108 | 288 | .557 | —30.8 |
| 124 | 304 | .448 | —25.7 | 118 | 298 | .502 | —35.0 |
| 134 | 314 | .403 | —25.7 | 128 | 308 | .441 | —35.0 |
| 144 | 324 | .361 | —22.6 | 138 | 318 | .385 | —30.8 |
| 154 | 334 | .328 | —16.8 | 148 | 328 | .339 | —22.8 |
| 164 | 344 | .307 | — 8.9 | 158 | 338 | .309 | —12.2 |
| 174 | 354 | .299 | 0.0 | 168 | 348 | .299 | 0.0 |
| 184 | 4 | .307 | + 8.9 | 178 | 358 | .309 | +12.2 |
| 194 | 14 | .328 | +16.8 | 188 | 8 | .339 | +22.8 |
| 204 | 24 | .361 | +22.6 | 198 | 18 | .385 | +30.8 |
| 214 | 34 | .403 | +25.7 | 208 | 28 | .441 | +35.0 |
| 224 | 44 | .448 | +25.7 | 218 | 38 | .502 | +35.0 |
| 234 | 54 | .489 | +22.6 | 228 | 48 | .557 | +30.8 |
| 244 | 64 | .523 | +16.8 | 238 | 58 | .603 | +22.8 |
| 254 | 74 | .544 | + 8.9 | 248 | 68 | .634 | +12.2 |
| 264 | 84 | .552 | 0.0 | 258 | 78 | .644 | 0.0 |
| PLATE 7. | | | | PLATE 8. | | | |
| 274° | 94° | +.498 | ″<br>0.0 | 266° | 86° | +.432 | ″<br>0.0 |
| 284 | 104 | .491 | — 7.6 | 276 | 96 | .427 | — 5.3 |
| 294 | 114 | .473 | —14.3 | 286 | 106 | .414 | — 9.8 |
| 304 | 124 | .444 | —19.3 | 296 | 116 | .394 | —13.3 |
| 314 | 134 | .409 | —21.9 | 306 | 126 | .370 | —15.1 |
| 324 | 144 | .372 | —21.9 | 316 | 136 | .344 | —15.1 |
| 334 | 154 | .336 | —19.3 | 326 | 146 | .320 | —13.3 |
| 344 | 164 | .308 | —14.3 | 336 | 156 | .300 | — 9.8 |
| 354 | 174 | .288 | — 7.6 | 346 | 166 | .286 | — 5.3 |
| 4 | 184 | .282 | 0.0 | 356 | 176 | .282 | 0.0 |
| 14 | 194 | .288 | + 7.6 | 6 | 186 | .286 | + 5.3 |
| 24 | 204 | .308 | +14.3 | 16 | 196 | .300 | + 9.8 |
| 34 | 214 | .336 | +19.3 | 26 | 206 | .320 | +13.3 |
| 44 | 224 | .372 | +21.9 | 36 | 216 | .344 | +15.1 |
| 54 | 234 | .409 | +21.9 | 46 | 226 | .370 | +15.1 |
| 64 | 244 | .444 | +19.3 | 56 | 236 | .394 | +13.3 |
| 74 | 254 | .473 | +14.3 | 66 | 246 | .414 | + 9.8 |
| 84 | 264 | .491 | + 7.6 | 76 | 256 | .427 | + 5.3 |
| 94 | 274 | .498 | 0.0 | 86 | 266 | .432 | 0.0 |

TABLE II.—CORRECTIONS FOR REFRACTION. (*Concluded.*)

| Position Angle, $p$ | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ | Position Angle, $p$ | | $\frac{\sigma - s}{s} \times 10^3$ | $\pi - p$ |
|---|---|---|---|---|---|---|---|
| **PLATE 9.** | | | | **PLATE 10.** | | | |
| 281° | 101° | +.580 | 0.0″ | 275° | 95° | +.498 | 0.0″ |
| 291 | 111 | .571 | —10.8 | 285 | 105 | .491 | — 7.9 |
| 301 | 121 | .544 | —20.2 | 295 | 115 | .471 | —14.8 |
| 311 | 131 | .504 | —27.2 | 305 | 125 | .442 | —20.0 |
| 321 | 141 | .454 | —31.0 | 315 | 135 | .405 | —22.7 |
| 331 | 151 | .400 | —31.0 | 325 | 145 | .367 | —22.7 |
| 341 | 161 | .350 | —27.2 | 335 | 155 | .330 | —20.0 |
| 351 | 171 | .310 | —20.2 | 345 | 165 | .301 | —14.8 |
| 1 | 181 | .283 | —10.8 | 355 | 175 | .280 | — 7.9 |
| 11 | 191 | .274 | 0.0 | 5 | 185 | .274 | 0.0 |
| 21 | 201 | .283 | +10.8 | 15 | 195 | .280 | + 7.9 |
| 31 | 211 | .310 | +20.2 | 25 | 205 | .301 | +14.8 |
| 41 | 221 | .350 | +27.2 | 35 | 215 | .330 | +20.0 |
| 51 | 231 | .400 | +31.0 | 45 | 225 | .367 | +22.7 |
| 61 | 241 | .454 | +31.0 | 55 | 235 | .405 | +22.7 |
| 71 | 251 | .504 | +27.2 | 65 | 245 | .442 | +20.0 |
| 81 | 261 | .544 | +20.2 | 75 | 255 | .471 | +14.8 |
| 91 | 271 | .571 | +10.8 | 85 | 265 | .491 | + 7.9 |
| 101 | 281 | .580 | 0.0 | 95 | 275 | .498 | 0.0 |
| **PLATE 11.** | | | | **PLATE 12.** | | | |
| 275° | 95° | +.518 | 0.0″ | 268° | 88° | +.452 | 0.0″ |
| 285 | 105 | .511 | — 8.2 | 278 | 98 | .447 | — 5.9 |
| 295 | 115 | .490 | —15.4 | 288 | 108 | .432 | —11.1 |
| 305 | 125 | .459 | —20.7 | 298 | 118 | .409 | —14.9 |
| 315 | 135 | .421 | —23.6 | 308 | 128 | .383 | —17.0 |
| 325 | 145 | .381 | —23.6 | 318 | 138 | .353 | —17.0 |
| 335 | 155 | .342 | —20.7 | 328 | 148 | .326 | —14.9 |
| 345 | 165 | .312 | —15.4 | 338 | 158 | .304 | —11.1 |
| 355 | 175 | .291 | — 8.2 | 348 | 168 | .289 | — 5.9 |
| 5 | 185 | .284 | 0.0 | 358 | 178 | .284 | 0 0 |
| 15 | 195 | .291 | + 8.2 | 8 | 188 | .289 | + 5.9 |
| 25 | 205 | .312 | +15.4 | 18 | 198 | .304 | +11.1 |
| 35 | 215 | .342 | +20.7 | 28 | 208 | .326 | +14.9 |
| 45 | 225 | .381 | +23.6 | 38 | 218 | .353 | +17.0 |
| 55 | 235 | .421 | +23.6 | 48 | 228 | .383 | +17.0 |
| 65 | 245 | .459 | +20.7 | 58 | 238 | .409 | +14.9 |
| 75 | 255 | .490 | +15.4 | 68 | 248 | .432 | +11.1 |
| 85 | 265 | .511 | + 8.2 | 78 | 258 | .447 | + 5.9 |
| 95 | 275 | .518 | 0.0 | 88 | 268 | .452 | 0.0 |

TABLE III.—CORRECTIONS FOR PRECESSION, ETC., TO 1874 AND ZERO CORRECTIONS.

| Plate No. | Precession, etc. | | Zero Correction ½(East + West) | Special Correction Mean. | Adopted Mean. |
|---|---|---|---|---|---|
| | Position Angle Correction. | Distance Factor × 10³ | | | |
| | ″ | | ′ ″ | ″ | ′ ″ |
| 1 | — 2.9 | —.0297 | +20 31 | —35 | +19 56 |
| 2 | — 2.9 | —.0297 | 22 23 | —38 | 21 45 |
| 3 | — 2.9 | —.0297 | 20 50 | —31 | 20 19 |
| 4 | + 1.0 | —.0363 | 19 16 | —54 | 18 22 |
| 5 | + 1.0 | —.0363 | 20 52 | —44 | 20 8 |
| 6 | + 1.0 | —.0363 | 14 39 | —35 | 14 4 |
| 7 | +16.6 | +.0437 | 19 18 | —41 | 18 37 |
| 8 | +16.6 | +.0437 | 19 36 | —42 | 18 54 |
| 9 | +11.5 | +.0497 | 19 5 | —52 | 18 13 |
| 10 | +11.5 | +.0497 | 17 22 | —52 | 16 30 |
| 11 | +11.2 | +.0502 | 19 14 | —36 | 18 38 |
| 12 | +11.2 | +.0502 | +19 21 | —41 | +18 40 |

TABLE IV.—TANGENT CORRECTION.

This correction is always *negative*, and is here expressed in terms of the *fourth* decimal place of the micrometer readings.

| Distance. | 0. | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. |
|---|---|---|---|---|---|---|---|---|---|---|
| 20. | — 0 | — 0 | — 0 | — 0 | — 0 | — 1 | — 1 | — 1 | — 1 | — 1 |
| 30. | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 40. | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 7 |
| 50. | 8 | 8 | 8 | 9 | 9 | 10 | 10 | 11 | 11 | 12 |
| 60. | 13 | 13 | 14 | 15 | 16 | 17 | 17 | 18 | 19 | 20 |
| 70. | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 30 | 31 |
| 80. | 32 | 34 | 35 | 36 | 37 | 38 | 40 | 41 | 42 | 43 |
| 90. | 45 | 46 | 48 | 50 | 52 | 53 | 55 | 57 | 59 | 61 |
| 100. | 62 | 64 | 65 | 67 | 69 | 71 | 73 | 75 | 77 | 79 |
| 110. | 81 | 83 | 85 | 87 | 90 | 93 | 95 | 98 | 100 | 103 |
| 120. | 106 | 109 | 112 | 114 | 117 | 120 | 123 | 126 | 129 | 132 |
| 130. | —135 | —138 | —141 | —145 | —148 | —151 | —155 | —158 | —162 | —165 |

## Table V.—Results of Measures of Distance.

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Corrected Mean. | Scale Variation. | Proper Motion. | Final Corrected Distance. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | $s$ | | | $\sigma$ |
| **1** | 11 | .9218 | .9090 | 625 | +62 | 80 | .9802 | − 46 | −.0334 | 123.9422 |
| (2) | 12 | .8604 | .9280 | 557 | +62 | 94 | .9536 | − 52 | −.0334 | .9150 |
| | | | | | | Mean | | | | 123.9286 |
| **2** | 1 | .0565 | .0314 | 426 | −35 | 118 | .0851 | − 11 | +.0088 | 117.0928 |
| (5) | 2 | .0288 | .0212 | 480 | −35 | 118 | .0715 | + 31 | +.0088 | .0834 |
| | 4 | .0233 | .0122 | 512 | −42 | 108 | .0658 | +135 | +.0073 | .0866 |
| | 5 | .0191 | .0307 | 603 | −35 | 112 | .0831 | + 21 | +.0073 | .0925 |
| | 7 | .0681 | .0718 | 508 | +51 | 118 | .1278 | − 8 | −.0290 | .0980 |
| | 8 | .0672 | .0506 | 473 | +51 | 118 | .1134 | + 8 | −.0290 | .0852 |
| | 11 | .0588 | .0687 | 518 | +59 | 118 | .1234 | − 44 | −.0312 | .0878 |
| | 12 | .0788 | .0600 | 490 | +59 | 118 | .1263 | − 49 | −.0312 | .0902 |
| | | | | | | Mean | | | | 117.0896 |
| **3** | 1 | .8405 | .8320 | 308 | −23 | 126 | .8747 | − 7 | +.0092 | 75.8832 |
| (37) | 2 | .8343 | .8318 | 345 | −23 | 126 | .8751 | + 20 | +.0092 | .8863 |
| | 3 | .8370 | .8265 | 393 | −23 | 126 | .8787 | + 3 | +.0092 | .8882 |
| | 4 | .8290 | .8253 | 365 | −28 | 119 | .8700 | + 87 | +.0077 | .8864 |
| | 5 | .8246 | .8268 | 414 | −28 | 120 | .8736 | + 14 | +.0077 | .8827 |
| | 6 | .8246 | .8302 | 470 | −28 | 126 | .8815 | − 39 | +.0077 | .8853 |
| | 7 | .8677 | .8751 | 377 | +33 | 125 | .9222 | − 5 | −.0305 | .8912 |
| | 8 | .8702 | .8771 | 326 | +33 | 125 | .9193 | + 5 | −.0305 | .8893 |
| | 9 | .8731 | .8745 | 434 | +38 | 118 | .9301 | − 30 | −.0327 | .8944 |
| | 10 | .8802 | .86[illegible]8 | 376 | +38 | 119 | .9221 | + 11 | −.0327 | .8905 |
| | 11 | .8722 | .8724 | 392 | +38 | 126 | .9251 | − 28 | −.0329 | .8894 |
| | 12 | .8680 | .8923 | 342 | +38 | 120 | .9275 | − 32 | −.0329 | .8914 |
| | | | | | | Mean | | | | 75.8882 |
| **4** | 1 | .6812 | .6768 | 297 | −24 | 125 | .7156 | − 8 | +.0090 | 79.7238 |
| (4) | 2 | .6670 | .6668 | 336 | −24 | 126 | .7075 | + 21 | +.0090 | .7186 |
| | 3 | .6482 | .6546 | 393 | −24 | 125 | .6976 | + 3 | +.0090 | .7069 |
| | 4 | .6526 | .6361 | 357 | −29 | 122 | .6861 | + 92 | +.0075 | .7028 |
| | 5 | .6528 | .6540 | 421 | −29 | 121 | .7015 | + 15 | +.0075 | .7105 |
| | 6 | .6520 | .6515 | 500 | −29 | 125 | .7082 | − 41 | +.0075 | .7116 |
| | 7 | .7078 | .7126 | 359 | +35 | 126 | .7590 | − 5 | −.0297 | .7288 |
| | 8 | .7097 | .7233 | 330 | +35 | 126 | .7624 | + 5 | −.0297 | .7332 |
| | 9 | .7018 | .7226 | 382 | +40 | 122 | .7634 | − 31 | −.0319 | .7284 |
| | 10 | .7171 | .7008 | 355 | +40 | 122 | .7575 | + 12 | −.0319 | .7268 |
| | 11 | .7009 | .7205 | 368 | +40 | 126 | .7609 | − 30 | −.0321 | .7258 |
| | 12 | .7038 | .7110 | 340 | +48 | 126 | .7548 | − 34 | −.0321 | .7193 |
| | | | | | | Mean | | | | 79.7197 |
| **5** | 1 | .4787 | .5182 | 383 | −36 | 112 | .5337 | − 12 | +.0062 | 120.5387 |
| (7) | 2 | .4734 | .4791 | 408 | −36 | 108 | .5136 | + 32 | +.0062 | .5230 |
| | 4 | .4728 | .4666 | 425 | −44 | 108 | .5079 | +139 | +.0052 | .5270 |
| | 7 | .5138 | .5006 | 406 | +53 | 109 | .5533 | − 8 | −.0206 | .5319 |
| | 9 | .5070 | .5259 | 389 | +60 | 109 | .5615 | − 47 | −.0220 | .5348 |
| | | | | | | Mean | | | | 120.5311 |

## Table VI.—Results of Measures of Angle.

| Plate | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. p | Proper Motion. | Final Corrected Angle. π |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ° ′ ″ | ′ ″ | ° ′ ″ |
| 11 | 351 38 20 | 39 25 | 18 38 | +10 | 261 57 41 | −0 2 | 261 57 53 |
| 12 | 40 50 | 41 45 | 18 40 | +4 | 262 0 2 | −0 2 | 57 22 |
| | | | | Mean | 261 58 52 | | 261 57 38 |
| 1 | 331 22 50 | 23 32 | 19 56 | +11 | 241 43 18 | +0 6 | 241 43 58 |
| 2 | 19 8 | 21 30 | 21 45 | +15 | 42 20 | +0 6 | 43 33 |
| 4 | 24 22 | 25 7 | 18 22 | +16 | 43 22 | +0 5 | 43 56 |
| 5 | 21 45 | 23 11 | 20 8 | +17 | 42 53 | +0 5 | 44 1 |
| 7 | 23 43 | 25 45 | 18 37 | +20 | 43 41 | −0 21 | 44 23 |
| 8 | 24 50 | 27 3 | 18 54 | +12 | 45 3 | −0 21 | 44 23 |
| 11 | 24 58 | 25 45 | 18 38 | +22 | 44 22 | −0 22 | 44 14 |
| 12 | 27 10 | 28 17 | 18 40 | +13 | 46 37 | −0 22 | 43 37 |
| | | | | Mean | 241 43 57 | | 241 44 1 |
| 1 | 2 29 48 | 31 34 | 19 56 | +4 | 272 50 41 | −0 4 | 272 51 11 |
| 2 | 27 40 | 28 38 | 21 45 | +2 | 49 56 | −0 4 | 50 59 |
| 3 | 31 3 | 32 6 | 20 19 | −4 | 51 50 | −0 4 | 51 25 |
| 4 | 31 57 | 34 8 | 18 22 | −2 | 51 22 | −0 4 | 51 47 |
| 5 | 30 6 | 30 50 | 20 8 | −6 | 50 30 | −0 4 | 51 29 |
| 6 | 30 12 | 31 32 | 14 4 | −17 | 44 39 | −0 4 | 51 42 |
| 7 | 30 26 | 31 32 | 18 37 | +2 | 49 38 | +0 14 | 50 55 |
| 8 | 31 48 | 33 13 | 18 54 | −3 | 51 22 | +0 14 | 51 17 |
| 9 | 33 15 | 33 48 | 18 13 | +9 | 51 54 | +0 15 | 51 13 |
| 10 | 33 42 | 35 27 | 16 30 | +2 | 51 6 | +0 15 | 51 6 |
| 11 | 31 26 | 32 34 | 18 38 | +2 | 50 40 | +0 15 | 51 9 |
| 12 | 34 28 | 34 54 | 18 40 | −3 | 53 18 | +0 15 | 50 55 |
| | | | | Mean | 272 50 35 | | 272 51 16 |
| 1 | 335 57 10 | 57 27 | 19 56 | +10 | 246 17 24 | +0 7 | 246 18 5 |
| 2 | 54 33 | 55 42 | 21 45 | +13 | 17 5 | +0 7 | 18 19 |
| 3 | 57 25 | 58 13 | 20 19 | +16 | 18 24 | +0 7 | 18 10 |
| 4 | 58 8 | 00 0 | 18 22 | +17 | 17 43 | +0 6 | 18 18 |
| 5 | 56 1 | 57 2 | 20 8 | +15 | 16 55 | +0 6 | 18 4 |
| 6 | 56 45 | 58 5 | 14 4 | +14 | 11 43 | +0 6 | 18 56 |
| 7 | 57 48 | 59 20 | 18 37 | +18 | 17 29 | −0 24 | 18 8 |
| 8 | 59 23 | 00 38 | 18 54 | +10 | 19 5 | −0 24 | 18 22 |
| 9 | 336 00 2 | 1 50 | 18 13 | +29 | 19 38 | −0 26 | 18 16 |
| 10 | 1 38 | 2 42 | 16 30 | +19 | 18 59 | −0 26 | 18 18 |
| 11 | 335 58 39 | 59 45 | 18 38 | +20 | 18 10 | −0 26 | 17 58 |
| 12 | 336 1 27 | 3 8 | 18 40 | +12 | 21 10 | −0 26 | 18 6 |
| | | | | Mean | 246 17 49 | | 246 18 15 |
| 1 | 303 48 8 | 49 33 | 19 56 | +8 | 214 8 54 | +0 12 | 214 9 40 |
| 2 | 45 14 | 46 12 | 21 45 | +14 | 7 41 | +0 12 | 9 0 |
| 4 | 48 57 | 51 5 | 18 22 | +17 | 8 40 | +0 10 | 9 19 |
| 7 | 49 6 | 50 40 | 18 37 | +19 | 8 49 | −0 41 | 9 11 |
| 9 | 51 40 | 54 10 | 18 13 | +22 | 11 30 | −0 44 | 9 50 |
| | | | | Mean | 214 9 7 | | 214 9 24 |

Table V.—Results of Measures of Distance. (*Continued.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **6** | 1 | .6300 | .6668 | 206 | —18 | 108 | .6767 | — 6 | +.0079 | 60.6840 |
| (6) | 7 | .6482 | .6756 | 237 | +27 | 104 | .6974 | — 4 | —.0260 | .6710 |
| | 8 | .6311 | .6802 | 229 | +27 | 104 | .6903 | + 4 | —.0260 | .6647 |
| | 11 | .6501 | .6848 | 242 | +30 | 104 | .7037 | — 23 | —.0280 | .6734 |
| | 12 | .6314 | .7006 | 234 | +30 | 104 | .7015 | — 26 | —.0280 | .6709 |
| | | | | | | Mean | | | | 60.6728 |
| **7** | 1 | .4126 | .4174 | 280 | —27 | 132 | .4491 | — 9 | +.0058 | 89.4540 |
| (8) | 2 | .4182 | .4170 | 297 | —27 | 132 | .4534 | + 24 | +.0058 | .4616 |
| | 3 | .4091 | .4190 | 329 | —27 | 135 | .4533 | + 3 | +.0058 | .4594 |
| | 4 | .4038 | .3977 | 307 | —32 | 132 | .4371 | +103 | +.0049 | .4523 |
| | 7 | .4462 | .4322 | 292 | +39 | 135 | .4814 | — 6 | —.0193 | .4615 |
| | 9 | .4520 | .4428 | 276 | +44 | 132 | .4882 | — 35 | —.0207 | .4640 |
| | 11 | .4362 | .4448 | 291 | +45 | 135 | .4832 | — 33 | —.0208 | .4591 |
| | 12 | .4324 | .4485 | 297 | +45 | 135 | .4838 | — 38 | —.0208 | .4592 |
| | | | | | | Mean | | | | 89.4589 |
| **8** | 1 | .4792 | .4746 | 226 | —17 | 98 | .5063 | — 6 | +.0063 | 58.5120 |
| (36) | 2 | .4758 | .4712 | 235 | —17 | 96 | .5037 | + 16 | +.0063 | .5116 |
| | 3 | .4737 | .4681 | 245 | —17 | 98 | .5023 | + 2 | +.0063 | .5088 |
| | 4 | .4762 | .4686 | 240 | —21 | 92 | .5023 | + 67 | +.0052 | .5142 |
| | 5 | .4792 | .4766 | 246 | —21 | 95 | .5087 | + 11 | +.0052 | .5150 |
| | 6 | .4765 | .4783 | 253 | —21 | 98 | .5092 | — 30 | +.0052 | .5114 |
| | 7 | .4964 | .4917 | 249 | +26 | 95 | .5298 | — 4 | —.0208 | .5086 |
| | 8 | .5143 | .5112 | 209 | +26 | 95 | .5446 | + 4 | —.0208 | .5242 |
| | 9 | .4998 | .5047 | 297 | +29 | 94 | .5430 | — 23 | —.0223 | .5184 |
| | 10 | .5128 | .5015 | 248 | +29 | 90 | .5427 | + 8 | —.0223 | .5212 |
| | 11 | .4968 | .5012 | 257 | +29 | 95 | .5359 | — 22 | —.0224 | .5113 |
| | 12 | .4998 | .4960 | 221 | +29 | 95 | .5312 | — 25 | —.0224 | .5063 |
| | | | | | | Mean | | | | 58.5136 |
| **9** | 1 | .6254 | .6327 | 120 | — 9 | —12 | .6387 | — 3 | +.0093 | 29.6477 |
| (1) | 2 | .6082 | .6068 | 134 | — 9 | — 9 | .6189 | + 8 | +.0093 | .6290 |
| | 3 | .6143 | .6124 | 154 | — 9 | —12 | .6264 | + 1 | +.0093 | .6358 |
| | 4 | .6158 | .5907 | 143 | —11 | —16 | .6147 | + 34 | +.0077 | .6258 |
| | 5 | .6198 | .6114 | 162 | —11 | —13 | .6292 | + 5 | +.0077 | .6374 |
| | 6 | .5928 | .6051 | 185 | —11 | —12 | .6149 | — 15 | +.0077 | .6211 |
| | 7 | .6592 | .6639 | 147 | +13 | — 9 | .6764 | — 2 | —.0307 | .6455 |
| | 8 | .6626 | .6476 | 128 | +13 | — 9 | .6681 | + 2 | —.0307 | .6376 |
| | 9 | .6701 | .6652 | 169 | +15 | —15 | .6844 | — 12 | —.0329 | .6503 |
| | 10 | .6486 | .6434 | 147 | +15 | —16 | .6604 | + 4 | —.0329 | .6279 |
| | 11 | .6690 | .6858 | 153 | +15 | — 9 | .6931 | — 11 | —.0331 | .6589 |
| | 12 | .6680 | .6870 | 134 | +15 | —13 | .6909 | — 13 | —.0331 | .6565 |
| | | | | | | Mean | | | | 29 6394 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. $p$ | Proper Motion. | Final Corrected Angle $\pi$ |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ° ′ ″ | ′ ″ | ° ′ ″ |
| 1 | 319 8 16 | 10 5 | 19 56 | +11 | 229 29 17 | + 0 18 | 229 30 9 |
| 7 | 11 20 | 12 14 | 18 37 | +22 | 30 46 | — 0 59 | 30 50 |
| 8 | 11 21 | 13 29 | 18 54 | +14 | 31 33 | — 0 59 | 30 15 |
| 11 | 11 43 | 12 58 | 18 38 | +24 | 31 23 | — 1 3 | 30 34 |
| 12 | 12 53 | 15 58 | 18 40 | +16 | 33 22 | — 1 3 | 29 41 |
| | | | | Mean | 229 31 16 | | 229 30 18 |
| 1 | 300 40 20 | 41 54 | 19 56 | + 6 | 211 1 9 | + 0 17 | 211 2 0 |
| 2 | 38 36 | 38 53 | 21 45 | +12 | 0 42 | + 0 17 | 2 6 |
| 3 | 41 35 | 41 28 | 20 19 | +21 | 2 12 | + 0 17 | 2 8 |
| 4 | 41 25 | 43 31 | 18 22 | +16 | 1 6 | + 0 14 | 1 49 |
| 7 | 43 42 | 44 35 | 18 37 | +18 | 3 3 | — 0 57 | 3 9 |
| 9 | 45 50 | 46 45 | 18 13 | +19 | 4 49 | — 1 1 | 2 52 |
| 11 | 43 47 | 44 37 | 18 38 | +18 | 3 8 | — 1 2 | 2 20 |
| 12 | 46 12 | 47 45 | 18 40 | +15 | 5 53 | — 1 2 | 2 13 |
| | | | | Mean | 211 2 45 | | 211 2 20 |
| 1 | 39 59 28 | 00 26 | 19 56 | — 9 | 310 19 45 | — 0 24 | 310 19 55 |
| 2 | 56 38 | 57 52 | 21 45 | —15 | 18 45 | — 0 24 | 19 28 |
| 3 | 40 0 35 | 2 8 | 20 19 | —23 | 21 18 | — 0 24 | 20 33 |
| 4 | 1 48 | 3 2 | 18 22 | —18 | 20 29 | — 0 20 | 20 38 |
| 5 | 39 59 44 | 59 48 | 20 8 | —26 | 19 28 | — 0 20 | 20 11 |
| 6 | 59 30 | 00 51 | 14 4 | —34 | 13 41 | — 0 20 | 20 28 |
| 7 | 58 3 | 59 55 | 18 37 | —20 | 17 16 | + 1 20 | 19 39 |
| 8 | 59 12 | 59 50 | 18 54 | —15 | 18 10 | + 1 20 | 19 11 |
| 9 | 40 1 2 | 1 44 | 18 13 | —27 | 19 9 | + 1 25 | 19 38 |
| 10 | 1 30 | 3 46 | 16 30 | —21 | 18 47 | + 1 25 | 19 57 |
| 11 | 39 59 5 | 59 40 | 18 38 | —22 | 17 38 | + 1 26 | 19 18 |
| 12 | 40 1 25 | 2 50 | 18 40 | —17 | 20 31 | + 1 26 | 19 19 |
| | | | | Mean | 310 18 45 | | 310 19 51 |
| 1 | 0 27 0 | 25 25 | 19 56 | + 5 | 270 46 13 | — 0 9 | 270 46 38 |
| 2 | 24 22 | 25 12 | 21 45 | + 3 | 46 35 | — 0 9 | 47 33 |
| 3 | 28 12 | 27 34 | 20 19 | — 3 | 48 8 | — 0 9 | 47 38 |
| 4 | 27 45 | 27 18 | 18 22 | + 1 | 45 55 | — 0 7 | 46 17 |
| 5 | 27 47 | 24 28 | 20 8 | — 5 | 46 11 | — 0 7 | 47 7 |
| 6 | 26 40 | 27 42 | 14 4 | —15 | 41 0 | — 0 7 | 48 0 |
| 7 | 28 26 | 28 50 | 18 37 | + 3 | 47 18 | + 0 29 | 48 50 |
| 8 | 28 2 | 31 00 | 18 54 | — 3 | 48 22 | + 0 29 | 48 32 |
| 9 | 30 8 | 32 55 | 18 13 | +12 | 49 57 | + 0 32 | 49 33 |
| 10 | 29 28 | 32 32 | 16 30 | + 4 | 47 34 | + 0 32 | 47 51 |
| 11 | 27 57 | 27 23 | 18 38 | + 4 | 46 22 | + 0 32 | 47 8 |
| 12 | 30 48 | 31 5 | 18 40 | — 2 | 49 35 | + 0 32 | 47 29 |
| | | | | Mean | 270 46 56 | | 270 47 43 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Corrected Mean. | Scale Variation. | Proper Motion. | Final Corrected Distance. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | $s$ | | | $\sigma$ |
| **10** | 1 | .5694 | .5805 | 71 | − 6 | 82 | .5897 | − 2 | +.0092 | 18.5987 |
| (3) | 2 | .5719 | .5707 | 80 | − 6 | 82 | .5869 | + 5 | +.0092 | .5966 |
| | 3 | .5654 | .5760 | 93 | − 6 | 82 | .5876 | + 1 | +.0092 | .5969 |
| | 4 | .5708 | .5648 | 86 | − 7 | 80 | .5837 | + 21 | +.0076 | .5934 |
| | 5 | .5722 | .5796 | 100 | − 7 | 79 | .5931 | + 3 | +.0076 | .6010 |
| | 6 | .5602 | .5624 | 118 | − 7 | 82 | .5806 | − 9 | +.0076 | .5873 |
| | 7 | .6199 | .6315 | 86 | + 8 | 84 | .6435 | − 1 | −.0303 | .6131 |
| | 8 | .6193 | .6273 | 78 | + 8 | 83 | .6402 | + 1 | −.0303 | .6100 |
| | 9 | .6193 | .6354 | 93 | + 9 | 80 | .6455 | − 7 | −.0325 | .6123 |
| | 10 | .6271 | .6077 | 85 | + 9 | 80 | .6348 | + 3 | −.0325 | .6026 |
| | 11 | .6221 | .6370 | 88 | + 9 | 83 | .6476 | − 7 | −.0327 | .6142 |
| | 12 | .6156 | .6302 | 81 | + 9 | 79 | .6397 | − 8 | −.0327 | .6062 |
| | | | | | | Mean | | | | 18.6027 |
| **11** | 1 | .8040 | .8069 | 321 | −31 | 114 | .8386 | − 10 | +.0022 | 105.8398 |
| (13) | 2 | .7998 | .7846 | 320 | −31 | 113 | .8251 | + 28 | +.0022 | .8301 |
| | 3 | .8079 | .7994 | 323 | −31 | 114 | .8369 | + 4 | +.0022 | .8395 |
| | 4 | .7984 | .7982 | 319 | −38 | 113 | .8304 | +122 | +.0018 | .8444 |
| | 5 | .7858 | .8043 | 329 | −38 | 114 | .8283 | + 19 | +.0018 | .8320 |
| | 6 | .8105 | .7979 | 351 | −38 | 114 | .8396 | − 54 | +.0018 | .8360 |
| | 7 | .8096 | .8005 | 300 | +46 | 111 | .8434 | − 7 | −.0072 | .8355 |
| | 8 | .8069 | .7925 | 302 | +46 | 111 | .8383 | + 7 | −.0072 | .8318 |
| | 9 | .8170 | .8218 | 295 | +53 | 115 | .8584 | − 41 | −.0077 | .8466 |
| | 10 | .8217 | .7905 | 292 | +53 | 113 | .8446 | + 15 | −.0077 | .8384 |
| | 11 | .8097 | .8067 | 302 | +53 | 114 | .8478 | − 39 | −.0077 | .8362 |
| | 12 | .8047 | .7993 | 304 | +53 | 114 | .8418 | − 45 | −.0077 | .8296 |
| | | | | | | Mean | | | | 105.8366 |
| **12** | 3 | .0888 | .0700 | 43 | − 4 | 48 | .0881 | 0 | +.0053 | 12.0934 |
| (9) | 6 | .0682 | .0690 | 52 | − 4 | 48 | .0782 | − 6 | +.0044 | .0820 |
| | 7 | .0909 | .1093 | 38 | + 5 | 48 | .1092 | − 1 | −.0176 | .0916 |
| | 11 | .1478 | .1806 | 39 | + 6 | 48 | .1735 | − 5 | −.0190 | .1540 |
| | | | | | | Mean | | | | 12.1052 |
| **13** | 1 | .0319 | .0384 | 73 | − 7 | 112 | .0529 | − 2 | +.0024 | 24.0551 |
| (10) | 2 | .0380 | .0307 | 72 | − 7 | 111 | .0518 | + 6 | +.0024 | .0584 |
| | 3 | .0364 | .0349 | 73 | − 7 | 112 | .0533 | + 1 | +.0024 | .0558 |
| | 4 | .0286 | .0345 | 72 | − 9 | 111 | .0489 | + 28 | +.0020 | .0537 |
| | 5 | .0258 | .0495 | 75 | − 9 | 112 | .0554 | + 4 | +.0020 | .0578 |
| | 6 | .0384 | .0380 | 80 | − 9 | 112 | .0564 | − 12 | +.0020 | .0572 |
| | 7 | .0418 | .0258 | 68 | +11 | 111 | .0527 | − 2 | −.0078 | .0447 |
| | 8 | .0542 | .0408 | 69 | +11 | 111 | .0665 | + 2 | −.0078 | .0589 |
| | 9 | .0473 | .0495 | 67 | +12 | 111 | .0673 | − 9 | −.0084 | .0580 |
| | 10 | .0457 | .0405 | 66 | +12 | 111 | .0621 | + 3 | −.0084 | .0540 |
| | 11 | .0405 | .0475 | 69 | +12 | 112 | .0632 | − 9 | −.0085 | .0538 |
| | 12 | .0508 | .0479 | 69 | +12 | 110 | .0684 | − 10 | −.0085 | .0589 |
| | | | | | | Mean | | | | 24.0552 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. $p$ | Proper Motion. | Final Corrected Angle. $\pi$ |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ° ′ ″ | ′ ″ | ° ′ ″ |
| 1 | 340 10 45 | 9 22 | 19 56 | +10 | 250 30 9 | +0 22 | 250 31 5 |
| 2 | 6 59 | 7 55 | 21 45 | +12 | 29 23 | +0 22 | 30 52 |
| 3 | 10 50 | 10 13 | 20 19 | +14 | 31 5 | +0 22 | 31 6 |
| 4 | 9 37 | 12 42 | 18 22 | +12 | 29 43 | +0 18 | 30 30 |
| 5 | 8 42 | 11 48 | 20 8 | +12 | 30 35 | +0 18 | 31 56 |
| 6 | 11 7 | 10 51 | 14 4 | +10 | 25 13 | +0 18 | 32 38 |
| 7 | 14 10 | 12 28 | 18 37 | +16 | 32 12 | −1 13 | 32 2 |
| 8 | 15 52 | 18 55 | 18 54 | +8 | 36 25 | −1 13 | 34 53 |
| 9 | 15 36 | 14 45 | 18 13 | +26 | 33 50 | −1 18 | 31 36 |
| 10 | 18 27 | 19 15 | 16 30 | +17 | 35 38 | −1 18 | 34 5 |
| 11 | 13 54 | 13 57 | 18 38 | +18 | 32 51 | −1 19 | 31 46 |
| 12 | 15 35 | 17 13 | 18 40 | +10 | 35 14 | −1 19 | 31 17 |
| | | | | Mean | 250 31 52 | | 250 31 59 |
| 1 | 275 37 43 | 39 10 | 19 56 | −2 | 185 58 20 | +0 18 | 185 59 12 |
| 2 | 35 33 | 36 32 | 21 45 | +1 | 57 48 | +0 18 | 59 13 |
| 3 | 38 0 | 39 25 | 20 19 | +5 | 59 6 | +0 18 | 59 3 |
| 4 | 38 55 | 40 35 | 18 22 | +3 | 58 10 | +0 15 | 58 54 |
| 5 | 36 16 | 38 15 | 20 8 | +9 | 57 33 | +0 15 | 58 51 |
| 6 | 36 45 | 37 52 | 14 4 | +19 | 51 41 | +0 15 | 59 3 |
| 7 | 40 10 | 41 13 | 18 37 | +1 | 59 20 | −1 0 | 59 23 |
| 8 | 40 58 | 42 47 | 18 54 | +5 | 186 0 51 | −1 0 | 59 32 |
| 9 | 42 15 | 44 20 | 18 13 | −5 | 1 26 | −1 4 | 59 26 |
| 10 | 43 28 | 44 48 | 16 30 | +1 | 0 39 | −1 4 | 59 20 |
| 11 | 40 46 | 42 15 | 18 38 | 0 | 0 9 | −1 5 | 59 18 |
| 12 | 43 52 | 45 30 | 18 40 | +5 | 3 26 | −1 5 | 59 43 |
| | | | | Mean | 185 59 2 | | 185 59 15 |
| 3 | 296 47 36 | 44 50 | 20 19 | +20 | 207 6 52 | +2 12 | 207 8 43 |
| 6 | 43 50 | 46 28 | 14 4 | +34 | 206 59 47 | +1 49 | 8 43 |
| 7 | 297 00 30 | 00 55 | 18 37 | +16 | 207 19 35 | −7 16 | 13 22 |
| 11 | 296 57 10 | 59 18 | 18 38 | +16 | 17 8 | −7 50 | 9 32 |
| | | | | Mean | 207 10 50 | | 207 10 5 |
| 1 | 276 49 34 | 50 6 | 19 56 | −2 | 187 9 44 | +1 18 | 187 11 36 |
| 2 | 45 12 | 46 0 | 21 45 | +2 | 7 23 | +1 18 | 9 48 |
| 3 | 48 37 | 48 27 | 20 19 | +7 | 8 58 | +1 18 | 9 55 |
| 4 | 48 28 | 48 32 | 18 22 | +4 | 6 56 | +1 5 | 8 30 |
| 5 | 48 32 | 51 20 | 20 8 | +11 | 10 15 | +1 5 | 12 23 |
| 6 | 47 48 | 49 27 | 14 4 | +21 | 3 3 | +1 5 | 11 15 |
| 7 | 55 40 | 57 54 | 18 37 | +2 | 15 26 | −4 18 | 12 11 |
| 8 | 56 38 | 59 32 | 18 54 | +6 | 17 5 | −4 18 | 12 28 |
| 9 | 57 27 | 58 28 | 18 13 | −7 | 16 3 | −4 37 | 10 30 |
| 10 | 59 31 | 57 45 | 16 30 | +2 | 15 10 | −4 37 | 10 18 |
| 11 | 57 23 | 58 26 | 18 38 | +2 | 16 35 | −4 39 | 12 10 |
| 12 | 277 00 42 | 4 8 | 18 40 | +5 | 21 10 | −4 39 | 13 53 |
| | | | | Mean | 187 12 19 | | 187 11 15 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **14** | 1 | .9921 | .9886 | 241 | —23 | 123 | .0214 | — 8 | +.0015 | 79.0221 |
| (11) | 2 | .9942 | .9893 | 238 | —23 | 123 | .0225 | +21 | +.0015 | .0261 |
| | 3 | .9912 | .9902 | 239 | —23 | 123 | .0215 | + 3 | +.0015 | .0233 |
| | 4 | .9856 | .9872 | 237 | —29 | 123 | .0164 | +91 | +.0012 | .0267 |
| | 5 | .9839 | .9894 | 241 | —29 | 123 | .0170 | +14 | +.0012 | .0196 |
| | 6 | .0009 | .9952 | 251 | —29 | 123 | .0295 | —40 | +.0012 | .0267 |
| | 7 | .0067 | .9917 | 224 | +35 | 123 | .0343 | — 5 | —.0048 | .0290 |
| | 8 | .9980 | .9899 | 224 | +35 | 123 | .0290 | + 5 | —.0048 | .0247 |
| | 9 | .0037 | .0073 | 224 | +39 | 124 | .0411 | —31 | —.0051 | .0329 |
| | 10 | .0043 | .0031 | 218 | +39 | 123 | .0386 | +11 | —.0051 | .0346 |
| | 11 | .0001 | .0040 | 227 | +40 | 122 | .0378 | —29 | —.0052 | .0297 |
| | 12 | .9977 | .9912 | 225 | +40 | 123 | .0302 | —33 | —.0052 | .0217 |
| | | | | | | Mean | | | | 79.0264 |
| **15** | | | | | | *Bradle* | *y 3077* | | | |
| **16** | 1 | .8460 | .8478 | 246 | —24 | 128 | .8787 | — 8 | +.0010 | 79.8789 |
| (12) | 2 | .8421 | .8386 | 243 | —24 | 128 | .8720 | +21 | +.0010 | .8751 |
| | 3 | .8450 | .8397 | 240 | —24 | 128 | .8737 | + 3 | +.0010 | .8750 |
| | 4 | .8380 | .8354 | 240 | —29 | 126 | .8672 | +92 | +.0008 | .8772 |
| | 5 | .8317 | .8400 | 241 | —29 | 128 | .8667 | +15 | +.0008 | .8690 |
| | 6 | .8454 | .8426 | 247 | —29 | 128 | .8755 | —41 | +.0008 | .8722 |
| | 7 | .8456 | .8497 | 227 | +35 | 126 | .8833 | — 5 | —.0032 | .8796 |
| | 8 | .8386 | .8396 | 227 | +35 | 126 | .8753 | + 5 | —.0032 | .8726 |
| | 9 | .8440 | .8532 | 233 | +40 | 126 | .8854 | —31 | —.0034 | .8789 |
| | 10 | .8516 | .8420 | 222 | +40 | 126 | .8825 | +12 | —.0034 | .8803 |
| | 11 | .8385 | .8405 | 231 | +40 | 126 | .8761 | —30 | —.0034 | .8697 |
| | 12 | .8381 | .8349 | 227 | +40 | 126 | .8727 | —34 | —.0034 | .8659 |
| | | | | | | Mean | | | | 79.8746 |
| **17** | 1 | .1610 | .1509 | 118 | —12 | 101 | .1763 | — 4 | —.0026 | 39.1733 |
| (34) | 2 | .1661 | .1638 | 119 | —12 | 102 | .1855 | +10 | —.0026 | .1839 |
| | 3 | .1664 | .1624 | 121 | —12 | 101 | .1850 | + 1 | —.0026 | .1825 |
| | 4 | .1569 | .1605 | 119 | —14 | 102 | .1790 | +45 | —.0022 | .1813 |
| | 5 | .1613 | .1573 | 124 | —14 | 102 | .1801 | + 7 | —.0022 | .1786 |
| | 6 | .1685 | .1719 | 134 | —14 | 101 | .1919 | —20 | —.0022 | .1877 |
| | 7 | .1522 | .1574 | 112 | +17 | 111 | .1784 | — 3 | +.0086 | .1867 |
| | 8 | .1550 | .1482 | 114 | +17 | 111 | .1754 | + 3 | +.0086 | .1843 |
| | 9 | .1546 | .1376 | 108 | +19 | 111 | .1696 | —15 | +.0121 | .1802 |
| | 10 | .1376 | .1481 | 108 | +19 | 105 | .1656 | + 6 | +.0121 | .1783 |
| | 11 | .1445 | .1444 | 112 | +20 | 101 | .1673 | —15 | +.0122 | .1780 |
| | 12 | .1461 | .1446 | 113 | +20 | 102 | .1684 | —17 | +.0122 | .1789 |
| | | | | | | Mean | | | | 39.1811 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. p | Proper Motion. | Final Corrected Angle π |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ° ′ ″ | ′ ″ | ° ′ ″ |
| 1 | 271 7 32 | 9 8 | 19 56 | − 5 | 181 28 11 | + 0 25 | 181 29 10 |
| 2 | 5 10 | 6 43 | 21 45 | − 2 | 27 40 | + 0 25 | 29 12 |
| 3 | 8 5 | 8 55 | 20 19 | + 4 | 28 53 | + 0 25 | 28 57 |
| 4 | 8 44 | 10 50 | 18 22 | + 1 | 28 10 | + 0 20 | 28 59 |
| 5 | 7 22 | 8 8 | 20 8 | + 5 | 27 58 | + 0 20 | 29 21 |
| 6 | 6 21 | 8 5 | 14 4 | +15 | 21 32 | + 0 20 | 28 59 |
| 7 | 10 35 | 11 40 | 18 37 | − 2 | 29 43 | − 1 21 | 29 25 |
| 8 | 11 18 | 12 33 | 18 54 | + 3 | 30 53 | − 1 21 | 29 13 |
| 9 | 12 55 | 15 18 | 18 13 | −10 | 32 9 | − 1 27 | 29 46 |
| 10 | 14 3 | 14 57 | 16 30 | − 3 | 30 57 | − 1 27 | 29 15 |
| 11 | 11 34 | 12 30 | 18 38 | − 5 | 30 35 | − 1 28 | 29 21 |
| 12 | 14 28 | 15 20 | 18 40 | + 2 | 33 36 | − 1 28 | 29 30 |
| | | | | Mean | 181 29 11 | | 181 29 16 |
| 1 | 268 8 40 | 10 24 | 19 56 | − 5 | 178 29 23 | + 0 25 | 178 30 22 |
| 2 | 6 23 | 7 8 | 21 45 | − 2 | 28 29 | + 0 25 | 30 1 |
| 3 | 9 17 | 10 12 | 20 19 | + 1 | 30 4 | + 0 25 | 30 8 |
| 4 | 9 52 | 11 38 | 18 22 | − 2 | 29 5 | + 0 20 | 29 54 |
| 5 | 7 56 | 9 50 | 20 8 | + 4 | 29 5 | + 0 20 | 30 28 |
| 6 | 7 23 | 9 14 | 14 4 | +13 | 22 35 | + 0 20 | 30 2 |
| 7 | 11 22 | 13 27 | 18 37 | − 4 | 30 57 | − 1 21 | 30 39 |
| 8 | 12 40 | 14 3 | 18 54 | + 1 | 32 17 | − 1 21 | 30 37 |
| 9 | 13 28 | 15 57 | 18 13 | −14 | 32 41 | − 1 27 | 30 18 |
| 10 | 15 0 | 15 57 | 16 30 | − 2 | 31 56 | − 1 27 | 30 14 |
| 11 | 12 38 | 13 43 | 18 38 | − 5 | 31 44 | − 1 27 | 30 31 |
| 12 | 14 28 | 16 47 | 18 40 | 0 | 34 18 | − 1 27 | 30 13 |
| | | | | Mean | 178 30 13 | | 178 30 17 |
| 1 | 98 30 35 | 31 20 | 19 56 | − 2 | 8 50 52 | − 0 47 | 8 50 39 |
| 2 | 27 55 | 30 13 | 21 45 | + 2 | 50 51 | − 0 47 | 51 11 |
| 3 | 31 38 | 31 55 | 20 19 | + 9 | 52 15 | − 0 47 | 51 7 |
| 4 | 33 5 | 33 0 | 18 22 | + 5 | 51 29 | − 0 39 | 51 19 |
| 5 | 29 6 | 30 26 | 20 8 | +13 | 50 7 | − 0 39 | 50 31 |
| 6 | 29 42 | 30 30 | 14 4 | +23 | 44 33 | − 0 39 | 51 1 |
| 7 | 26 3 | 28 3 | 18 37 | +11 | 45 51 | + 2 35 | 49 29 |
| 8 | 27 41 | 28 27 | 18 54 | + 7 | 47 5 | + 2 35 | 49 21 |
| 9 | 28 47 | 30 28 | 18 13 | − 3 | 47 48 | + 2 47 | 49 39 |
| 10 | 29 34 | 31 40 | 16 30 | + 3 | 47 10 | + 2 47 | 49 42 |
| 11 | 27 50 | 29 25 | 18 38 | + 3 | 47 19 | + 2 48 | 50 21 |
| 12 | 29 18 | 30 12 | 18 40 | + 6 | 48 31 | + 2 48 | 48 41 |
| | | | | Mean | 8 48 39 | | 8 50 15 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. | | Corrections for | | | Corrected Mean. | Scale Variation. | Proper Motion. | Final Corrected Distance. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | East. | West. | Refrac. | Aberr. | Scale. | $s$ | | | $\sigma$ |
| **18** | 1 | .3692 | .3590 | 88 | — 8 | 113 | .3832 | — 3 | —.0053 | 28.3776 |
| (33) | 3 | .3860 | .3727 | 101 | — 8 | 113 | .3998 | + 1 | —.0053 | .3946 |
| | 4 | .3821 | .3729 | 95 | —10 | 124 | .3982 | + 33 | —.0044 | .3971 |
| | 6 | .3806 | .3646 | 122 | —10 | 112 | .3948 | — 14 | —.0044 | .3890 |
| | 11 | .3330 | .3232 | 90 | +14 | 113 | .3496 | — 11 | +.0188 | .3673 |
| | 12 | .3444 | .3357 | 91 | +14 | 113 | .3616 | — 12 | +.0188 | .3792 |
| | | | | | | Mean | | | | 28.3841 |
| **19** | 1 | .9604 | .9622 | 182 | —17 | 103 | .9871 | — 5 | —.0013 | 55.9853 |
| (14) | 2 | .9638 | .9538 | 178 | —17 | 103 | .9837 | + 15 | —.0013 | .9839 |
| | 3 | .9560 | .9669 | 174 | —17 | 104 | .9865 | + 2 | —.0013 | .9854 |
| | 4 | .9503 | .9490 | 176 | —20 | 104 | .9747 | + 64 | —.0011 | .9800 |
| | 5 | .9515 | .9655 | 172 | —20 | 103 | .9830 | + 10 | —.0011 | .9829 |
| | 6 | .9636 | .9625 | 169 | —20 | 103 | .9872 | — 28 | —.0011 | .9833 |
| | 7 | .9464 | .9467 | 172 | +24 | 100 | .9752 | — 4 | +.0042 | .9790 |
| | 8 | .9410 | .9460 | 162 | +24 | 100 | .9711 | + 4 | +.0042 | .9757 |
| | 9 | .9478 | .9522 | 188 | +28 | 100 | .9806 | — 22 | +.0045 | .9829 |
| | 10 | .9449 | .9497 | 168 | +28 | 103 | .9763 | + 8 | +.0045 | .9816 |
| | 11 | .9503 | .9477 | 176 | +28 | 106 | .9790 | — 21 | +.0046 | .9815 |
| | 12 | .9530 | .9375 | 165 | +28 | 103 | .9738 | — 24 | +.0046 | .9760 |
| | | | | | | Mean | | | | 55.9815 |
| **20** | 1 | .5073 | .5128 | 269 | —27 | 134 | .5432 | — 9 | —.0033 | 89.5390 |
| (35) | 2 | .5142 | .5126 | 273 | —27 | 135 | .5471 | + 24 | —.0033 | .5462 |
| | 3 | .5201 | .5099 | 284 | —27 | 134 | .5497 | + 3 | —.0033 | .5467 |
| | 4 | .5090 | .5036 | 275 | —32 | 134 | .5396 | +103 | —.0027 | .5472 |
| | 5 | .5176 | .5086 | 291 | —32 | 134 | .5480 | + 16 | —.0027 | .5469 |
| | 6 | .5228 | .5256 | 322 | —32 | 134 | .5622 | — 46 | —.0027 | .5549 |
| | 7 | .4895 | .4994 | 256 | +39 | 132 | .5327 | — 6 | +.0108 | .5429 |
| | 8 | .4880 | .4998 | 264 | +39 | 133 | .5331 | + 6 | +.0108 | .5445 |
| | 9 | .4948 | .4784 | 247 | +44 | 129 | .5242 | — 35 | +.0116 | .5323 |
| | 10 | .4964 | .4906 | 249 | +44 | 134 | .5318 | + 13 | +.0116 | .5447 |
| | 11 | .4836 | .4807 | 259 | +45 | 134 | .5216 | — 33 | +.0117 | .5300 |
| | 12 | .4925 | .4884 | 266 | +45 | 134 | .5306 | — 38 | +.0117 | .5385 |
| | | | | | | Mean | | | | 89.5428 |
| **21** | 1 | .9995 | .0222 | 122 | —10 | 119 | .0337 | — 3 | —.0059 | 32.0275 |
| (22) | 3 | .0215 | .0238 | 130 | —10 | 119 | .0463 | + 1 | —.0059 | .0405 |
| | 4 | .0225 | .0284 | 128 | —12 | 124 | .0492 | + 37 | —.0049 | .0480 |
| | 6 | .0242 | .0170 | 132 | —12 | 119 | .0443 | — 16 | —.0049 | .0378 |
| | 7 | .9806 | .9690 | 132 | +14 | 121 | .0013 | — 2 | +.0195 | .0206 |
| | 8 | .9991 | .9762 | 112 | +14 | 121 | .0122 | + 2 | +.0195 | .0319 |
| | 9 | .9821 | .9786 | 157 | +16 | 122 | .0097 | — 12 | +.0209 | .0294 |
| | 11 | .9916 | .9710 | 137 | +16 | 121 | .0085 | — 12 | +.0210 | .0283 |
| | 12 | .0040 | .9812 | 118 | +16 | 121 | .0179 | — 14 | +.0210 | .0375 |
| | | | | | | Mean | | | | 32.0335 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. $p$ | Proper Motion. | Final Corrected Angle. $\pi$ |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ° ′ ″ | ′ ″ | ° ′ ″ |
| 1 | 116 31 5 | 31 42 | 19 56 | + 5 | 26 51 24 | — 0 56 | 26 51 2 |
| 3 | 34 8 | 34 50 | 20 19 | +19 | 55 7 | — 0 56 | 53 50 |
| 4 | 35 7 | 38 0 | 18 22 | +14 | 55 9 | — 0 47 | 54 51 |
| 6 | 32 25 | 33 14 | 14 4 | +34 | 47 28 | — 0 47 | 53 48 |
| 11 | 29 35 | 29 14 | 18 38 | +16 | 48 18 | + 3 20 | 51 52 |
| 12 | 32 24 | 30 35 | 18 40 | +14 | 50 23 | + 3 20 | 51 5 |
| | | | | Mean | 26 51 18 | | 26 52 45 |
| 1 | 254 20 16 | 22 27 | 19 56 | — 9 | 164 41 9 | + 0 35 | 164 42 18 |
| 2 | 18 45 | 19 38 | 21 45 | —10 | 40 47 | + 0 35 | 42 29 |
| 3 | 21 12 | 21 48 | 20 19 | — 9 | 41 40 | + 0 35 | 41 54 |
| 4 | 22 3 | 24 22 | 18 22 | —10 | 41 24 | + 0 29 | 42 22 |
| 5 | 18 50 | 22 6 | 20 8 | — 8 | 40 28 | + 0 29 | 42 0 |
| 6 | 20 30 | 21 18 | 14 4 | — 5 | 34 53 | + 0 29 | 42 29 |
| 7 | 24 34 | 25 40 | 18 37 | —14 | 43 30 | — 1 54 | 42 39 |
| 8 | 25 47 | 26 45 | 18 54 | — 6 | 45 4 | — 1 54 | 42 51 |
| 9 | 27 8 | 28 50 | 18 13 | —24 | 45 48 | — 2 3 | 42 49 |
| 10 | 29 26 | 28 11 | 16 30 | —15 | 45 3 | — 2 3 | 42 45 |
| 11 | 26 18 | 27 40 | 18 38 | —16 | 45 21 | — 2 3 | 43 32 |
| 12 | 27 40 | 29 58 | 18 40 | — 8 | 47 21 | — 2 3 | 42 40 |
| | | | | Mean | 164 42 42 | | 164 42 34 |
| 1 | 102 41 28 | 43 28 | 19 56 | 0 | 13 2 24 | — 0 20 | 13 2 38 |
| 2 | 39 38 | 40 45 | 21 45 | + 5 | 2 2 | — 0 20 | 2 49 |
| 3 | 42 35 | 43 28 | 20 19 | +11 | 3 32 | — 0 20 | 2 51 |
| 4 | 43 27 | 45 10 | 18 22 | + 8 | 2 49 | — 0 16 | 3 2 |
| 5 | 40 45 | 42 10 | 20 8 | +15 | 1 51 | — 0 16 | 2 38 |
| 6 | 41 10 | 41 42 | 14 4 | +27 | 12 55 57 | — 0 16 | 2 48 |
| 7 | 40 53 | 41 48 | 18 37 | + 7 | 13 0 5 | + 1 6 | 2 14 |
| 8 | 42 3 | 43 8 | 18 54 | + 8 | 1 38 | + 1 6 | 2 25 |
| 9 | 43 27 | 44 25 | 18 13 | + 3 | 2 12 | + 1 10 | 1 26 |
| 10 | 43 50 | 45 32 | 16 30 | + 6 | 1 17 | + 1 10 | 2 12 |
| 11 | 41 32 | 42 47 | 18 38 | + 6 | 0 53 | + 1 11 | 2 18 |
| 12 | 43 56 | 45 30 | 18 40 | + 8 | 3 31 | + 1 11 | 2 4 |
| | | | | Mean | 13 1 31 | | 13 2 27 |
| 1 | 223 10 27 | 13 8 | 19 56 | —10 | 133 31 34 | + 0 48 | 133 32 56 |
| 3 | 10 35 | 12 2 | 20 19 | —22 | 31 15 | + 0 48 | 31 42 |
| 4 | 11 24 | 15 35 | 18 22 | —19 | 31 32 | + 0 39 | 32 40 |
| 6 | 9 13 | 11 20 | 14 4 | —33 | 23 48 | + 0 39 | 31 34 |
| 7 | 13 28 | 14 32 | 18 37 | —21 | 32 16 | — 2 36 | 30 43 |
| 8 | 15 6 | 17 0 | 18 54 | —15 | 34 42 | — 2 36 | 31 47 |
| 9 | 16 50 | 20 25 | 18 13 | —28 | 36 23 | — 2 48 | 32 39 |
| 11 | 17 5 | 17 45 | 18 38 | —23 | 35 40 | — 2 49 | 33 5 |
| 12 | 16 7 | 17 37 | 18 40 | —17 | 35 15 | — 2 49 | 29 48 |
| | | | | Mean | 133 32 29 | | 133 31 53 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean $s$ | Scale Variation. | Proper Motion. | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **22** | 8 | .2376 | .2377 | 295 | +45 | 125 | .2775 | + 7 | +.0040 | 102.2822 |
| (15) | 11 | .2489 | .2607 | 320 | +51 | 134 | .2987 | —38 | +.0043 | .2992 |
| | 12 | .2472 | .2366 | 301 | +51 | 125 | .2830 | —43 | +.0043 | .2830 |
| | | | | | | Mean | | | | 102.2881 |
| **23** | 1 | .5766 | .5912 | 410 | —37 | 84 | .6175 | — 12 | —.0016 | 124.6147 |
| (16) | 2 | .5746 | .5729 | 404 | —37 | 84 | .6068 | + 33 | —.0016 | .6085 |
| | 4 | .5400 | .5510 | 397 | —45 | 84 | .5770 | +144 | —.0013 | .5901 |
| | 5 | .5488 | .5608 | 389 | —45 | 82 | .5853 | + 23 | —.0013 | .5863 |
| | 6 | .5830 | .6004 | 381 | —45 | 82 | .6214 | — 63 | —.0013 | .6138 |
| | 7 | .5582 | .5378 | 392 | +54 | 84 | .5889 | — 8 | +.0054 | .5935 |
| | 8 | .5514 | .5656 | 364 | +54 | 85 | .5967 | + 8 | +.0054 | .6029 |
| | 10 | .5485 | .5727 | 385 | +62 | 84 | .6016 | + 18 | +.0058 | .6092 |
| | 11 | .5523 | .5609 | 397 | +63 | 84 | .5989 | — 46 | +.0058 | .6001 |
| | 12 | .5545 | .5378 | 370 | +63 | 104 | .5878 | — 53 | +.0058 | .5883 |
| | | | | | | Mean | | | | 124.6007 |
| **24** | 1 | .5444 | .5442 | 238 | —20 | 107 | .5750 | — 6 | —.0043 | 66.5701 |
| (21) | 2 | .5444 | .5316 | 241 | —20 | 107 | .5690 | + 18 | —.0043 | .5665 |
| | 3 | .5391 | .5332 | 240 | —20 | 106 | .5669 | + 2 | —.0043 | .5628 |
| | 4 | .5466 | .5563 | 240 | —24 | 109 | .5821 | + 77 | —.0035 | .5863 |
| | 5 | .5401 | .5340 | 237 | —24 | 107 | .5672 | + 12 | —.0035 | .5649 |
| | 6 | .5583 | .5482 | 234 | —24 | 107 | .5832 | — 34 | —.0035 | .5763 |
| | 7 | .5331 | .5149 | 245 | +29 | 110 | .5606 | — 5 | +.0140 | .5741 |
| | 8 | .5166 | .5144 | 214 | +29 | 110 | .5490 | + 5 | +.0140 | .5635 |
| | 9 | .5112 | .4964 | 290 | +33 | 110 | .5453 | — 26 | +.0150 | .5577 |
| | 11 | .5372 | .5161 | 253 | +33 | 107 | .5641 | — 25 | +.0151 | .5767 |
| | 12 | .5177 | .5113 | 223 | +33 | 106 | .5489 | — 28 | +.0151 | .5612 |
| | | | | | | Mean | | | | 66.5691 |
| **25** | 1 | .5484 | .5453 | 396 | —35 | 123 | .5851 | — 11 | —.0022 | 118.5818 |
| (17) | 2 | .5400 | .5337 | 391 | —35 | 123 | .5746 | + 32 | —.0022 | .5756 |
| | 3 | .5540 | .5545 | 383 | —35 | 123 | .5913 | + 4 | —.0022 | .5895 |
| | 4 | .5350 | .5390 | 386 | —43 | 123 | .5735 | +137 | —.0018 | .5854 |
| | 5 | .5296 | .5345 | 378 | —43 | 123 | .5677 | + 22 | —.0018 | .5681 |
| | 7 | .5290 | .5176 | 383 | +52 | 123 | .5690 | — 8 | +.0071 | .5753 |
| | 8 | .5395 | .5224 | 352 | +52 | 124 | .5737 | + 8 | +.0071 | .5816 |
| | 9 | .5226 | .5122 | 428 | +59 | 123 | .5683 | — 46 | +.0076 | .5713 |
| | 11 | .5294 | .5288 | 393 | +60 | 123 | .5766 | — 44 | +.0076 | .5798 |
| | 12 | .5205 | .5310 | 358 | +59 | 123 | .5697 | — 50 | +.0076 | .5723 |
| | | | | | | Mean | | | | 118.5781 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. $p$ | Proper Motion. | Final Corrected Angle. $\pi$ |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ° ′ ″ | ′ ″ | ° ′ ″ |
| 8 | 254 45 34 | 46 15 | 18 54 | — 6 | 165 4 42 | — 1 3 | 165 3 20 |
| 11 | 44 57 | 46 50 | 18 38 | —15 | 4 17 | — 1 8 | 3 23 |
| 12 | 47 47 | 48 55 | 18 40 | — 8 | 6 53 | — 1 8 | 3 7 |
| | | | | Mean | 165 5 17 | | 165 3 17 |
| 1 | 252 10 42 | 11 42 | 19 56 | —10 | 162 30 58 | + 0 16 | 162 31 48 |
| 2 | 8 48 | 9 52 | 21 45 | —10 | 30 55 | + 0 16 | 32 18 |
| 4 | 11 56 | 14 7 | 18 22 | —11 | 31 13 | + 0 13 | 31 55 |
| 5 | 9 28 | 11 32 | 20 8 | —10 | 30 28 | + 0 13 | 31 44 |
| 6 | 9 56 | 11 8 | 14 4 | — 5 | 24 31 | + 0 13 | 31 51 |
| 7 | 13 3 | 14 13 | 18 37 | —15 | 32 0 | — 0 52 | 32 11 |
| 8 | 13 53 | 15 27 | 18 54 | — 7 | 33 27 | — 0 52 | 32 16 |
| 10 | 16 26 | 17 50 | 16 30 | —16 | 33 22 | — 0 56 | 32 11 |
| 11 | 13 38 | 15 12 | 18 38 | —17 | 32 46 | — 0 56 | 32 4 |
| 12 | 16 2 | 18 13 | 18 40 | — 8 | 35 40 | — 0 56 | 32 6 |
| | | | | Mean | 162 31 32 | | 162 32 2 |
| 1 | 235 18 8 | 19 22 | 19 56 | —11 | 145 38 30 | + 0 26 | 145 39 30 |
| 2 | 15 38 | 16 32 | 21 45 | —16 | 37 34 | + 0 26 | 39 7 |
| 3 | 18 42 | 19 8 | 20 19 | —20 | 38 54 | + 0 26 | 38 59 |
| 4 | 19 20 | 19 53 | 18 22 | —17 | 37 41 | + 0 22 | 38 32 |
| 5 | 16 34 | 18 50 | 20 8 | —22 | 37 28 | + 0 22 | 38 53 |
| 6 | 16 48 | 18 18 | 14 4 | —27 | 31 10 | + 0 22 | 38 39 |
| 7 | 20 35 | 21 45 | 18 37 | —21 | 39 26 | — 1 27 | 39 2 |
| 8 | 21 48 | 23 18 | 18 54 | —14 | 41 13 | — 1 27 | 39 27 |
| 9 | 23 26 | 26 48 | 18 13 | —31 | 42 49 | — 1 33 | 40 20 |
| 11 | 21 23 | 23 22 | 18 38 | —23 | 40 37 | — 1 34 | 39 17 |
| 12 | 23 2 | 26 6 | 18 40 | —16 | 42 58 | — 1 34 | 38 46 |
| | | | | Mean | 145 38 56 | | 145 39 8 |
| 1 | 248 57 30 | 58 56 | 19 56 | —10 | 159 17 59 | + 0 16 | 159 18 49 |
| 2 | 55 48 | 56 46 | 21 45 | —12 | 17 50 | + 0 16 | 19 13 |
| 3 | 58 18 | 59 38 | 20 19 | —13 | 19 4 | + 0 16 | 18 59 |
| 4 | 59 18 | 00 35 | 18 22 | —13 | 18 5 | + 0 14 | 18 48 |
| 5 | 57 0 | 58 55 | 20 8 | —13 | 17 53 | + 0 14 | 19 10 |
| 7 | 249 00 7 | 1 32 | 18 37 | —17 | 19 9 | — 0 54 | 19 18 |
| 8 | 1 15 | 2 5 | 18 54 | — 8 | 20 26 | — 0 54 | 19 13 |
| 9 | 2 18 | 4 18 | 18 13 | —27 | 21 4 | — 0 58 | 19 10 |
| 11 | 1 18 | 2 45 | 18 38 | —18 | 20 22 | — 0 58 | 19 38 |
| 12 | 2 55 | 4 58 | 18 40 | —10 | 22 26 | — 0 58 | 18 50 |
| | | | | Mean | 159 19 26 | | 159 19 7 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Continued.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **26** | 1 | .9975 | .0135 | 183 | −15 | 114 | .0330 | − 5 | −.0091 | 49.0234 |
| (29) | 2 | .0162 | .0226 | 207 | −15 | 114 | .0492 | +13 | −.0091 | .0414 |
| | 3 | .0286 | .0154 | 242 | −15 | 114 | .0553 | + 2 | −.0091 | .0464 |
| | 4 | .0159 | .0140 | 220 | −18 | 121 | .0464 | +56 | −.0075 | .0445 |
| | 5 | .0173 | .9999 | 259 | −18 | 120 | .0439 | + 9 | −.0075 | .0373 |
| | 6 | .0185 | .0212 | 309 | −18 | 110 | .0591 | −25 | −.0075 | .0491 |
| | 7 | .9586 | .9565 | 221 | +21 | 114 | .9923 | − 3 | +.0299 | .0219 |
| | 8 | .9839 | .9789 | 203 | +21 | 114 | .0144 | + 3 | +.0299 | .0446 |
| | 11 | .9594 | .9571 | 228 | +25 | 124 | .9951 | −18 | +.0322 | .0255 |
| | 12 | .9566 | .9410 | 209 | +25 | 120 | .9834 | −21 | +.0322 | .0135 |
| | | | | | | Mean | | | | 49.0348 |
| **27** | 12 | .8166 | .8112 | 298 | +45 | 132 | .8570 | −38 | +.0144 | 89.8676 |
| (20) | | | | | | | | | | |
| **28** | 4 | .7395 | .7356 | 265 | −23 | 117 | .7720 | +72 | −.0056 | 62.7736 |
| (24) | 6 | .7193 | .7225 | 269 | −23 | 114 | .7554 | −32 | −.0056 | .7466 |
| | 11 | .7391 | .7261 | 285 | +31 | 114 | .7741 | −23 | +.0241 | .7959 |
| | 12 | .6891 | .6803 | 243 | +31 | 113 | .7219 | −26 | +.0241 | .7434 |
| | | | | | | Mean | | | | 62.7649 |
| **29** | 1 | .0709 | .0682 | 200 | −15 | 110 | .0982 | − 5 | −.0094 | 51.0883 |
| (28) | 2 | .0724 | .0725 | 227 | −15 | 110 | .1038 | +14 | −.0094 | .0958 |
| | 3 | .0856 | .0750 | 264 | −15 | 110 | .1154 | + 2 | −.0094 | .1062 |
| | 4 | .0794 | .0760 | 242 | −19 | 117 | .1109 | +59 | −.0078 | .1090 |
| | 5 | .0785 | .0611 | 280 | −19 | 114 | .1065 | + 9 | −.0078 | .0996 |
| | 6 | .0877 | .0677 | 329 | −19 | 110 | .1189 | −26 | −.0078 | .1085 |
| | 7 | .9937 | .9865 | 246 | +22 | 115 | .0276 | − 3 | +.0309 | .0582 |
| | 8 | .0371 | .0175 | 219 | +22 | 113 | .0619 | + 3 | +.0309 | .0931 |
| | 11 | .0104 | .0034 | 254 | +26 | 110 | .0451 | −19 | +.0333 | .0765 |
| | 12 | .0354 | .0176 | 228 | +26 | 113 | .0624 | −22 | +.0333 | .0935 |
| | | | | | | Mean | | | | 51.0929 |
| **30** | 4 | .5448 | .5838 | 259 | −22 | 110 | .5977 | +69 | −.0072 | 59.5974 |
| (30) | | | | | | | | | | |
| **31** | 1 | .4623 | .4634 | 307 | −24 | 137 | .5014 | − 8 | −.0053 | 82.4953 |
| (23) | 2 | .4626 | .4558 | 314 | −24 | 137 | .4984 | +22 | −.0053 | .4953 |
| | 3 | .4533 | .4532 | 318 | −24 | 137 | .4928 | + 3 | −.0053 | .4878 |
| | 4 | .4606 | .4474 | 318 | −30 | 136 | .4929 | +95 | −.0044 | .4980 |
| | 5 | .4502 | .4638 | 318 | −30 | 140 | .4963 | +15 | −.0044 | .4934 |
| | 6 | .4646 | .4577 | 316 | −30 | 137 | .5000 | −42 | −.0044 | .4914 |
| | 7 | .4279 | .4294 | 327 | +36 | 141 | .4756 | − 6 | +.0173 | .4923 |
| | 8 | .4457 | .4360 | 279 | +36 | 138 | .4826 | + 6 | +.0173 | .5005 |
| | 9 | .4184 | .4200 | 386 | +41 | 136 | .4720 | −32 | +.0186 | .4874 |
| | 10 | .4276 | .4293 | 323 | +41 | 140 | .4754 | +12 | +.0186 | .4952 |
| | 11 | .4321 | .4333 | 336 | +41 | 137 | .4806 | −31 | +.0187 | .4962 |
| | 12 | .4344 | .4208 | 290 | +41 | 140 | .4712 | −35 | +.0187 | .4864 |
| | | | | | | Mean | | | | 82.4933 |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Continued.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected. Mean. $p$ | Proper Motion. | Final Corrected Angle. $\pi$ |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ° ′ ″ | ′ ″ | ° ′ ″ |
| 1 | 156 31 26 | 34 24 | 19 56 | +10 | 66 53 1 | − 0 10 | 66 53 25 |
| 2 | 29 3 | 30 55 | 21 45 | +13 | 51 57 | − 0 10 | 52 54 |
| 3 | 31 42 | 33 17 | 20 19 | +15 | 53 5 | − 0 10 | 52 34 |
| 4 | 33 38 | 35 55 | 18 22 | +14 | 53 23 | − 0 9 | 53 43 |
| 5 | 31 1 | 32 35 | 20 8 | +14 | 52 10 | − 0 9 | 53 4 |
| 6 | 31 5 | 32 18 | 14 4 | +15 | 46 1 | − 0 9 | 52 59 |
| 7 | 31 20 | 30 45 | 18 37 | +18 | 49 58 | + 0 34 | 51 35 |
| 8 | 30 52 | 31 58 | 18 54 | + 9 | 50 28 | + 0 34 | 50 43 |
| 11 | 32 25 | 34 26 | 18 38 | +19 | 52 23 | + 0 37 | 53 14 |
| 12 | 33 13 | 35 15 | 18 40 | +13 | 53 7 | + 0 37 | 51 6 |
| | | | | Mean | 66 51 33 | | 66 52 32 |
| 12 | 236 48 54 | 50 17 | 18 40 | −15 | 147 8 1 | − 1 11 | 147 4 12 |
| 4 | 216 8 8 | 10 18 | 18 22 | −17 | 126 27 18 | + 0 18 | 126 28 5 |
| 6 | 6 47 | 8 0 | 14 4 | −35 | 20 53 | + 0 18 | 28 18 |
| 11 | 9 50 | 13 3 | 18 38 | −21 | 29 43 | − 1 18 | 28 39 |
| 12 | 11 12 | 14 53 | 18 40 | −16 | 31 26 | − 1 18 | 27 30 |
| | | | | Mean | 126 27 20 | | 126 28 8 |
| 1 | 168 36 24 | 38 27 | 19 56 | + 8 | 78 57 29 | − 0 2 | 78 58 1 |
| 2 | 33 52 | 35 5 | 21 45 | + 8 | 56 21 | − 0 2 | 57 26 |
| 3 | 36 8 | 38 8 | 20 19 | + 7 | 57 34 | − 0 2 | 57 11 |
| 4 | 38 28 | 38 36 | 18 22 | + 8 | 57 2 | − 0 2 | 57 29 |
| 5 | 35 23 | 37 50 | 20 8 | + 5 | 56 49 | − 0 2 | 57 50 |
| 6 | 36 16 | 36 30 | 14 4 | − 1 | 50 26 | − 0 2 | 57 31 |
| 7 | 37 2 | 36 42 | 18 37 | +10 | 55 39 | + 0 7 | 56 49 |
| 8 | 38 30 | 38 32 | 18 54 | + 3 | 57 28 | + 0 7 | 57 16 |
| 11 | 39 16 | 39 55 | 18 38 | +13 | 58 27 | + 0 7 | 58 48 |
| 12 | 39 38 | 42 6 | 18 40 | + 5 | 59 37 | + 0 7 | 57 6 |
| | | | | Mean | 78 56 41 | | 78 57 33 |
| 4 | 150 3 18 | 5 32 | 18 22 | +16 | 60 23 3 | − 0 10 | 60 23 22 |
| 1 | 228 14 25 | 15 55 | 19 56 | −11 | 138 34 55 | + 0 20 | 138 35 49 |
| 2 | 12 0 | 13 53 | 21 45 | −16 | 34 26 | + 0 20 | 35 53 |
| 3 | 15 42 | 16 5 | 20 19 | −22 | 35 50 | + 0 20 | 35 49 |
| 4 | 16 0 | 17 28 | 18 22 | −19 | 34 47 | + 0 16 | 35 32 |
| 5 | 14 8 | 15 30 | 20 8 | −24 | 34 33 | + 0 16 | 35 52 |
| 6 | 13 55 | 14 50 | 14 4 | −31 | 27 55 | + 0 16 | 35 18 |
| 7 | 17 7 | 18 8 | 18 37 | −22 | 35 53 | − 1 6 | 35 50 |
| 8 | 18 3 | 19 36 | 18 54 | −14 | 37 30 | − 1 6 | 36 5 |
| 9 | 19 25 | 21 48 | 18 13 | −30 | 38 19 | − 1 10 | 36 13 |
| 10 | 20 45 | 21 43 | 16 30 | −23 | 37 21 | − 1 10 | 35 56 |
| 11 | 18 52 | 19 5 | 18 38 | −24 | 37 13 | − 1 11 | 36 16 |
| 12 | 19 38 | 22 5 | 18 40 | −17 | 39 15 | − 1 11 | 35 26 |
| | | | | Mean | 138 35 40 | | 138 35 50 |

TABLE V.—RESULTS OF MEASURES OF DISTANCE. (*Concluded.*)

| Star No. | Plate. | Observed Dist. East. | Observed Dist. West. | Corrections for Refrac. | Corrections for Aberr. | Corrections for Scale. | Corrected Mean. $s$ | Scale Variation. | Proper Motion. | Final Corrected Distance. $\sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **32** | 1 | .2646 | .2658 | 344 | —32 | 120 | .3005 | — 10 | —.0062 | 109.2933 |
| (32) | 2 | .2655 | .2600 | 368 | —32 | 138 | .3014 | + 29 | —.0062 | .2981 |
| | 4 | .2768 | .2702 | 384 | —40 | 128 | .3128 | +125 | —.0052 | .3201 |
| | 7 | .2306 | .2495 | 364 | +48 | 130 | .2863 | — 7 | +.0205 | .3061 |
| | 8 | .2388 | .2309 | 368 | +48 | 130 | .2815 | + 7 | +.0205 | .3027 |
| | 9 | .2557 | .2180 | 349 | +54 | 139 | .2831 | — 43 | +.0219 | .3007 |
| | 10 | .2360 | .2386 | 355 | +54 | 128 | .2831 | + 16 | +.0219 | .3066 |
| | 11 | .2292 | .2214 | 368 | +55 | 138 | .2735 | — 41 | +.0221 | .2915 |
| | 12 | .2333 | .2124 | 370 | +55 | 118 | .2693 | — 46 | +.0221 | .2868 |
| | | | | | | Mean | | | | 109.3007 |
| **33** | 1 | .0454 | .0412 | 321 | —28 | 140 | .0812 | — 9 | —.0078 | 95.0725 |
| (31) | 2 | .0511 | .0403 | 357 | —28 | 144 | .0876 | + 25 | —.0078 | .0823 |
| | 3 | .0424 | .0366 | 412 | —28 | 140 | .0865 | + 4 | —.0078 | .0791 |
| | 4 | .0404 | .0354 | 377 | —34 | 144 | .0812 | +109 | —.0064 | .0857 |
| | 5 | .0409 | .0282 | 441 | —34 | 144 | .0843 | + 17 | —.0064 | .0796 |
| | 6 | .0380 | .0428 | 529 | —35 | 138 | .0982 | — 48 | —.0064 | .0870 |
| | 7 | .0000 | .9866 | 366 | +42 | 143 | .0430 | — 6 | +.0256 | .0680 |
| | 8 | .0001 | .9929 | 356 | +42 | 142 | .0451 | + 6 | +.0256 | .0713 |
| | 9 | .0036 | .9918 | 366 | +47 | 140 | .0476 | — 37 | +.0274 | .0713 |
| | 10 | .9968 | .0042 | 360 | +47 | 143 | .0500 | + 14 | +.0274 | .0788 |
| | 11 | .9996 | .9859 | 373 | +48 | 143 | .0388 | — 35 | +.0276 | .0629 |
| | 12 | .0000 | .9922 | 364 | +48 | 144 | .0463 | — 40 | +.0276 | .0699 |
| | | | | | | Mean | | | | 95.0757 |
| **34** | 7 | .9473 | .9391 | 472 | +54 | 118 | .9957 | — 8 | +.0158 | 124.0107 |
| (19) | 8 | .9583 | .9454 | 410 | +54 | 118 | .9981 | + 8 | +.0158 | .0147 |
| | 11 | .9655 | .9507 | 490 | +62 | 108 | .0122 | — 46 | +.0171 | .0247 |
| | 12 | .9702 | .9496 | 427 | +62 | 113 | .0082 | — 52 | +.0171 | .0201 |
| | | | | | | Mean | | | | 124.0175 |
| **35** | 10 | .5560 | .5567 | 516 | +57 | 119 | .6164 | + 17 | +.0251 | 114.6432 |
| (27) | 11 | .5637 | .5550 | 535 | +58 | 114 | .6209 | — 43 | +.0253 | .6419 |
| | | | | | | Mean | | | | .6426, |

TABLE VI.—RESULTS OF MEASURES OF ANGLE. (*Concluded.*)

| Plate. | Observed Position Angle. East. | Observed Position Angle. West. | Zero Correction plus precession, etc. | Refrac. | Corrected Mean. $p$ | Proper Motion. | Final Corrected Angle. $\pi$ |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | ′ ″ | ′ ″ | ″ | ° ′ ″ | ′ ″ | ° ′ ″ |
| 1 | 123 33 26 | 35 6 | 19 56 | + 7 | 33 54 19 | — 0 13 | 33 54 40 |
| 2 | 31 20 | 32 52 | 21 45 | +14 | 54 5 | — 0 13 | 54 59 |
| 4 | 35 45 | 37 38 | 18 22 | +16 | 55 20 | — 0 11 | 55 38 |
| 7 | 33 42 | 34 58 | 18 37 | +18 | 53 15 | + 0 43 | 55 1 |
| 8 | 34 55 | 35 55 | 18 54 | +14 | 54 33 | + 0 43 | 54 57 |
| 9 | 35 42 | 37 33 | 18 13 | +22 | 55 13 | + 0 46 | 55 3 |
| 10 | 37 3 | 38 19 | 16 30 | +19 | 54 30 | + 0 46 | 55 1 |
| 11 | 35 10 | 35 40 | 18 38 | +19 | 54 22 | + 0 46 | 55 22 |
| 12 | 37 10 | 38 13 | 18 40 | +16 | 56 38 | + 0 46 | 54 46 |
| | | | | Mean | 33 54 42 | | 33 55 3 |
| 1 | 137 57 13 | 58 37 | 19 56 | +10 | 48 18 1 | — 0 11 | 48 18 24 |
| 2 | 54 50 | 56 2 | 21 45 | +16 | 17 27 | — 0 11 | 18 23 |
| 3 | 57 53 | 58 23 | 20 19 | +22 | 18 49 | — 0 11 | 18 17 |
| 4 | 58 37 | 00 23 | 18 22 | +19 | 18 11 | — 0 9 | 18 31 |
| 5 | 56 2 | 57 58 | 20 8 | +24 | 17 32 | — 0 9 | 18 26 |
| 6 | 56 15 | 57 18 | 14 4 | +31 | 11 21 | — 0 9 | 18 19 |
| 7 | 56 45 | 57 41 | 18 37 | +22 | 16 12 | + 0 37 | 17 52 |
| 8 | 57 38 | 59 4 | 18 54 | +14 | 17 29 | + 0 37 | 17 47 |
| 9 | 58 53 | 00 58 | 18 13 | +30 | 18 39 | + 0 39 | 18 22 |
| 10 | 138 00 7 | 1 45 | 16 30 | +23 | 17 49 | + 0 39 | 18 13 |
| 11 | 137 57 36 | 58 55 | 18 38 | +24 | 17 18 | + 0 40 | 18 12 |
| 12 | 138 00 23 | 2 5 | 18 40 | +17 | 20 11 | + 0 40 | 18 13 |
| | | | | | 48 17 25 | | 48 18 15 |
| 7 | 231 32 22 | 33 3 | 18 37 | —22 | 141 50 57 | — 0 46 | 141 51 14 |
| 8 | 33 2 | 34 40 | 18 54 | —14 | 52 32 | — 0 46 | 51 27 |
| 11 | 33 8 | 34 38 | 18 38 | —24 | 52 7 | — 0 49 | 51 32 |
| 12 | 34 47 | 37 13 | 18 40 | —16 | 54 24 | — 0 49 | 50 57 |
| | | | | Mean | 141 52 30 | | 141 51 18 |
| 10 | 213 4 38 | 6 18 | 16 30 | —19 | 123 21 39 | — 0 41 | 123 20 43 |
| 11 | 2 32 | 3 35 | 18 38 | —20 | 21 21 | — 0 41 | 20 54 |
| | | | | Mean | 123 21 30 | | 123 20 48 |

TABLE VII.—FOR PROPER MOTION, ETC.

| Plate No. | $t$—1874 $\tau$ | $P_1$ | $P_5$ | $F$ | Correction for Variation. | |
|---|---|---|---|---|---|---|
| | | | | | Scale $\times 10^3$ | Orientation. |
| | | | | $''$ | | $'$ $''$ |
| 1 | —0.127 | —.0094 | —1942.6 | +0.4 | —.00957 | +0 34 |
| 2 | — .127 | —.0094 | —1942.6 | +0.4 | +.02660 | +1 7 |
| 3 | — .127 | —.0094 | —1942.6 | +0.4 | +.00373 | —0 21 |
| 4 | — .105 | —.0078 | —1606.2 | +0.3 | +.11455 | +0 29 |
| 5 | — .105 | —.0078 | —1606.2 | +0.3 | +.01820 | +1 3 |
| 6 | — .105 | —.0078 | —1606.2 | +0.3 | —.05086 | +7 7 |
| 7 | + .418 | +.0310 | +6394.2 | —1.3 | —.00677 | +1 3 |
| 8 | + .418 | +.0310 | +6394.2 | —1.3 | +.00677 | —0 19 |
| 9 | + .448 | +.0332 | +6852.9 | —1.4 | —.03896 | —0 56 |
| 10 | + .448 | +.0332 | +6852.9 | —1.4 | +.01446 | —0 15 |
| 11 | + .451 | +.0334 | +6898.7 | —1.4 | —.03733 | +0 14 |
| 12 | + .451 | +.0334 | +6898.7 | —1.4 | —.04223 | —2 38 |

## Table VIII.—For Proper Motion.

| Star No. | In Distance. | In Position Angle. | | |
|---|---|---|---|---|
| | $s_1$ | $s_5$ | $s_6$ | $s_7$ |
| 1 | —1.000 | —.0104 | .0081 | —.00008 |
| 2 | —0.935 | —.3558 | .0085 | —.00304 |
| 3 | — .984 | +.1783 | .0132 | +.00235 |
| 4 | — .960 | —.2803 | .0125 | —.00352 |
| 5 | — .664 | —.7481 | .0083 | —.00621 |
| 6 | —0.838 | —.5454 | .0165 | —.00899 |
| 7 | — .622 | —.7829 | .0112 | —.00875 |
| 8 | — .673 | +.7401 | .0171 | +.01265 |
| 9 | — .990 | +.1428 | .0337 | +.00482 |
| 10 | — .978 | —.2087 | .0538 | —.01122 |
| 11 | —0.232 | —.9727 | .0094 | —.00919 |
| 12 | — .568 | —.8231 | .0826 | —.06795 |
| 13 | — .253 | —.9676 | .0416 | —.04022 |
| 14 | — .155 | —.9879 | .0126 | —.01250 |
| 15 | | | | |
| 16 | —0.103 | —.9947 | .0125 | —.01245 |
| 17 | + .280 | +.9601 | .0255 | +.02450 |
| 18 | + .563 | +.8263 | .0352 | +.02911 |
| 19 | + .137 | —.9906 | .0179 | —.01769 |
| 20 | + .349 | +.9370 | .0112 | +.01047 |
| 21 | +0.630 | —.7768 | .0312 | —.02424 |
| 22 | + .130 | —.9915 | .0098 | —.00970 |
| 23 | + .174 | —.9847 | .0080 | —.00791 |
| 24 | + .453 | —.8916 | .0150 | —.01339 |
| 25 | + .229 | —.9734 | .0084 | —.00821 |
| 26 | +0.963 | +.2709 | .0204 | +.00553 |
| 27 | + .430 | —.9030 | .0111 | —.01005 |
| 28 | + .721 | —.6932 | .0159 | —.01104 |
| 29 | + .998 | +.0633 | .0196 | +.00124 |
| 30 | + .926 | +.3777 | .0168 | +.00634 |
| 31 | +0.559 | —.8292 | .0121 | —.01005 |
| 32 | + .661 | +.7508 | .0092 | +.00687 |
| 33 | + .826 | +.5636 | .0105 | +.00593 |
| 34 | + .510 | —.8599 | .0081 | —.00693 |
| 35 | + .757 | —.6532 | .0087 | —.00570 |

TABLE IX.—MEAN RESULTS.

| Star No. | Distance. | Position Angle. | α′—α | δ′—δ | No. of Plates. | Durchmusterung. No. | Durchmusterung. Mag. |
|---|---|---|---|---|---|---|---|
| | ″ | ° ′ ″ | ″ | ″ | | ° | |
| 1 | 3471.54 | 261 57 38 | —6200.11 | — 528.57 | 2 | 56.2942 | 9.4 |
| 2 | 3279.96 | 241 44 1 | —5170.81 | —1583.43 | 8 | 55.2898 | 9.1 |
| 3 | 2125.81 | 272 51 16 | —3846.67 | + 89.36 | 12 | 56.2952 | 7.5 |
| 4 | 2233.14 | 246 18 15 | —3677.83 | — 912.64 | 12 | 56.2953 | 8.6 |
| 5 | 3376.37 | 214 9 24 | —3363.40 | —2806.80 | 5 | 55.2908 | 9.3 |
| 6 | 1699.59 | 229 30 18 | —2321.22 | —1109.73 | 5 | 56.2956 | 8.5 |
| 7 | 2505.96 | 211 2 20 | —2303.23 | —2153.15 | 8 | | |
| 8 | 1639.11 | 310 19 51 | —2279.93 | +1055.07 | 12 | 56.2958 | 7.0 |
| 9 | 830.27 | 270 47 43 | —1503.17 | + 9.01 | 12 | 56.2961 | 9.0 |
| 10 | 521.11 | 250 31 59 | — 888.41 | — 174.55 | 12 | 56.2962 | 9.0 |
| 11 | 2964.74 | 185 59 15 | — 548.13 | —2948.90 | 12 | 55.2915 | 9.3 |
| 12 | 339.10 | 207 10 5 | — 279.71 | — 301.78 | 4 | 56.2963 | 8.7 |
| 13 | 673.84 | 187 11 15 | — 151.89 | — 668.58 | 12 | 56.2964 | 9.1 |
| 14 | 2213.72 | 181 29 16 | — 102.40 | —2212.98 | 12 | 55.2917 | 8.2 |
| 15 | | *Bradley* | *3077* | | | 56.2966 | 6.0 |
| 16 | 2237.48 | 178 30 17 | + 104.00 | —2236.73 | 12 | 55.2919 | 7.6 |
| 17 | 1097.56 | 8 50 15 | + 307.73 | +1084.43 | 12 | 56.2969 | 8.0 |
| 18 | 795.11 | 26 52 45 | + 654.24 | + 708.74 | 6 | 56.2970 | 9.1 |
| 19 | 1568.18 | 164 42 34 | + 740.56 | —1513.29 | 12 | 55.2920 | 9.3 |
| 20 | 2508.31 | 13 2 27 | +1043.41 | +2442.43 | 12 | 57.2712 | 8.0 |
| 21 | 897.34 | 133 31 53 | +1172.55 | — 619.58 | 9 | 56.2972 | 9.3 |
| 22 | 2865.34 | 165 3 17 | +1311.41 | —2770.35 | 3 | 55.2922 | 9.5 |
| 23 | 3490.36 | 162 32 2 | +1851.74 | —3333.34 | 10 | 55.2925 | 8.5 |
| 24 | 1864.76 | 145 39 8 | +1883.65 | —1543.60 | 11 | 55.2926 | 8.5 |
| 25 | 3321.66 | 159 19 7 | +2076.84 | —3112.52 | 10 | 55.2928 | 8.3 |
| 26 | 1373.58 | 66 52 32 | +2296.06 | + 533.57 | 10 | 56.2974 | 9.4 |
| 27 | 2517.41 | 147 4 12 | +2439.97 | —2119.69 | 1 | | |
| 28 | 1758.20 | 126 28 8 | +2540.40 | —1052.30 | 4 | | |
| 29 | 1431.23 | 78 57 33 | +2548.30 | + 266.85 | 10 | 56.2975 | 9.4 |
| 30 | 1669.47 | 60 23 22 | +2643.71 | + 817.13 | 1 | 56.2976 | 9.5 |
| 31 | 2310.84 | 138 35 50 | +2732.23 | —1741.73 | 12 | 55.2929 | 7.6 |
| 32 | 3061.77 | 33 55 3 | +3151.75 | +2529.88 | 9 | 57.2715 | 8.5 |
| 33 | 2663.30 | 48 18 15 | +3647.57 | +1756.88 | 12 | 56.2978 | 7.0 |
| 34 | 3474.03 | 141 51 18 | +3808.68 | —2748.62 | 4 | 55.2933 | 8.9 |
| 35 | 3211.41 | 123 20 48 | +4794.57 | —1791.25 | 2 | 55.2935 | 9.4 |

TABLE X.—CATALOGUE OF STARS.

| Star No. | Helsingsfors-Gotha No. | Right Ascension, 1874. | Precession, J | Sec. Var., K | Declination, 1874. | Precession, L | Sec. Var. M |
|---|---|---|---|---|---|---|---|
| | | h m s | s | s | ° ′ ″ | ″ | ″ |
| 1 | | 23 0 20.015 | +2.5557 | +.0276 | 56 19 33.38 | +19.378 | +.088 |
| 2 | 13747 | 1 28.635 | 2.5709 | .0279 | 56 1 58.52 | 19.404 | .086 |
| 3 | 13768 | 2 56.911 | 2.5746 | .0286 | 56 29 51.31 | 19.436 | .084 |
| 4 | 13773 | 3 8.167 | 2.5814 | .0285 | 56 13 9.31 | 19.440 | .084 |
| 5 | | 3 29.129 | 2.5939 | .0283 | 55 41 35.15 | 19.447 | .084 |
| 6 | 13801 | 4 38.608 | +2.5952 | +.0289 | 56 9 52.22 | +19.472 | +.082 |
| 7 | | 4 39.807 | 2.6004 | .0288 | 55 52 28.80 | 19.473 | .083 |
| 8 | 13805 | 4 41.361 | 2.5846 | .0293 | 56 45 57.02 | 19.473 | .082 |
| 9 | 13814 | 5 33.145 | 2.5973 | .0294 | 56 28 30.96 | 19.491 | .081 |
| 10 | 13826 | 6 14.129 | 2.6041 | .0296 | 56 25 27.40 | 19.505 | .080 |
| 11 | 13829 | 6 36.814 | +2.6206 | +.0292 | 55 39 13.05 | +19.513 | +.080 |
| 12 | 13836 | 6 54.709 | 2.6105 | .0298 | 56 23 20.17 | 19.519 | .079 |
| 13 | 13837 | 7 3.230 | 2.6134 | .0298 | 56 17 13.37 | 19.522 | .079 |
| 14 | 13839 | 7 6.529 | 2.6213 | .0295 | 55 51 28.97 | 19.523 | .079 |
| 15 | **13841** | **23 7 13.356** | **2.6116** | **.0300** | **56 28 21.95** | **19.525** | **.078** |
| 16 | 13844 | 7 20.289 | +2.6233 | +.0296 | 55 51 5.22 | +19.527 | +.079 |
| 17 | 13848 | 7 33.871 | 2.6093 | .0303 | 56 46 26.38 | 19.532 | .078 |
| 18 | 13850 | 7 56.972 | 2.6145 | .0303 | 56 40 10.69 | 19.539 | .077 |
| 19 | 13852 | 8 2.727 | 2.6259 | .0299 | 56 3 8.66 | 19.541 | .078 |
| 20 | 13856 | 8 22.917 | 2.6098 | .0308 | 57 9 4.38 | 19.548 | .077 |
| 21 | | 8 31.526 | +2.6255 | +.0303 | 56 18 2.37 | +19.551 | +.077 |
| 22 | | 8 40.783 | 2.6369 | .0303 | 55 42 11.60 | 19.554 | .077 |
| 23 | 13870 | 9 16.805 | 2.6445 | .0300 | 55 32 48.61 | 19.565 | .076 |
| 24 | 13871 | 9 18.933 | 2.6367 | .0303 | 56 2 38.35 | 19.566 | .076 |
| 25 | 13875 | 9 31.812 | 2.6454 | .0301 | 55 36 29.43 | 19.570 | .076 |
| 26 | | 9 46.427 | +2.6310 | +.0308 | 56 37 15.52 | +19.575 | +.074 |
| 27 | | 9 56.021 | 2.6445 | .0304 | 55 53 2.26 | 19.578 | .076 |
| 28 | | 10 2.716 | 2.6407 | .0304 | 56 10 49.65 | 19.580 | .076 |
| 29 | | 10 3.243 | 2.6347 | .0304 | 56 32 48.80 | 19.580 | .076 |
| 30 | | 10 9.603 | 2.6332 | .0304 | 56 41 59.08 | 19.582 | .076 |
| 31 | 13885 | 10 15.505 | +2.6455 | +.0306 | 55 59 20.22 | +19.584 | +.075 |
| 32 | 13894 | 10 43.473 | 2.6300 | .0316 | 57 10 31.83 | 19.593 | .073 |
| 33 | 13903 | 11 16.527 | 2.6385 | .0316 | 56 57 38.83 | 19.603 | .073 |
| 34 | 13907 | 11 27.268 | 2.6600 | .0308 | 55 42 33.33 | 19.606 | .073 |
| 35 | | 12 32.994 | 2.6652 | .0313 | 55 58 30.70 | 19.626 | .071 |

## VI.—*The Præsepe Group; Measurement and Reduction of the Rutherfurd Photographs.*

By Frank Schlesinger.

Read April 4, 1898.

## I.

### Description of the Plates.

The collection of astronomical photographs presented by the late Lewis M. Rutherfurd to the Observatory of Columbia University contains eleven photographs of Præsepe taken with his larger and improved instrument; only eight of these were measured and reduced, three having been judged inferior to the rest. According to Rutherfurd's invariable practice, each plate shows two complete pictures of the group separated by about a millimetre in right ascension, the driving clock of the instrument having been stopped for a few seconds after the completion of the first or eastern impression. Near the west edge of the plate still a third image of each of the brighter stars in the group is found, separated by about forty millimetres from the two other impressions, the driving clock having been stopped for an interval of about three minutes after the completion of the second impression, and then started again and allowed to run long enough to permit the brighter stars to leave well-defined images. The object in securing these third impressions or *trails* was to afford means for orienting the group, but in the present work they were not used for this purpose, the orientation having been effected in another way. It is important, however, to know how accurately the use of trails will give the orientation, and they were therefore completely measured and reduced, and the results compared with those obtained by the method actually employed, which is of unquestioned accuracy but may not be always available.

A perpendicular to the plate passing through the optical centre of the object glass pierces the plate at a point whose approximate position must be known in order to reduce the measures of the stars to right ascensions and declinations. Rutherfurd so adjusted his plate holder that this point coincides approximately with the image of the central star of the group, numbered 15 in the following pages.

Table I gives the data of exposure for the plates. Plates VI, X and XI do not appear, these being the ones that were not measured, on account of their inferiority. This is due to the fact that the photographic images of the stars on these plates, when viewed under the microscope of the measuring machine were neither so round nor so well defined as on the other plates and therefore did not admit of so accurate measurement. The irregularity of the images is not due to a deterioration of the plates since they were taken, but to the bad behavior of RUTHERFURD's clock during the exposures. For this reason these three plates were never measured, it being deemed probable that more reliable results are to be obtained from the eight plates actually reduced, than if all the plates had been measured, in spite of the greater number of observations in the latter case. In this connection I should also say that not all the stars which appear on the plates were measured. A few whose images come near the edges of the plates were rejected, for not only are these images much distorted, but as we shall see later, the corrections become uncertain as we recede from the centre of the plate.

TABLE I.—PHOTOGRAPHS OF PRÆSEPE.

Observatory of L. M. Rutherfurd, New York.

Lat. $= 40°43'48''.5$ Long. $= 4^h55^m56^s.62$ W.

| No. | Date. | Sidereal Time. | Bar. | Thermometers. | | | Focus |
|---|---|---|---|---|---|---|---|
| | | | | Att. | Ext. | Tel. | |
| | | h m s | | ° | ° | ° | |
| I | 1870 Apr. 24 | 10 45 05 | 30.01 | 60 | 55 | 58 | 8.4 |
| II | 1870 Apr. 24 | 11 25 35 | 30.01 | 60 | 55 | 58 | 8.4 |
| III | 1870 Apr. 25 | 11 10 35 | 30.26 | 53 | 47 | 53 | 8.4 |
| IV | 1870 Apr. 25 | 11 59 35 | 30.26 | 53 | 47 | 53 | 8.4 |
| V | 1877 Apr. 14 | 10 39 38 | 30.06 | 47 | 45 | 48 | 7.8 |
| VII | 1877 Apr. 25 | 11 26 02 | 30.06 | 57 | 56 | 58 | 7.7 |
| VIII | 1877 Apr. 25 | 11 53 32 | 30.06 | 57 | 56 | 58 | 7.7 |
| IX | 1877 May 2 | 10 57 08 | 29.86 | 47 | 46 | 48 | 7.8 |

The column marked "sidereal time" gives the mean of four instants for each plate: beginning of east exposure, end of east exposure, beginning of west exposure and end of west exposure; each exposure lasted six minutes. Three thermometers were read: attached, external and telescope, the last being in contact with the telescope-tube. The last column, marked "focus," gives the reading of a micrometer head attached to the eye end of the telescope and shows the position of the plate holder; this information is not used in the reductions and is given only to provide for the possibility of determining a relation between this reading and the scale-value after a sufficient number of the photographs made with this instrument has been reduced.

## II.

## Measurement of the Plates.

The plates were measured with the older Repsold Measuring Machine of this Observatory, which is a counterpart of the one by the same maker belonging to the University of Leyden except that an alteration has been made which obviates "projection errors." (See III.) A full description of the Leyden machine is given in the "Bulletin du Comité Permanent," Vol. 1, page 169, and also in the recent work by Dr. Scheiner, "Photographie der Gestirne," page 148. The machine is so constructed that the position of a star may be determined either by position angle and distance or by rectangular coördinates; the latter method was adopted in the present case. A star which is to be measured may be brought into the field of the reading microscope by moving the plate along a straight guiding cylinder and then moving the microscope at right angles to the cylinder on another straight guiding way. The wire of the micrometer is made to bisect the image of the star and the micrometer head is read. Then the whole microscope is revolved through a small vertical angle and the wire set upon a scale of millimetres placed parallel to the motion of the microscope. The difference of the two readings on star and scale, together with the number of the line on the scale gives us the position of the star. Having gone through the same operation for all the stars we obtain their relative positions, at least in one direction; the plate is now revolved through 90° by means of the graduated circle and the stars are again measured; these two sets of measures are sufficient to fix the relative positions of the stars, but in order to secure greater accuracy and especially to eliminate personality the plate is turned 180° and 270° respectively from its original position, and the stars are read a third and a fourth time. By means of the trails or otherwise the plate may be so placed in the machine that a circle of declination through the central star shall be approximately parallel to the guiding cylinder; in this way we obtain rectangular coördinates which are nearly in the directions of right ascensions and declinations, thus rendering their conversion into the latter a comparatively easy matter.

Two observers alternated in the measurements, one recording while the other observed; the details of each morning's work, which usually lasted a little over two hours, are as follows: the first observer reads the circle, runs and temperature, the second reads on the central star thus: East image, scale, scale, east image; west image, scale, scale, west image. Continuing, the second observer goes through the same operations for usually three other stars, experience having shown that four stars could be read conveniently without fatiguing the eye; thus the observers alternate till twenty or twenty-five stars have been read and then the temperature is recorded a second time. The morning's work is now half finished; the same stars are then observed in the reverse order, care being taken that each observer shall now read those stars that he had not read in the first half; having finally gotten back to the central star, temperature, runs and the circle are read as at the beginning. This process of repeating all the measurements in the reverse order, eliminates the effects of any change in the machine or in the observers that is proportionate to the time, for the mean of the two times of observation is nearly the same for all the stars. In the first half of the morning's work the micrometer head is set at about $9.^R0$ when pointed at a star; but in the second half the reading is made $9.^R5$; in this way periodic errors of the screw are nearly eliminated, for both star and scale are read with two different parts of the screw separated by half a turn.

The measurements made in the first position of the plate, *i. e.*, with the stars having the greatest *right ascensions* farthest from the cylinder are recorded as "$x$ direct;" on the next day the plate is turned 90° in a counter-clockwise direction so that now the stars having the greatest *north polar distances* are farthest from the cylinder. The measurements taken in this position are called "$y$ direct," while those taken in the two opposite positions, 180° and 270° from the original position are called respectively "$x$ reversed" and "$y$ reversed." As only twenty or twenty-five stars could be measured on each day, and as the photographs of Præsepe show about forty-five stars that admit of measurement, it was necessary to spend two days on each position of the plate. To eliminate the effect of a possible motion of the plate or of the scale the central star 15 was read each day by both observers. After three of the plates had been measured, viz.: III, VII and IX, it was decided to read the central star more often, so that on the succeeding plates four such readings were made every day, instead of two.

Three observers were engaged in the measurement of the first five plates, but only two were concerned in the work for any single day. Care was always taken to have the same pair of observers make both the direct and the reversed measurements of a particular set of stars, in order to eliminate personality. Suppose one of the observers has contracted the habit of always setting the micrometer wire too far to the right of the centre of a star's image by an amount depending upon the size of the image; the distance between two stars as obtained by such an observer will be subject to an error which depends upon the difference of magnitudes of the stars. But when the plate is reversed 180°, the same observer will get a distance which is too small by as much as the first distance was too large or vice versa; consequently the mean of the two measurements will be free from such personality as we have supposed. However, this method of measurement does not eliminate all personality, for the star images are seldom round and are usually more sharply defined on one edge than upon the other; two observers will thus sometimes differ considerably in their estimations of the true centre of the image.

Table II gives the runs, circle reading, etc., for each day. Runs were observed twice daily, once before and once after the measurement of the stars; the number in the column headed "runs" is the mean of the two determinations expressed in millimetres. The circle was also read twice, employing two microscopes 180° apart for each reading; in the column marked "circle" the degrees and minutes are always taken from the right-hand microscope, while the number of seconds is the mean of both microscopes. The thermometer occupied a fixed position near the plate and was graduated in Fahrenheit degrees. The last column gives the initials of the three observers, Kretz, Hays and Schlesinger.

TABLE II.—DAILY RECORDS.

| Date, 1897. | Runs in mm. | Circle. | Ther. | Position of Plate, and Stars Measured. | Obs'rs. |
|---|---|---|---|---|---|
| | | Plate III. | | | |
| Jan. 12 | —0.0029 | 185° 58′ 00″ | 63.3 | *x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–24, 26, 28, 29, 45. | S, K |
| " 13 | —0.0026 | 275 57 57 | 67.0 | *y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–26, 28, 29, 33. | S, H |
| " 18 | —0.0026 | 5 58 00 | 63.2 | *x* reversed; see Jan. 12. | S, K |
| " 19 | —0.0021 | 185 57 57 | 60.8 | *x* direct; 1, 2, 5, 7, 15, 23A, 25, 27, 31–37; 39, 40, 43–45. | K, H |
| " 20 | —0.0016 | 95 58 02 | 63.6 | *y* reversed; see Jan. 13. | S, H |
| " 21 | —0.0025 | 275 58 01 | 65.2 | *y* direct; 1, 5, 7, 15, 23A, 27, 31–37, 39, 40, 43–45. | S, H |
| " 23 | —0.0035 | 5 58 00 | 60.5 | *x* reversed; see Jan. 19. | K, H |
| " 26 | | 275 58 00 | | Trails; 15, 23, 27, 31. | S, K |
| " 27 | —0.0020 | 95 58 00 | 61.6 | *y* reversed; see Jan. 21. | S, H |
| | | Plate IX. | | | |
| Feb. 5 | +0.0028 | 177° 37′ 02″ | 63.2 | *x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 45. | S, K |
| " 8 | | 267 37 01 | | Trails; 15, 23, 31, 37. | S, K |
| " 9 | +0.0016 | 267 37 00 | 62.2 | *y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 33. | K, H |
| " 10 | +0.0010 | 267 36 58 | 63.6 | *y* direct; 1, 5, 7, 15, 23A, 31–40, 43–45. | S, H |
| " 11 | +0.0021 | 87 37 02 | 60.9 | *y* reversed; see Feb. 10. | S, H |
| " 13 | +0.0006 | 87 37 01 | 63.5 | *y* reversed; see Feb. 9. | K, H |
| " 16 | +0.0031 | 357 37 02 | 64.2 | *x* reversed; see Feb. 19. | K, H |
| " 17 | —0.0016 | 357 37 00 | 65.9 | *x* reversed; see Feb. 5. | S, K |
| " 19 | +0.0036 | 177 37 02 | 66.4 | *x* direct; 1, 2, 5, 7, 15, 23A, 31–40, 43–45. | K, H |
| | | Plate VII. | | | |
| Feb. 26 | +0.0026 | 86° 54′ 00″ | 63.8 | *x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 31–33, 45. | S, H |
| " 27 | +0.0030 | 356 54 00 | 62.1 | *y* reversed; see Mar. 1. | S, K |
| Mar. 1 | +0.0039 | 176 54 02 | 59.4 | *y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 31–33. | S, K |
| " 2 | +0.0011 | 176 54 02 | 65.1 | *y* direct; 1, 5, 7, 7A, 15, 19, 21, 23A, 33–45. | K, H |
| " 3 | +0.0039 | 86 53 58 | 65.9 | *x* direct; 1, 2, 5, 7, 7A, 15, 19, 21, 23A, 34–45 | S, H |
| " 4 | +0.0044 | 266 53 56 | 66.8 | *x* reversed; see Feb. 26. | S, H |
| " 5 | | 176 54 00 | | Trails; 15, 22, 23, 31. | S, H |
| " 6 | +0.0045 | 356 54 03 | 65.8 | *y* reversed; see Mar. 2. | K, H |
| " 8 | +0.0026 | 266 54 00 | 60.8 | *x* reversed; see Mar. 3. | S, H |

TABLE II.—DAILY RECORDS. (*Continued.*)

| Date, 1897. | Runs in mm. | Circle. | Ther. | Position of Plate, and Stars Measured. | Obsr's. |
|---|---|---|---|---|---|
| | | Plate VIII. | | | |
| Mar. 15 | +0.0036 | 177° 02′ 28″ | 56.8 | *x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 31, 45. | S, K |
| " 16 | +0.0036 | 267 02 30 | 62.6 | *y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22, 29, 31, 33. | K, H |
| " 17 | +0.0039 | 357 02 31 | 60.4 | *x* reversed; see Mar. 15. | S, K |
| " 18 | +0.0036 | 357 02 27 | 62.3 | *x* reversed; see Mar. 25. | S, H |
| " 20 | +0.0050 | 87 02 32 | 62.0 | *y* reversed; see Mar. 16. | K, H |
| " 22 | +0.0045 | 87 02 28 | 64.6 | *y* reversed; see Mar. 24. | S, K |
| " 23 | | 267 02 29 | | Trails; 15, 22, 23, 31. | K, H |
| " 24 | +0.0042 | 267 02 34 | 63.9 | *y* direct; 1, 5, 7, 7A, 15, 19, 23A, 32–45. | S, K |
| " 25 | +0.0045 | 177 02 29 | 62.8 | *x* direct; 1, 2, 5, 7, 7A, 15, 19, 23A, 32–45. | S, H |
| | | Plate II. | | | |
| Apr. 3 | +0.0015 | 276° 00′ 00″ | 65.9 | *y* direct; 2, 4, 6, 8, 10, 11, 14–18, 20, 22–26, 28, 29, 33. | K, H |
| " 5 | +0.0015 | 185 59 59 | 65.9 | *x* direct; 2, 4, 6, 8, 10, 11, 14–18, 20, 22–29, 45. | S, K |
| " 6 | +0.0001 | 96 00 02 | 67.8 | *y* reversed; see Apr. 3. | K, H |
| " 7 | +0.0018 | 6 00 00 | 67.8 | *x* reversed; see Apr. 5. | S, K |
| " 8 | +0.0035 | 6 00 00 | 67.6 | *x* reversed; see Apr. 10. | S, H |
| " 9 | +0.0046 | 276 00 00 | 64.7 | *y* direct; 1, 5, 7, 7A, 15, 19, 23A, 27, 31–40, 43–45. | K, H |
| " 10 | +0.0055 | 185 59 58 | 65.6 | *x* direct; 1, 2, 5, 7, 7A, 15, 19, 23A, 31–40, 43–45. | S, H |
| " 14 | +0.0062 | 95 59 59 | 65.9 | *y* reversed; see Apr. 9. | K, H |
| | | Plate IV. | | | |
| Apr. 24 | +0.0101 | 186° 16′ 58″ | 69.7 | *x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 45. | S, K |
| " 28 | +0.0109 | 6 17 01 | 65.9 | *x* reversed; see Apr. 24. | S, K |
| " 29 | +0.0151 | 276 17 00 | 66.9 | *y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–26, 28, 29, 33. | S, K |
| May 1 | +0.0165 | 96 17 02 | 67.5 | *y* reversed; see Apr. 29. | S, K |
| " 3 | +0.0155 | 96 16 58 | 65.0 | *y* reversed; see May 5. | S, K |
| " 4 | +0.0136 | 186 16 58 | 66.0 | *x* direct; 1, 2, 5, 7, 7A, 15, 19, 23A, 31–40, 43–45. | S, K |
| " 5 | +0.0156 | 276 16 57 | 66.9 | *y* direct; 1, 5, 7, 7A, 15, 19, 23A, 27, 31–40, 43–45. | S, K |
| " 6 | +0.0160 | 6 17 00 | 68.8 | *x* reversed; see May 4. | S, K |
| " 8 | | 276 17 01 | | Trails; 15, 23, 31, 37. | S, K |

TABLE II.—DAILY RECORDS. (*Concluded.*)

| Date, 1897. | Runs in mm. | Circle. | Ther. | Position of Plate, and Stars Measured. | Obs'rs. |
|---|---|---|---|---|---|
| Plate I. | | | | | |
| Nov. 3 | —0.0080 | 187° 10′ 05″ | 65.3 | *x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29. | S, K |
| " 4 | —0.0062 | 187 10 04 | 63.8 | *x* direct; 1, 2, 5, 7, 15, 23A, 31–40, 43, 44. | S, K |
| " 6 | —0.0076 | 277 10 06 | 65.4 | *y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 33. | S, K |
| " 10 | —0.0056 | 277 10 03 | 65.0 | *y* direct; 1, 5, 7, 15, 23A, 31–40, 43, 44. | S, K |
| " 11 | —0.0064 | 7 10 07 | 67.0 | *x* reversed; see Nov. 3. | S, K |
| " 13 | —0.0066 | 7 10 05 | 64.1 | *x* reversed; see Nov. 4. | S, K |
| " 16 | —0.0069 | 97 10 05 | 65.2 | *y* reversed; see Nov. 6. | S, K |
| " 17 | | 277 10 08 | | Trails; 15, 23, 31, 37. | S, K |
| " 18 | —0 0065 | 97 10 05 | 64.6 | *y* reversed; see Nov. 10. | S, K |
| Plate V. | | | | | |
| Nov. 20 | —0.0041 | 176° 09′ 07″ | 64.5 | *x* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29, 45. | S, K |
| " 23 | —0.0060 | 176 09 07 | 64.2 | *x* direct; 1, 2, 5, 7, 15, 19, 23A, 31, 32, 34, 35,37,39,40,43–45. | S, K |
| " 24 | —0.0061 | 266 09 07 | 68.7 | *y* direct; 2–4, 6, 8, 10, 11, 14–18, 20, 22–29. | S, K |
| " 26 | —0.0059 | 266 09 06 | 71.0 | *y* direct; 1, 5, 7, 15, 19, 23A, 31, 32, 34, 35,37,39,40,43–45. | S, K |
| " 27 | —0.0068 | 356 09 07 | 68.5 | *x* reversed; see Nov. 20. | S, K |
| " 30 | —0.0072 | 356 09 04 | 63.4 | *x* reversed; see Nov. 23. | S, K |
| Dec. 1 | —0.0065 | 86 09 07 | 66.1 | *y* reversed; see Nov. 24. | S, K |
| " 2 | —0.0058 | 86 09 08 | 65.4 | *y* reversed; see Nov. 26. | S, K |

On the next page is given a specimen of the recording sheets; all the measurements relating to the same star for any one plate are recorded on one sheet. The forms are not designed for the separate reduction of the two impressions of a group which appear on each plate, but the mean of the measurements on the two images of a star is taken at once; that is, each star is treated as though it occupied the middle point between its two images. The place of this point is known when we have given the lines of the scale used in the measurement and the quantity $\frac{1}{2}m$, which is obtained thus: from the reading on the scale we subtract the reading on the star, and the mean of these differences for both images is taken, giving "Mean of Diff's;" as the scale is one of millimetres and as *two* complete turns of the screw correspond to a space on the scale we divide by 2 and get $\frac{1}{2}m$. In reading on the scale it was made a rule to select the line having the next lower number; consequently the place of a star is obtained by *adding* $\frac{1}{2}m$ to the mean of the numbers of the lines used; in rare cases, however, the next higher line was employed when it came nearly opposite to a star, as on March 24; this has been indicated by affixing a minus sign to $\frac{1}{2}m$. In the $y$ measurements the same line was always used for both images, since the latter differ only in apparent right ascension.

Table III gives the uncorrected observations; it is only necessary to set down the numbers of the lines used and $\frac{1}{2}m$, for these not only fix the place of the star but, as we shall see later, they are sufficient for the application of all instrumental corrections. The numbers of the stars are in the order of increasing right ascensions and are those given by Professor Schur,* excepting $7A$ and $23A$, which do not appear in his triangulation of the group. The table gives the observations of $\frac{1}{2}m$ by both observers, followed by the difference reduced to seconds of arc in order to facilitate a comparison.

* "Astronomische Mittheilungen der K. Sternwarte zu Göttingen," part IV.

## Præsepe. Plate VIII. Star 7.

**March 25, 1897; $x$ direct.**

| | Star. Microm. | Scale. Line. | Scale. Microm. | Diff's of Mean |
|---|---|---|---|---|
| East | 9.053 | 74 | 10.680 | |
| | .050 | | .681 | |
| Mean | 9.0515 | | 10.6805 | 1.6290 |
| West | 9.050 | 76 | 9.280 | |
| | .051 | | .280 | |
| Mean | 9.0505 | | 9.2800 | 0.2295 |

Mean of Diff's = 0.9292
$\frac{1}{2}m$ = 0.4646
Measured by Hays.
Recorded by Schl.

| | Star. Microm. | Scale. Line. | Scale. Microm. | Diff's of Mean |
|---|---|---|---|---|
| East | 9.597 | 74 | 11.229 | |
| | .598 | | .230 | |
| Mean | 9.5975 | | 11.2295 | 1.6320 |
| West | 9.579 | 76 | 9.800 | |
| | .574 | | .800 | |
| Mean | 9.5765 | | 9.8000 | 0.2235 |

Mean of Diff's = 0.9278
$\frac{1}{2}m$ = 0.4639
Measured by Schl.
Recorded by Hays.

**March 24, 1897; $y$ direct.**

| | Star. Microm. | Scale. Line. | Scale. Microm. | Diff's of Mean |
|---|---|---|---|---|
| East | 9.030 | 36 | 9.009 | |
| | .030 | | .010 | |
| Mean | 9.0300 | | 9.0095 | —0.0205 |
| West | 9.050 | 36 | 9.009 | |
| | .050 | | .009 | |
| Mean | 9.0500 | | 9.0090 | —0.0410 |

Mean of Diff's = —0.0308
$\frac{1}{2}m$ = —0.0154
Measured by Schl.
Recorded by Kretz.

| | Star. Microm. | Scale. Line. | Scale. Microm. | Diff's of Mean |
|---|---|---|---|---|
| East | 9.547 | 36 | 9.515 | |
| | .540 | | .518 | |
| Mean | 9.5435 | | 9.5165 | —0.0270 |
| West | 9.562 | 36 | 9.517 | |
| | .560 | | .517 | |
| Mean | 9.5610 | | 9.5170 | —0.0440 |

Mean of Diff's = —0.0355
$\frac{1}{2}m$ = —0.0178
Measured by Kretz.
Recorded by Schl.

**March 18, 1897; $x$ reversed.**

| | Star. Microm. | Scale. Line. | Scale. Microm. | Diff's of Mean |
|---|---|---|---|---|
| East | 9.024 | 44 | 10.513 | |
| | .035 | | .512 | |
| Mean | 9.0295 | | 10.5125 | 1.4830 |
| West | 9.013 | 43 | 9.910 | |
| | .023 | | .910 | |
| Mean | 9.0180 | | 9.9100 | 0.8920 |

Mean of Diff's = 1.1875
$\frac{1}{2}m$ = 0.5938
Measured by Schl.
Recorded by Hays.

| | Star. Microm. | Scale. Line. | Scale. Microm. | Diff's of Mean |
|---|---|---|---|---|
| East | 9.550 | 44 | 11.021 | |
| | .543 | | .020 | |
| Mean | 9.5465 | | 11.0205 | 1.4740 |
| West | 9.535 | 43 | 10.420 | |
| | .535 | | .419 | |
| Mean | 9.5350 | | 10.4195 | 0.8845 |

Mean of Diff's = 1.1792
$\frac{1}{2}m$ = 0.5896
Measured by Hays.
Recorded by Schl.

**March 22, 1897; $y$ reversed.**

| | Star. Microm. | Scale. Line. | Scale. Microm. | Diff's of Mean |
|---|---|---|---|---|
| East | 9.081 | 83 | 10.214 | |
| | .085 | | .212 | |
| Mean | 9.0830 | | 10.2130 | 1.1300 |
| West | 9.070 | 83 | 10.212 | |
| | .069 | | .211 | |
| Mean | 9.0695 | | 10.2115 | 1.1420 |

Mean of Diff's = 1.1360
$\frac{1}{2}m$ = 0.5680
Measured by Schl.
Recorded by Kretz.

| | Star. Microm. | Scale. Line. | Scale. Microm. | Diff's of Mean |
|---|---|---|---|---|
| East | 9.555 | 83 | 10.681 | |
| | .555 | | .684 | |
| Mean | 9.5550 | | 10.6825 | 1.1275 |
| West | 9.545 | 83 | 10.683 | |
| | .540 | | .683 | |
| Mean | 9.5425 | | 10.6830 | 1.1405 |

Mean of Diff's = 1.1340
$\frac{1}{2}m$ = 0.5670
Measured by Kretz.
Recorded by Schl.

### Table III.—Plate I: $x$ Measurements.

| Star. | $x$ direct. Lines. | ½ $m$, or Scale *minus* Star. Schl. | ½ $m$, or Scale *minus* Star. Kretz. | $S-K$ | $x$ reversed. Lines. | ½ $m$, or Scale *minus* Star. Schl. | ½ $m$, or Scale *minus* Star. Kretz. | $S-K$ |
|---|---|---|---|---|---|---|---|---|
| 15 | 60,61 | 0.9016 | 0.8984 | +0″.19 | 57,58 | 0.6695 | 0 6681 | +0″.07 |
| 15 | 60,61 | 0.9010 | 0.8994 | + .07 | 57,58 | 0.6685 | 0.6696 | − .06 |
| 2 | 94,95 | 0.4114 | 0.4114 | .00 | 24,25 | 0.1652 | 0.1635 | + .08 |
| 3 | 93,94 | 0.2961 | 0.2954 | + .04 | 25,26 | 0.2798 | 0.2782 | + .08 |
| 4 | 91,92 | 0.5395 | 0.5419 | − .13 | 27,28 | 0.0356 | 0.0348 | + .04 |
| 6 | 78,79 | 0.3274 | 0.3290 | − .08 | 40,41 | 0.2472 | 0.2455 | + .08 |
| 8 | 71,72 | 0.4849 | 0.4878 | − .15 | 47,48 | 0.0884 | 0.0849 | + .19 |
| 10 | 70,71 | 0.5885 | 0.5859 | + .14 | 48,49 | − .0174 | − .0169 | − .03 |
| 11 | 69,70 | 0.7241 | 0.7252 | − .06 | 48,49 | 0.8429 | 0.8451 | − .12 |
| 14 | 61.62 | 0.1022 | 0.1020 | + .01 | 57,58 | 0.4649 | 0.4684 | − .19 |
| 16 | 60 | 0.4836 | 0.4858 | − .12 | 58,59 | 0.5859 | 0.5871 | − .06 |
| 17 | 58,59 | 0.5726 | 0.5739 | − .07 | 60,61 | − .0020 | − .0006 | − .07 |
| 18 | 57,58 | 0.0299 | 0.0321 | − .12 | 61,62 | 0.5404 | 0.5391 | + .07 |
| 20 | 56.57 | 0.6860 | 0.6865 | − .03 | 61,62 | 0.8866 | 0.8865 | .00 |
| 22 | 54,55 | 0.7451 | 0.7494 | − .23 | 63,64 | 0 8208 | 0.8221 | − .08 |
| 23 | 53,54 | 0.3750 | 0.3759 | − .05 | 65,66 | 0.1946 | 0.1944 | + .01 |
| 24 | 51,52 | 0.2446 | 0.2451 | − .03 | 67,68 | 0.3272 | 0.3256 | + .08 |
| 25 | 50,51 | 0.6644 | 0.6640 | + .02 | 67,68 | 0.9106 | 0.9080 | + .13 |
| 26 | 50,51 | 0.5456 | 0.5480 | − .13 | 68,69 | 0.0282 | 0.0231 | + .27 |
| 27 | 50,51 | 0.2915 | 0.2942 | − .14 | 68,69 | 0.2752 | 0.2784 | − .17 |
| 28 | 50,51 | 0.0596 | 0.0622 | − .14 | 68,69 | 0.5080 | 0.5075 | + .03 |
| 29 | 49,50 | 0.4759 | 0.4772 | − .07 | 69,70 | 0.0936 | 0.0944 | − .04 |
| 15 | 60,61 | 0.9005 | 0.8999 | +0″.02 | 57,58 | 0.6698 | 0.6682 | +0″.08 |
| 15 | 60,61 | 0.9009 | 0.8990 | + .12 | 57,58 | 0.6688 | 0.6669 | + .10 |
| 1 | 95,96 | 0.4069 | 0.4066 | + .02 | 23,24 | 0.1675 | 0.1684 | − .05 |
| 2 | 94,95 | 0.4126 | 0.4120 | + .03 | 24,25 | 0.1625 | 0.1616 | + .05 |
| 5 | 82,83 | 0.5152 | 0.5181 | − .15 | 36,37 | 0.0534 | 0.0540 | − .03 |
| 7 | 75,76 | 0.5840 | 0.5830 | + .05 | 43,44 | − .0130 | − .0164 | + .18 |
| 23A | 52,53 | 0.3599 | 0.3531 | + .36 | 66,67 | 0.2135 | 0.2155 | − .11 |
| 31 | 48,49 | 0.8738 | 0.8725 | + .08 | 69,70 | 0.6971 | 0.6972 | − .01 |
| 32 | 47,48 | − .0078 | − .0088 | + .05 | 71,72 | 0.5745 | 0.5799 | − .29 |
| 33 | 45,46 | 0.3332 | 0.3376 | − .23 | 73,74 | 0.2350 | 0.2410 | − .32 |
| 34 | 44,45 | 0.6959 | 0.7006 | − .25 | 73,74 | 0.8731 | 0.8708 | + .13 |
| 35 | 42,43 | 0.7008 | 0.7029 | − .12 | 75,76 | 0.8659 | 0.8645 | + .08 |
| 36 | 41,42 | 0.2239 | 0.2221 | + .09 | 77,78 | 0.3489 | 0.3515 | − .14 |
| 37 | 41,42 | 0.0792 | 0.0799 | − .04 | 77,78 | 0.4944 | 0.4919 | + .13 |
| 38 | 37,38 | 0.4668 | 0.4691 | − .12 | 81,82 | 0.1081 | 0.1061 | + .10 |
| 39 | 36,37 | 0.7224 | 0.7174 | + .26 | 81,82 | 0.8555 | 0.8554 | .00 |
| 40 | 34,35 | 0.8836 | 0.8819 | + .08 | 83,84 | 0.6880 | 0.6890 | − .05 |
| 43 | 27,28 | − .0094 | − .0124 | + .16 | 91,92 | 0.5789 | 0.5781 | + .04 |
| 44 | 26,27 | 0.4574 | 0.4624 | − .26 | 92,93 | 0.1164 | 0.1168 | − .02 |

TABLE III.—PLATE I: *y* MEASUREMENTS.

| Star. | *y* direct. | | | | *y* reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Line. | ½ *m*, or Scale *minus* Star. | | *S—K* | Line. | ½ *m*, or Scale *minus* Star. | | *S—K* |
| | | Schl. | Kretz. | | | Schl. | Kretz. | |
| | | | | ″ | | | | ″ |
| 15 | 52 | 0.3166 | 0.3169 | —0.02 | 67 | 0.2538 | 0.2550 | —0.06 |
| 15 | 52 | 0.3140 | 0.3176 | — .19 | 67 | 0.2551 | 0.2545 | + .03 |
| 2 | 48 | 0.8969 | 0.8979 | — .06 | 70 | 0.6722 | 0.6735 | — .07 |
| 3 | 34 | 0.3140 | 0.3131 | + .05 | 85 | 0.2620 | 0.2640 | — .11 |
| 4 | 17 | 0.2278 | 0.2255 | + .12 | 102 | 0.3502 | 0.3512 | — .05 |
| 6 | 66 | 0.5180 | 0.5181 | — .01 | 53 | 0.0520 | 0.0530 | — .05 |
| 8 | 67 | 0.2651 | 0.2636 | + .08 | 52 | 0.3064 | 0.3069 | — .03 |
| 10 | 45 | 0.2985 | 0.2952 | + .17 | 74 | 0.2756 | 0.2744 | + .06 |
| 11 | 39 | 0.5589 | 0.5594 | — .03 | 80 | 0.0149 | 0.0134 | + .08 |
| 14 | 73 | 0.2576 | 0.2595 | — .10 | 46 | 0.3138 | 0.3102 | + .19 |
| 16 | 18 | 0.0766 | 0.0752 | + .07 | 101 | 0.4996 | 0.5044 | — .25 |
| 17 | 36 | 0.1639 | 0.1634 | + .03 | 83 | 0.4050 | 0.4050 | .00 |
| 18 | 37 | 0.0128 | 0.0138 | — .05 | 82 | 0.5598 | 0.5579 | + .10 |
| 20 | 36 | 0.2369 | 0.2336 | + .17 | 83 | 0.3358 | 0.3385 | — .14 |
| 22 | 68 | —.0124 | —.0101 | — .12 | 51 | 0.5811 | 0.5822 | — .06 |
| 23 | 65 | 0.5135 | 0.5144 | — .05 | 54 | 0.0558 | 0.0571 | — .07 |
| 24 | 35 | 0.6510 | 0.6511 | — .01 | 83 | 0.9205 | 0.9208 | — .03 |
| 25 | 46 | 0.1918 | 0.1918 | .00 | 73 | 0.3802 | 0.3779 | + .12 |
| 26 | 23 | 0.2064 | 0.2035 | + .15 | 96 | 0.3684 | 0.3689 | — .03 |
| 27 | 45 | 0.0530 | 0.0535 | — .03 | 74 | 0.5215 | 0.5174 | + .22 |
| 28 | 56 | 0.2920 | 0.2919 | + .01 | 63 | 0.2778 | 0.2786 | — .04 |
| 29 | 79 | 0.9150 | 0.9150 | .00 | 39 | 0.6569 | 0.6605 | — .19 |
| 33 | 15 | 0.0512 | 0.0539 | — .14 | 104 | 0.5241 | 0.5222 | + .10 |
| | | | | ″ | | | | ″ |
| 15 | 52 | 0.3161 | 0.3172 | —0.06 | 67 | 0.2540 | 0.2525 | +0.08 |
| 15 | 52 | 0.3174 | 0.3172 | + .01 | 67 | 0.2535 | 0.2536 | — .01 |
| 1 | 68 | 0.0005 | 0.0006 | — .01 | 51 | 0.5711 | 0.5720 | — .05 |
| 5 | 81 | 0.2686 | 0.2674 | + .06 | 38 | 0.3002 | 0.2992 | + .05 |
| 7 | 33 | 0.2762 | 0.2805 | — .23 | 86 | 0.2989 | 0.2975 | + .07 |
| 23A | 67 | 0.1061 | 0.1066 | — .03 | 52 | 0.4675 | 0.4684 | — .05 |
| 31 | 36 | 0.5514 | 0.5510 | + .02 | 83 | 0.0161 | 0.0155 | + .03 |
| 32 | 12 | 0.7218 | 0.7219 | — .01 | 106 | 0.8538 | 0.8489 | + .26 |
| 33 | 15 | 0.0512 | 0.0515 | — .02 | 104 | 0.5244 | 0.5242 | + .01 |
| 34 | 48 | 0.4732 | 0.4788 | — .30 | 71 | 0.0906 | 0.0889 | + .09 |
| 35 | 85 | 0.7528 | 0.7519 | + .05 | 33 | 0.8198 | 0.8231 | — .16 |
| 36 | 63 | 0.1924 | 0.1936 | — .06 | 56 | 0.3759 | 0.3762 | — .02 |
| 37 | 39 | 0.0658 | 0.0655 | + .02 | 80 | 0.5042 | 0.5071 | — .15 |
| 38 | 56 | 0.0759 | 0.0802 | — .23 | 63 | 0.4912 | 0.4900 | + .06 |
| 39 | 62 | 0.3799 | 0.3780 | + .10 | 57 | 0.1916 | 0.1932 | — .08 |
| 40 | 17 | 0.4095 | 0.4081 | + .07 | 102 | 0.1689 | 0.1674 | + .08 |
| 43 | 59 | 0.2589 | 0.2636 | — .25 | 60 | 0.3096 | 0.3105 | — .05 |
| 44 | 78 | 0.6826 | 0.6850 | — .13 | 40 | 0.8895 | 0.8870 | + .12 |

TABLE III.—(*Continued.*) PLATE II: *x* MEASUREMENTS.

| Star. | *x* direct. | | | | *x* reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Lines. | ½ *m*, or Scale *minus* Star. Schl. | Kretz. | *S—K* | Lines. | ½ *m*, or Scale *minus* Star. Schl. | Kretz. | *S—K* |
| | | | | ″ | | | | ″ |
| 15 | 63,64 | 0.7105 | 0.7096 | +0.05 | 54,55 | 0.8424 | 0.8400 | +0.12 |
| 15 | 63,64 | 0.7085 | 0.7099 | — .07 | 54.55 | 0.8422 | 0.8426 | — .02 |
| 2 | 97,98 | 0.2185 | 0.2192 | — .04 | 21,22 | 0.3390 | 0.3380 | + .05 |
| 4 | 94,95 | 0.3538 | 0.3585 | — .25 | 24,25 | 0.2039 | 0.1984 | + .29 |
| 6 | 81,82 | 0.1314 | 0.1352 | — .20 | 37,38 | 0.4219 | 0.4200 | + .10 |
| 8 | 74,75 | 0.2901 | 0.2916 | — .08 | 44,45 | 0.2625 | 0.2612 | + .07 |
| 10 | 73,74 | 0.3949 | 0.3975 | — .14 | 45,46 | 0.1579 | 0.1584 | — .03 |
| 11 | 72,73 | 0.5386 | 0.5364 | + .12 | 46 | 0.5189 | 0.5141 | + .25 |
| 14 | 64 | 0.4098 | 0.4100 | — .01 | 54,55 | 0.6420 | 0.6401 | + .10 |
| 16 | 62,63 | 0.7976 | 0.7986 | — .05 | 55,56 | 0.7551 | 0.7531 | + .10 |
| 17 | 61,62 | 0.3892 | 0.3901 | — .05 | 57,58 | 0.1654 | 0.1615 | + .21 |
| 18 | 59,60 | 0.8448 | 0.8468 | — .12 | 58,59 | 0.7078 | 0.7072 | + .03 |
| 20 | 59,60 | 0.5010 | 0.4991 | + .10 | 59,60 | 0.0539 | 0.0565 | — .14 |
| 22 | 57,58 | 0.5558 | 0.5589 | — .16 | 61 | 0.4941 | 0.4908 | + .19 |
| 23 | 56,57 | 0.1874 | 0.1871 | + .02 | 62,63 | 0.3664 | 0.3642 | + .12 |
| 24 | 54,55 | 0.0610 | 0.0612 | — .01 | 64,65 | 0.4884 | 0.4902 | — .10 |
| 25 | 53,54 | 0.4784 | 0.4780 | + .02 | 65,66 | 0.0745 | 0.0722 | + .12 |
| 26 | 53,54 | 0.3661 | 0.3669 | — .04 | 65,66 | 0.1869 | 0.1885 | — .09 |
| 27 | 53,54 | 0.1111 | 0.1118 | — .04 | 65,66 | 0.4440 | 0.4401 | + .21 |
| 28 | 52,53 | 0.8736 | 0.8748 | — .06 | 65,66 | 0.6789 | 0.6774 | + .08 |
| 29 | 52.53 | 0.2845 | 0.2878 | — .17 | 66,67 | 0.2669 | 0.2612 | + .30 |
| 45 | 25 | 0.4730 | 0.4744 | — .07 | 93,94 | 0.5818 | 0.5840 | — .12 |
| | | Schl. | Hays | *S—H* | | Schl. | Hays | *S—H* |
| | | | | ″ | | | | ″ |
| 15 | 63,64 | 0.7105 | 0.7124 | —0.10 | 54,55 | 0.8412 | 0.8419 | —0.03 |
| 15 | 63,64 | 0.7130 | 0.7108 | + .12 | 54,55 | 0.8408 | 0.8409 | — .01 |
| 1 | 98,99 | 0.2198 | 0.2182 | + .08 | 20,21 | 0.3396 | 0.3376 | + .10 |
| 2 | 97,98 | 0.2161 | 0.2202 | — .22 | 21,22 | 0.3398 | 0.3376 | + .12 |
| 5 | 85,86 | 0.3189 | 0.3158 | + .16 | 33,34 | 0.2370 | 0.2384 | — .07 |
| 7 | 78,79 | 0.4000 | 0.3978 | + .12 | 40,41 | 0.1598 | 0.1588 | + .05 |
| 7A | 74,75 | 0.3018 | 0.3010 | + .04 | 44,45 | 0.2538 | 0.2531 | + .04 |
| 19 | 59,60 | 0.8144 | 0.8172 | — .15 | 58.59 | 0.7409 | 0.7334 | + .39 |
| 23A | 55,56 | 0.1681 | 0.1626 | + .29 | 63,64 | 0.3889 | 0.3884 | + .03 |
| 31 | 51,52 | 0.6894 | 0.6871 | + .12 | 66,67 | 0.8675 | 0.8676 | — .01 |
| 32 | 49,50 | 0.8098 | 0.8086 | + .06 | 68.69 | 0.7445 | 0.7426 | + .10 |
| 33 | 48,49 | 0.1569 | 0.1561 | + .04 | 70,71 | 0.3988 | 0.4004 | — .08 |
| 34 | 47,48 | 0.5111 | 0.5140 | — .15 | 71 | 0.5398 | 0.5425 | — .15 |
| 35 | 45,46 | 0.5094 | 0.5122 | — .15 | 73 | 0.5412 | 0.5445 | — .18 |
| 36 | 44 | 0.5342 | 0.5275 | + .36 | 74,75 | 0.5245 | 0.5174 | + .38 |
| 37 | 43,44 | 0.8969 | 0.8980 | — .05 | 74,75 | 0.6581 | 0.6594 | — .07 |
| 38 | 40,41 | 0.2764 | 0.2762 | + .01 | 78,79 | 0.2790 | 0.2751 | + .21 |
| 39 | 39,40 | 0.5344 | 0.5344 | .00 | 79 | 0.5228 | 0.5226 | + .01 |
| 40 | 37,38 | 0.6996 | 0.6971 | + .13 | 80,81 | 0.8536 | 0.8578 | — .21 |
| 43 | 29,30 | 0.8098 | 0.8078 | + .11 | 88,89 | 0.7468 | 0.7445 | + .13 |
| 44 | 29,30 | 0.2696 | 0.2618 | + .41 | 89.90 | 0.2901 | 0.2881 | + .11 |
| 45 | 25 | 0.4734 | 0.4758 | — .12 | 93,94 | 0.5821 | 0.5852 | — .16 |

TABLE III.—(*Continued.*) PLATE II: *y* MEASUREMENTS.

| Star. | *y* direct. | | | | *y* reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Line. | ½ *m*, or Scale *minus* Star. | | *K—H* | Line. | ½ *m*, or Scale *minus* Star. | | *K—H* |
| | | Kretz. | Hays. | | | Kretz. | Hays. | |
| 15 | 51 | 0.4148 | 0.4171 | —0″.12 | 68 | 0.1352 | 0.1344 | +0″.04 |
| 15 | | | | | 68 | 0.1355 | 0.1368 | — .07 |
| 2 | 48 | 0.0102 | 0.0088 | + .07 | 71 | 0.5406 | 0.5432 | — .14 |
| 4 | 16 | 0.3411 | 0.3412 | — .01 | 103 | 0.2192 | 0.2192 | .00 |
| 6 | 65 | 0.6206 | 0.6175 | + .16 | 53 | 0.9330 | 0.9344 | — .08 |
| 8 | 66 | 0.3665 | 0.3671 | — .03 | 53 | 0.1856 | 0.1838 | + .10 |
| 10 | 44 | 0.3996 | 0.3972 | + .13 | 75 | 0.1539 | 0.1514 | + .13 |
| 11 | 38 | 0.6644 | 0.6645 | — .01 | 80 | 0.8918 | 0.8906 | + .07 |
| 14 | 72 | 0.3570 | 0.3578 | — .04 | 47 | 0.1970 | 0.1950 | + .11 |
| 16 | 17 | 0.1786 | 0.1791 | — .03 | 102 | 0.3780 | 0.3768 | + .06 |
| 17 | 35 | 0.2662 | 0.2641 | + .11 | 84 | 0.2851 | 0.2858 | — .04 |
| 18 | 36 | 0.1135 | 0.1128 | + .04 | 83 | 0.4404 | 0.4381 | + .12 |
| 20 | 35 | 0.3360 | 0.3325 | + .19 | 84 | 0.2159 | 0.2160 | — .01 |
| 22 | 67 | 0.0880 | 0.0889 | — .05 | 52 | 0.4618 | 0.4609 | + .05 |
| 23 | 64 | 0.6105 | 0.6099 | + .03 | 54 | 0.9411 | 0.9408 | + .03 |
| 24 | 34 | 0.7494 | 0.7484 | + .06 | 84 | 0.8025 | 0.8048 | — .13 |
| 25 | 45 | 0.2892 | 0.2860 | + .17 | 74 | 0.2620 | 0.2612 | + .04 |
| 26 | 22 | 0.3085 | 0.3072 | + .07 | 97 | 0.2479 | 0.2501 | — .11 |
| 28 | 55 | 0.3882 | 0.3879 | + .02 | 64 | 0.1601 | 0.1598 | + .02 |
| 29 | 79 | 0.0066 | 0.0085 | — .10 | 40 | 0.5452 | 0.5449 | + .02 |
| 33 | 14 | 0.1540 | 0.1538 | + .01 | 105 | 0.4014 | 0.3988 | + .14 |
| 15 | 51 | 0.4176 | 0.4178 | —0″.01 | 68 | 0.1374 | 0.1369 | +0″.03 |
| 15 | 51 | 0.4146 | 0.4166 | — .11 | 68 | 0.1348 | 0.1381 | — .17 |
| 1 | 67 | 0.1062 | 0.1050 | + .06 | 52 | 0.4448 | 0.4442 | + .03 |
| 5 | 80 | 0.3721 | 0.3734 | — .07 | 39 | 0.1791 | 0.1778 | + .07 |
| 7 | 32 | 0.3801 | 0.3786 | + .08 | 87 | 0.1742 | 0.1741 | + .01 |
| 7A | 47 | 0.6575 | 0.6584 | — .04 | 71 | 0.8970 | 0.8958 | + .07 |
| 19 | 77 | 0.3065 | 0.3075 | — .05 | 42 | 0.2455 | 0.2440 | + .08 |
| 23A | 66 | 0.1972 | 0.1936 | + .19 | 53 | 0.3584 | 0.3549 | + .19 |
| 27 | 44 | 0.1530 | 0.1530 | .00 | 75 | 0.4005 | 0.3972 | + .17 |
| 31 | 35 | 0.6549 | 0.6524 | + .13 | 83 | 0.9032 | 0.9024 | + .05 |
| 32 | 11 | 0.8212 | 0.8249 | — .21 | 107 | 0.7351 | 0.7302 | + .26 |
| 33 | 14 | 0.1548 | 0.1532 | + .08 | 105 | 0.4031 | 0.4030 | + .01 |
| 34 | 47 | 0.5749 | 0.5725 | + .13 | 71 | 0.9784 | 0.9769 | + .10 |
| 35 | 84 | 0.8458 | 0.8426 | + .16 | 34 | 0.7100 | 0.7115 | — .08 |
| 36 | 62 | 0.2885 | 0.2879 | + .03 | 57 | 0.2629 | 0.2646 | — .09 |
| 37 | 38 | 0.1672 | 0.1659 | + .07 | 81 | 0.3884 | 0.3875 | + .05 |
| 38 | 55 | 0.1725 | 0.1746 | — .11 | 64 | 0.3778 | 0.3762 | + .08 |
| 39 | 61 | 0.4712 | 0.4724 | — .06 | 58 | 0.0776 | 0.0781 | — .03 |
| 40 | 16 | 0.5089 | 0.5050 | + .21 | 103 | 0.0502 | 0.0514 | — .06 |
| 43 | 58 | 0.3500 | 0.3474 | + .14 | 61 | 0.2022 | 0.2029 | — .04 |
| 44 | 77 | 0.7740 | 0.7744 | — .02 | 41 | 0.7819 | 0.7749 | + .37 |
| 45 | 26 | 0.9096 | 0.9109 | — .06 | 92 | 0.6474 | 0.6468 | + .03 |

TABLE III.—(*Continued.*) PLATE III : $x$ MEASUREMENTS.

| Star. | $x$ direct. | | | | $x$ reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Lines. | ½ $m$, or Scale *minus* Star. | | $S-K$ | Lines. | ½ $m$, or Scale *minus* Star. | | $S-K$ |
| | | Schl. | Kretz. | | | Schl. | Kretz. | |
| | | | | ″ | | | | ″ |
| 15 | 56 | 0.3911 | 0.3919 | —0.04 | 62,63 | 0.6618 | 0.6571 | +0.25 |
| 2 | 89,90 | 0.4000 | 0.3988 | + .06 | 29 | 0.6560 | 0.6566 | — .04 |
| 3 | 88,89 | 0.2970 | 0.2958 | + .06 | 30,31 | 0.2614 | 0.2550 | + .34 |
| 4 | 86,87 | 0.5528 | 0.5500 | + .16 | 32 | 0.5092 | 0.5078 | + .06 |
| 6 | 73,74 | 0.3035 | 0.3024 | + .06 | 45,46 | 0.2494 | 0.2486 | + .04 |
| 8 | 66,67 | 0.4601 | 0.4549 | + .28 | 52 | 0.5961 | 0.5900 | + .31 |
| 10 | 65,66 | 0.5760 | 0.5751 | + .06 | 53 | 0.4779 | 0.4745 | + .17 |
| 11 | 64,65 | 0.7194 | 0.7164 | + .15 | 53,54 | 0.8316 | 0.8298 | + .10 |
| 14 | 56 | 0.5784 | 0.5782 | + .01 | 62,63 | 0.4718 | 0.4712 | + .04 |
| 16 | 55 | 0.4950 | 0.4929 | + .11 | 63,64 | 0.5551 | 0.5549 | + .02 |
| 17 | 53,54 | 0.5736 | 0.5715 | + .10 | 65 | 0.4799 | 0.4765 | + .19 |
| 18 | 52 | 0.5315 | 0.5326 | — .05 | 66,67 | 0.5189 | 0.5174 | + .07 |
| 20 | 51,52 | 0.6865 | 0.6869 | — .02 | 67 | 0.3662 | 0.3678 | — .08 |
| 22 | 49,50 | 0.7265 | 0.7282 | — .08 | 68,69 | 0.8251 | 0.8240 | + .05 |
| 23 | 48,49 | 0.3615 | 0.3651 | — .19 | 70,71 | 0.1871 | 0.1900 | — .16 |
| 24 | 46,47 | 0.2424 | 0.2431 | — .04 | 72,73 | 0.3086 | 0.3092 | — .03 |
| 26 | 45,46 | 0.5581 | 0.5551 | + .15 | 73 | 0.4976 | 0.4960 | + .10 |
| 28 | 45 | 0.5479 | 0.5492 | — .07 | 73,74 | 0.5059 | 0.5044 | + .08 |
| 29 | 44,45 | 0.4485 | 0.4481 | + .02 | 74 | 0.6046 | 0.6075 | — .15 |
| 45 | 17,18 | 0.1620 | 0.1652 | — .18 | 101,102 | 0.3970 | 0.3919 | + .28 |
| | | Kretz. | Hays. | $K-H$ | | Kretz. | Hays. | $K-H$ |
| | | | | ″ | | | | ″ |
| 15 | 56 | 0.3914 | 0.3921 | —0.04 | 62,63 | 0.6609 | 0.6606 | +0.01 |
| 1 | 90,91 | 0.3850 | 0.3879 | — .15 | 28,29 | 0.1676 | 0.1706 | — .15 |
| 2 | 89,90 | 0.4021 | 0.3982 | + .19 | 29,30 | 0.1490 | 0.1516 | — .15 |
| 5 | 77,78 | 0.4799 | 0.4805 | — .03 | 41 | 0.5679 | 0.5720 | — .21 |
| 7 | 70,71 | 0.5824 | 0.5838 | — .07 | 48 | 0.4679 | 0.4664 | + .08 |
| 23A | 47,48 | 0.3338 | 0.3400 | — .33 | 71,72 | 0.2149 | 0.2169 | — .12 |
| 25 | 45,46 | 0.6594 | 0.6636 | — .23 | 73 | 0.3872 | 0.3941 | — .37 |
| 27 | 45,46 | 0.2888 | 0.2896 | — .04 | 73,74 | 0.2650 | 0.2638 | + .07 |
| 31 | 44 | 0.3776 | 0.3795 | — .10 | 74,75 | 0.6784 | 0.6780 | + .03 |
| 32 | 42 | 0.5044 | 0.5028 | + .09 | 76,77 | 0.5489 | 0.5510 | — .11 |
| 33 | 40,41 | 0.3505 | 0.3565 | — .31 | 78,79 | 0.2052 | 0 2025 | + .15 |
| 34 | 39,40 | 0.6875 | 0.6896 | — .12 | 79 | 0.3648 | 0.3654 | — .04 |
| 35 | 37,38 | 0.6701 | 0.6732 | — .16 | 81 | 0.3848 | 0.3850 | — .01 |
| 36 | 36,37 | 0.2011 | 0.2008 | + .01 | 82,83 | 0.3482 | 0.3489 | — .04 |
| 37 | 36 | 0.5816 | 0.5810 | + .03 | 82,83 | 0.4754 | 0.4729 | + .13 |
| 39 | 31,32 | 0.7004 | 0.7045 | — .22 | 87 | 0.3522 | 0.3499 | + .12 |
| 40 | 30 | 0.3930 | 0.3948 | — .11 | 88,89 | 0.6641 | 0.6649 | — .05 |
| 43 | 22 | 0.4799 | 0.4785 | + .07 | 96,97 | 0.5762 | 0.5755 | + .03 |
| 44 | 21,22 | 0.4258 | 0.4301 | — .24 | 97 | 0.6301 | 0.6301 | .00 |
| 45 | 17,18 | 0.1648 | 0.1620 | + .14 | 101,102 | 0.3924 | 0.3916 | + .04 |

TABLE III.—(*Continued.*) PLATE III: *y* MEASUREMENTS.

| Star. | *y* direct. Line. | ½ *m*, or Scale *minus* Star. Schl. | Hays. | *S–H* | *y* reversed. Line. | ½ *m*, or Scale *minus* Star. Schl. | Hays. | *S–H* |
|---|---|---|---|---|---|---|---|---|
| 15 | 53 | 0.7856 | 0.7866 | —0.″06 | 65 | 0.7708 | 0.7681 | +0.″14 |
| 2 | 50 | 0.3928 | 0.3918 | + .05 | 69 | 0.1626 | 0.1632 | — .04 |
| 3 | 35 | 0.8020 | 0.8015 | + .03 | 83 | 0.7534 | 0.7555 | — .11 |
| 4 | 18 | 0.7200 | 0.7194 | + .03 | 100 | 0.8375 | 0.8408 | — .17 |
| 6 | 67 | 0.9966 | 0.9959 | + .05 | 51 | 0.5574 | 0.5572 | + .01 |
| 8 | 68 | 0.7408 | 0.7428 | — .10 | 50 | 0.8144 | 0.8135 | + .05 |
| 10 | 46 | 0.7719 | 0.7692 | + .14 | 72 | 0.7849 | 0.7830 | + .10 |
| 11 | 41 | 0.0348 | 0.0328 | + .11 | 78 | 0.5232 | 0.5200 | + .16 |
| 14 | 74 | 0.7250 | 0.7204 | + .24 | 44 | 0.8316 | 0.8282 | + .17 |
| 16 | 19 | 0.5458 | 0.5422 | + .18 | 100 | 0.0146 | 0.0119 | + .14 |
| 17 | 37 | 0.6339 | 0.6324 | + .08 | 81 | 0.9212 | 0.9208 | + .03 |
| 18 | 38 | 0.4796 | 0.4758 | + .21 | 81 | 0.0778 | 0.0741 | + .20 |
| 20 | 37 | 0.7001 | 0.7011 | — .05 | 81 | 0.8534 | 0.8512 | + .12 |
| 22 | 69 | 0.4481 | 0.4520 | — .20 | 50 | 0.1001 | 0.0995 | + .04 |
| 23 | 66 | 0.9716 | 0.9748 | — .18 | 52 | 0.5775 | 0.5795 | — .11 |
| 24 | 37 | 0.1121 | 0.1108 | + .07 | 82 | 0.4415 | 0.4392 | + .13 |
| 25 | 47 | 0.6516 | 0.6499 | + .10 | 71 | 0.9010 | 0.8996 | + .08 |
| 26 | 24 | 0.6665 | 0.6665 | .00 | 94 | 0.8871 | 0 8880 | — .04 |
| 28 | 57 | 0.7496 | 0.7475 | + .11 | 61 | 0.8059 | 0.8040 | + .10 |
| 29 | 81 | 0.3720 | 0.3685 | + .18 | 38 | 0.1829 | 0.1800 | + .15 |
| 33 | 16 | 0.5105 | 0.5121 | — .10 | 103 | 0.0479 | 0.0425 | + .28 |
| 15 | 53 | 0.7829 | 0.7849 | —0.″10 | 65 | 0.7679 | 0.7654 | +0.″14 |
| 1 | 69 | 0 4875 | 0.4878 | — .03 | 50 | 0.0631 | 0.0631 | .00 |
| 5 | 82 | 0.7499 | 0.7450 | + .25 | 36 | 0.8035 | 0.8031 | + .02 |
| 7 | 34 | 0.7538 | 0.7535 | + .02 | 84 | 0.8054 | 0.8001 | + .29 |
| 23A | 68 | 0.5646 | 0.5611 | + .19 | 50 | 0.9911 | 0.9874 | + .21 |
| 27 | 46 | 0.5160 | 0.5145 | + .08 | 73 | 0.0391 | 0.0369 | + .12 |
| 31 | 38 | 0.0155 | 0.0181 | — .14 | 81 | 0.5379 | 0.5371 | + .04 |
| 32 | 14 | 0.1861 | 0.1812 | + .25 | 105 | 0.3760 | 0.3750 | + .05 |
| 33 | 16 | 0.5112 | 0.5112 | .00 | 103 | 0.0484 | 0.0438 | + .24 |
| 34 | 49 | 0.9341 | 0.9330 | + .05 | 69 | 0.6175 | 0.6154 | + .11 |
| 35 | 87 | 0.2068 | 0.2039 | + .15 | 32 | 0.3486 | 0.3469 | + .08 |
| 36 | 64 | 0.6476 | 0.6454 | + .12 | 54 | 0.9068 | 0.9066 | + .02 |
| 37 | 40 | 0.5184 | 0.5215 | — .16 | 79 | 0.0340 | 0.0320 | + .11 |
| 39 | 63 | 0.8299 | 0.8256 | + .22 | 55 | 0.7232 | 0.7225 | + .03 |
| 40 | 18 | 0.8654 | 0.8618 | + .20 | 100 | 0.6912 | 0.6911 | + .01 |
| 43 | 60 | 0.7026 | 0.7032 | — .03 | 58 | 0.8524 | 0.8500 | + .13 |
| 44 | 80 | 0.1296 | 0.1265 | + .17 | 39 | 0.4255 | 0.4234 | + .12 |
| 45 | 29 | 0.2606 | 0.2582 | + .13 | 90 | 0.2991 | 0.2939 | + .28 |

TABLE III.—(*Continued.*) PLATE IV: $x$ MEASUREMENTS.

| Star. | $x$ direct. | | | | $x$ reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Lines. | ½ $m$, or Scale *minus* Star. Schl. | ½ $m$, or Scale *minus* Star. Kretz. | $S—K$ | Lines. | ½ $m$, or Scale *minus* Star. Schl. | ½ $m$, or Scale *minus* Star. Kretz. | $S—K$ |
| | | | | ″ | | | | ″ |
| 15 | 58,59 | 0.1086 | 0.1090 | —0.02 | 60,61 | 0.4401 | 0.4376 | +0.13 |
| 15 | 58,59 | 0.1098 | 0.1102 | — .02 | 60,61 | 0.4404 | 0.4382 | + .12 |
| 2 | 91,92 | 0.6132 | 0.6136 | — .02 | 27 | 0.4422 | 0.4411 | + .06 |
| 3 | 90,91 | 0.4950 | 0.4922 | + .15 | 28 | 0.5600 | 0.5594 | + .04 |
| 4 | 88,89 | 0.7311 | 0.7309 | + .01 | 29,30 | 0.8258 | 0.8249 | + .05 |
| 6 | 75,76 | 0.5378 | 0.5355 | + .12 | 43 | 0.5160 | 0.5156 | + .02 |
| 8 | 68,69 | 0.7006 | 0.6994 | + .06 | 50 | 0.3525 | 0.3500 | + .13 |
| 10 | 67,68 | 0.7929 | 0.7919 | + .06 | 50,51 | 0.7615 | 0.7609 | + .03 |
| 11 | 67 | 0.4274 | 0.4251 | + .12 | 51,52 | 0.6255 | 0.6258 | — .02 |
| 14 | 58,59 | 0.3225 | 0.3204 | + .11 | 60,61 | 0.2276 | 0.2272 | + .02 |
| 16 | 57,58 | 0.1772 | 0.1769 | + .02 | 61,62 | 0.3724 | 0.3735 | — .06 |
| 17 | 55,56 | 0.7785 | 0.7760 | + .13 | 62,63 | 0.7741 | 0.7760 | — .09 |
| 18 | 54,55 | 0.2394 | 0.2390 | + .02 | 64,65 | 0.3106 | 0.3105 | + .01 |
| 20 | 54 | 0.3919 | 0.3916 | + .02 | 64,65 | 0.6571 | 0.6581 | — .05 |
| 22 | 52 | 0.4664 | 0.4679 | — .08 | 66,67 | 0.5841 | 0.5841 | .00 |
| 23 | 50,51 | 0.5970 | 0.5962 | + .04 | 68 | 0.4560 | 0.4542 | + .10 |
| 24 | 48,49 | 0.4505 | 0.4506 | — .01 | 70 | 0.6004 | 0.6036 | — .17 |
| 25 | 48 | 0.3772 | 0.3728 | + .23 | 70,71 | 0.6758 | 0.6746 | + .06 |
| 26 | 47,48 | 0.7520 | 0.7505 | + .07 | 70,71 | 0.8045 | 0.8032 | + .08 |
| 27 | 47,48 | 0.5058 | 0.5064 | — .03 | 71 | 0.5465 | 0.5438 | + .15 |
| 28 | 47,48 | 0.2779 | 0.2762 | + .08 | 71,72 | 0.2745 | 0.2740 | + .03 |
| 29 | 46,47 | 0.7029 | 0.7000 | + .15 | 72 | 0.3510 | 0.3495 | + .08 |
| 45 | 19,20 | 0.3636 | 0.3658 | — .12 | 99,100 | 0.1926 | 0.1918 | + .04 |
| | | | | ″ | | | | ″ |
| 15 | 58 | 0.6106 | 0.6114 | —0.03 | 60,61 | 0.4404 | 0.4411 | —0.03 |
| 15 | 58 | 0.6108 | 0.6094 | + .06 | 60,61 | 0.4415 | 0.4379 | + .19 |
| 1 | 92,93 | 0.6165 | 0.6235 | — .37 | 26 | 0.4415 | 0.4395 | + .10 |
| 2 | 91,92 | 0.6136 | 0.6129 | + .04 | 27 | 0.4419 | 0.4405 | + .07 |
| 5 | 79,80 | 0.7375 | 0.7375 | .00 | 38,39 | 0.8199 | 0.8202 | — .01 |
| 7 | 72,73 | 0.7816 | 0.7840 | — .12 | 45,46 | 0.7742 | 0.7744 | — .02 |
| 7A | 68,69 | 0.6918 | 0.6942 | — .13 | 50 | 0.3619 | 0.3602 | + .09 |
| 19 | 54,55 | 0.2284 | 0.2284 | .00 | 64,65 | 0.3215 | 0.3205 | + .05 |
| 23A | 49,50 | 0.5751 | 0.5765 | — .07 | 69 | 0.4772 | 0.4790 | — .10 |
| 31 | 46 | 0.5839 | 0.5828 | + .05 | 72,73 | 0.4711 | 0.4691 | + .11 |
| 32 | 44,45 | 0.1821 | 0.1831 | — .05 | 74,75 | 0.3680 | 0.3692 | — .06 |
| 33 | 42,43 | 0.5291 | 0.5280 | + .05 | 76 | 0.5155 | 0.5175 | — .11 |
| 34 | 42 | 0.4086 | 0.4081 | + .03 | 76,77 | 0.6442 | 0.6416 | + .14 |
| 35 | 40 | 0.4341 | 0.4365 | — .13 | 78,79 | 0.6210 | 0.6191 | + .10 |
| 36 | 38,39 | 0.4386 | 0.4406 | — .11 | 80 | 0.6144 | 0.6154 | — .06 |
| 37 | 38,39 | 0.2875 | 0.2868 | + .04 | 80,81 | 0.2640 | 0.2649 | — .05 |
| 38 | 34,35 | 0.6826 | 0.6850 | — .12 | 84 | 0.3724 | 0.3726 | — .02 |
| 39 | 34 | 0.4401 | 0.4415 | — .07 | 84,85 | 0.6141 | 0.6149 | — .04 |
| 40 | 32 | 0.5829 | 0.5836 | — .03 | 86,87 | 0.4729 | 0.4742 | — .07 |
| 43 | 24,25 | 0.2176 | 0.2154 | + .12 | 94,95 | 0.3385 | 0.3400 | — .08 |
| 44 | 23,24 | 0.6931 | 0.6961 | — .15 | 95 | 0.3649 | 0.3628 | + .12 |
| 45 | 19,20 | 0.3628 | 0.3605 | + .12 | 99,100 | 0.1922 | 0.1905 | + .09 |

TABLE III.—(*Continued.*) PLATE IV: *y* MEASUREMENTS.

| Star. | *y* direct. | | | | *y* reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Line. | ½ *m*, or Scale *minus* Star. | | *S—K* | Line. | ½ *m*, or Scale *minus* Star. | | *S—K.* |
| | | Schl. | Kretz. | | | Schl. | Kretz. | |
| | | | | ″ | | | | ″ |
| 15 | 54 | 0.3544 | 0.3561 | —0.09 | 65 | 0.1952 | 0.1934 | +0.10 |
| 15 | 54 | 0.3545 | 0.3578 | — .17 | 65 | 0.1926 | 0.1939 | — .07 |
| 2 | 50 | 0.9360 | 0.9344 | + .07 | 68 | 0.6195 | 0.6199 | — .02 |
| 3 | 36 | 0.3470 | 0.3464 | + .03 | 83 | 0.2059 | 0.2051 | + .04 |
| 4 | 19 | 0.2672 | 0.2691 | — .10 | 100 | 0.2875 | 0.2898 | — .12 |
| 6 | 68 | 0.5526 | 0.5525 | + .01 | 50 | 0.9996 | 1.0015 | — .12 |
| 8 | 69 | 0 2996 | 0.3001 | — .03 | 50 | 0.2510 | 0.2481 | + .15 |
| 10 | 47 | 0.3356 | 0.3349 | + .03 | 72 | 0.2148 | 0.2164 | — .08 |
| 11 | 41 | 0.5992 | 0.5962 | + .16 | 77 | 0.9564 | 0.9561 | + .03 |
| 14 | 75 | 0.2926 | 0.2945 | — .10 | 44 | 0.2558 | 0.2565 | — .04 |
| 16 | 20 | 0.1172 | 0.1185 | — .07 | 99 | 0.4378 | 0.4361 | + .09 |
| 17 | 38 | 0.2076 | 0.2078 | — .01 | 81 | 0.3446 | 0.3442 | + .02 |
| 18 | 39 | 0.0536 | 0.0534 | + .01 | 80 | 0.4979 | 0.4991 | — .06 |
| 20 | 38 | 0.2798 | 0.2785 | + .07 | 81 | 0.2716 | 0.2736 | — .11 |
| 22 | 70 | 0.0256 | 0.0255 | + .01 | 49 | 0.5252 | 0.5246 | + .03 |
| 23 | 67 | 0.5522 | 0.5525 | — .02 | 52 | —.0032 | 0.0002 | — .18 |
| 24 | 37 | 0.6928 | 0.6925 | + .02 | 81 | 0.8572 | 0.8588 | — .10 |
| 25 | 48 | 0.2345 | 0.2330 | + .08 | 71 | 0.3155 | 0.3162 | — .04 |
| 26 | 25 | 0.2515 | 0.2508 | + .04 | 94 | 0.3014 | 0.3042 | — .15 |
| 28 | 58 | 0.3315 | 0.3305 | + .05 | 61 | 0.2180 | 0.2182 | — .01 |
| 29 | 81 | 0.9495 | 0.9505 | — .06 | 37 | 0.6024 | 0.6021 | + .02 |
| 33 | 17 | 0.1019 | 0.0998 | + .11 | 102 | 0.4535 | 0.4555 | — .11 |
| | | | | ″ | | | | ″ |
| 15 | 54 | 0.3538 | 0.3568 | —0.15 | 65 | 0.1951 | 0.1922 | +0.15 |
| 15 | 54 | 0.3562 | 0.3579 | — .08 | 65 | 0.1929 | 0.1904 | + .13 |
| 1 | 70 | 0.0282 | 0.0304 | — .12 | 49 | 0.5239 | 0.5224 | + .07 |
| 5 | 83 | 0.2979 | 0.2979 | .00 | 36 | 0.2529 | 0.2540 | — .06 |
| 7 | 35 | 0.3186 | 0.3182 | + .02 | 84 | 0.2356 | 0.2362 | — .03 |
| 7A | 50 | 0.5930 | 0.5936 | — .03 | 68 | 0.9646 | 0.9656 | — .07 |
| 19 | 80 | 0.2471 | 0.2455 | + .08 | 39 | 0.3060 | 0.3088 | — .15 |
| 23A | 69 | 0.1386 | 0.1401 | — .08 | 50 | 0.4115 | 0.4120 | — .03 |
| 27 | 47 | 0.0961 | 0.0966 | — .03 | 72 | 0.4552 | 0.4564 | — .06 |
| 31 | 38 | 0.5966 | 0.5961 | + .02 | 80 | 0.9584 | 0.9589 | — .04 |
| 32 | 14 | 0.7720 | 0.7728 | — .04 | 104 | 0.7861 | 0.7886 | — .13 |
| 33 | 17 | 0.1015 | 0.1024 | — .05 | 102 | 0.4555 | 0.4562 | — .04 |
| 34 | 50 | 0.5242 | 0.5254 | — .06 | 69 | 0.0256 | 0.0276 | — .11 |
| 35 | 87 | 0.7922 | 0.7922 | .00 | 31 | 0.7645 | 0.7664 | — .10 |
| 36 | 65 | 0.2356 | 0.2331 | + .13 | 54 | 0.3152 | 0.3154 | — .01 |
| 37 | 41 | 0.1111 | 0.1115 | — .02 | 78 | 0.4406 | 0.4410 | — .02 |
| 38 | 58 | 0.1198 | 0.1186 | + .06 | 61 | 0.4311 | 0.4320 | — .05 |
| 39 | 64 | 0.4198 | 0.4202 | — .02 | 55 | 0.1292 | 0.1296 | — .02 |
| 40 | 19 | 0.4612 | 0.4622 | — .05 | 100 | 0.0895 | 0.0895 | .00 |
| 43 | 61 | 0.2991 | 0.3002 | — .06 | 58 | 0.2488 | 0.2490 | — .01 |
| 44 | 80 | 0.7300 | 0.7276 | + .13 | 38 | 0.8281 | 0.8304 | — .13 |
| 45 | 29 | 0.8686 | 0.8679 | + .03 | 89 | 0.6874 | 0.6874 | .00 |

TABLE III.—(*Continued.*) PLATE V: $x$ MEASUREMENTS.

| Star. | $x$ direct. | | | | $x$ reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Lines. | ½ *m.* or Scale *minus* Star. | | $S—K$ | Lines. | ½ *m.* or Scale *minus* Star. | | $S—K$ |
| | | Schl. | Kretz. | | | Schl. | Kretz. | |
| | | | | ″ | | | | ″ |
| 15 | 55,56 | 0.2626 | 0.2598 | +0.15 | 63,64 | 0.3082 | 0.3041 | +0.22 |
| 15 | 55,56 | 0.2629 | 0.2598 | + .16 | 63,64 | 0.3078 | 0.3055 | + .12 |
| 2 | 88,89 | 0.7681 | 0.7676 | + .03 | 29,30 | 0.8032 | 0.8031 | + .01 |
| 3 | 87,88 | 0.6692 | 0.6708 | — .08 | 30,31 | 0.9018 | 0.9005 | + .06 |
| 4 | 85,86 | 0.9279 | 0.9281 | — .02 | 32,33 | 0.6450 | 0.6451 | — .01 |
| 6 | 72,73 | 0.6664 | 0.6684 | — .11 | 45,46 | 0.8999 | 0.9011 | — .07 |
| 8 | 65,66 | 0.8274 | 0.8279 | — .03 | 52,53 | 0.7400 | 0.7415 | — .08 |
| 10 | 64,66 | 0.4472 | 0.4454 | + .10 | 53,54 | 0.6195 | 0.6194 | + .01 |
| 11 | 64,65 | 0.0944 | 0.0921 | + .12 | 54,55 | 0.4770 | 0.4764 | + .03 |
| 14 | 55,56 | 0.4405 | 0.4400 | + .03 | 63,64 | 0.1269 | 0.1251 | + .10 |
| 16 | 54,55 | 0.3751 | 0.3738 | + .07 | 64,65 | 0.1938 | 0.1938 | .00 |
| 17 | 52,54 | 0.4486 | 0.4476 | + .05 | 65,66 | 0.6221 | 0.6204 | + .09 |
| 18 | 51,52 | 0.4046 | 0.4030 | + .08 | 67,68 | 0.1645 | 0.1631 | + .07 |
| 20 | 51,52 | 0.0611 | 0.0592 | + .10 | 67,68 | 0.5110 | 0.5089 | + .11 |
| 22 | 49,50 | 0.0939 | 0.0929 | + .05 | 69,70 | 0.4755 | 0.4735 | + .11 |
| 23 | 47,48 | 0.7248 | 0.7234 | + .07 | 70,71 | 0.8448 | 0.8422 | + .14 |
| 24 | 45,46 | 0.6199 | 0.6192 | + .04 | 72,74 | 0.4516 | 0.4486 | + .17 |
| 25 | 45,46 | 0.0336 | 0.0326 | + .05 | 73,74 | 0.5389 | 0.5368 | + .11 |
| 26 | 44,46 | 0.4384 | 0.4380 | + .02 | 73,74 | 0.6342 | 0.6314 | + .15 |
| 27 | 44,45 | 0.6610 | 0.6584 | + .14 | 73,74 | 0.9106 | 0.9106 | .00 |
| 28 | 44,45 | 0.4170 | 0.4146 | + .13 | 74,75 | 0.1540 | 0.1514 | + .14 |
| 29 | 43,44 | 0.8122 | 0.8128 | — .03 | 74,75 | 0.7590 | 0.7554 | + .19 |
| 45 | 16,17 | 0.5412 | 0.5450 | — .20 | 102,103 | 0.0298 | 0.0298 | .00 |
| | | | | ″ | | | | ″ |
| 15 | 55,56 | 0.2614 | 0.2596 | +0.10 | 63,64 | 0.3075 | 0.3050 | +0.13 |
| 15 | 55,56 | 0.2590 | 0.2598 | — .04 | 63,64 | 0.3069 | 0.3049 | + .11 |
| 1 | 89,90 | 0.7531 | 0.7504 | + .14 | 28,29 | 0.8219 | 0.8161 | + .31 |
| 2 | 88,89 | 0.7692 | 0.7650 | + .22 | 29,30 | 0.8012 | 0.8020 | — .05 |
| 5 | 76,77 | 0.8410 | 0.8396 | + .08 | 41,42 | 0.7296 | 0.7272 | + .13 |
| 7 | 69,71 | 0.4560 | 0.4555 | + .02 | 48,49 | 0.6126 | 0.6108 | + .10 |
| 19 | 51,52 | 0.3436 | 0.3415 | + .11 | 67,68 | 0.2275 | 0.2262 | + .07 |
| 23A | 46,47 | 0.7032 | 0.7029 | + .02 | 71,72 | 0.8665 | 0.8656 | + .04 |
| 31 | 43,44 | 0.2522 | 0.2494 | + .15 | 75,76 | 0.3184 | 0.3155 | + .15 |
| 32 | 41,42 | 0.3892 | 0.3901 | — .05 | 77,78 | 0.1858 | 0.1832 | + .14 |
| 34 | 39,40 | 0.0630 | 0.0658 | — .15 | 79,80 | 0.5071 | 0.5039 | + .17 |
| 35 | 37,38 | 0.0308 | 0.0279 | + .15 | 81,82 | 0.5371 | 0.5326 | + .24 |
| 37 | 35,36 | 0.4526 | 0.4510 | + .08 | 83,84 | 0.1158 | 0.1126 | + .17 |
| 39 | 31,32 | 0.0745 | 0.0725 | + .11 | 87,88 | 0.4980 | 0.4962 | + .10 |
| 40 | 29,30 | 0.2818 | 0.2772 | + .24 | 89,90 | 0.2950 | 0.2902 | + .25 |
| 43 | 21,22 | 0.3564 | 0.3550 | + .07 | 97,98 | 0.2196 | 0.2159 | + .20 |
| 44 | 20,21 | 0.7966 | 0.7962 | + .02 | 97,98 | 0.7794 | 0.7735 | + .31 |
| 45 | 16,17 | 0.5421 | 0.5444 | — .12 | 102,103 | 0.0304 | 0.0251 | + .28 |

TABLE III.—(*Continued.*) PLATE V: *y* MEASUREMENTS.

| Star. | *y* direct. | | | | *y* reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Line. | ½ *m*, or Scale *minus* Star. | | *S—K* | Line. | ½ *m*, or Scale *minus* Star. | | *S—K* |
| | | Schl. | Kretz. | | | Schl. | Kretz. | |
| 15 | 54 | 0.7016 | 0.7006 | +0.″05 | 64 | 0.8646 | 0.8650 | —0.″02 |
| 15 | 54 | 0.6999 | 0.7008 | — .05 | 64 | 0.8626 | 0.8652 | — .14 |
| 2 | 51 | 0.3171 | 0.3152 | + .10 | 68 | 0.2526 | 0.2556 | — .16 |
| 3 | 36 | 0.7258 | 0.7270 | — .06 | 82 | 0.8448 | 0.8426 | + .11 |
| 4 | 19 | 0.6431 | 0.6422 | + .05 | 99 | 0.9318 | 0.9300 | + .08 |
| 6 | 68 | 0.9181 | 0.9175 | + .02 | 50 | 0.6506 | 0.6496 | + .05 |
| 8 | 69 | 0.6558 | 0.6568 | — .05 | 49 | 0.9089 | 0.9072 | + .10 |
| 10 | 47 | 0.6930 | 0.6931 | — .01 | 71 | 0.8759 | 0.8748 | + .06 |
| 11 | 41 | 0.9518 | 0.9546 | — .13 | 77 | 0.6155 | 0.6144 | + .06 |
| 14 | 75 | 0.6389 | 0.6386 | + .02 | 43 | 0.9291 | 0.9300 | — .04 |
| 16 | 20 | 0.4612 | 0.4616 | — .02 | 99 | 0.1106 | 0.1068 | + .20 |
| 17 | 38 | 0.5500 | 0.5489 | + .06 | 81 | 0.0182 | 0.0166 | + .08 |
| 18 | 39 | 0.3969 | 0.3975 | — .03 | 80 | 0.1698 | 0.1715 | — .09 |
| 20 | 38 | 0.6178 | 0.6168 | + .05 | 80 | 0.9494 | 0.9476 | + .08 |
| 22 | 70 | 0.3664 | 0.3648 | + .08 | 49 | 0.2002 | 0.2016 | — .07 |
| 23 | 67 | 0.8894 | 0.8892 | + .02 | 51 | 0.6755 | 0.6768 | — .07 |
| 24 | 38 | 0.0304 | 0.0291 | + .07 | 81 | 0.5392 | 0.5402 | — .05 |
| 25 | 48 | 0.5638 | 0.5661 | — .12 | 71 | —.0008 | —.0005 | — .02 |
| 26 | 25 | 0.5840 | 0.5829 | + .06 | 94 | —.0120 | —.0119 | — .01 |
| 27 | 47 | 0.4309 | 0.4311 | — .01 | 72 | 0.1349 | 0.1350 | — .01 |
| 28 | 58 | 0.6628 | 0.6626 | + .01 | 60 | 0.9031 | 0.9042 | — .05 |
| 29 | 82 | 0.2832 | 0.2811 | + .11 | 37 | 0.2871 | 0.2846 | + .13 |
| 15 | 54 | 0.7029 | 0.7028 | +0.″01 | 64 | 0.8622 | 0.8644 | —0.″13 |
| 15 | 54 | 0.7035 | 0.7011 | + .13 | 64 | 0.8644 | 0.8636 | + .03 |
| 1 | 70 | 0.4172 | 0.4164 | + .04 | 49 | 0.1516 | 0.1570 | — .29 |
| 5 | 83 | 0.6724 | 0.6675 | + .26 | 35 | 0.8962 | 0.8986 | — .12 |
| 7 | 35 | 0.6772 | 0.6771 | + .01 | 83 | 0.8942 | 0.8971 | — .14 |
| 19 | 80 | 0.5896 | 0.5870 | + .14 | 39 | —.0152 | —.0150 | — .01 |
| 23A | 69 | 0.4802 | 0.4760 | + .22 | 50 | 0.0929 | 0.0920 | + .05 |
| 31 | 38 | 0.9318 | 0.9305 | + .08 | 80 | 0.6404 | 0.6350 | + .29 |
| 32 | 15 | 0.1042 | 0.1020 | + .12 | 104 | 0.4722 | 0.4699 | + .12 |
| 34 | 50 | 0.8502 | 0.8475 | + .15 | 68 | 0.7165 | 0.7156 | + .05 |
| 35 | 88 | 0.1154 | 0.1148 | + .03 | 31 | 0.4542 | 0.4576 | — .18 |
| 37 | 41 | 0.4381 | 0.4368 | + .07 | 78 | 0.1349 | 0.1339 | + .05 |
| 39 | 64 | 0.7380 | 0.7364 | + .08 | 54 | 0.8279 | 0.8278 | + .01 |
| 40 | 19 | 0.7798 | 0.7792 | + .03 | 99 | 0.7938 | 0.7948 | — .06 |
| 43 | 61 | 0.6096 | 0.6090 | + .03 | 57 | 0.9594 | 0.9584 | + .04 |
| 44 | 81 | 0.0361 | 0.0339 | + .12 | 38 | 0.5328 | 0.5342 | — .07 |
| 45 | 30 | 0.1700 | 0.1699 | + .01 | 89 | 0.3978 | 0.4001 | — .13 |

TABLE III.—(*Continued.*) PLATE VII: *x* MEASUREMENTS.

| Star. | *x* direct. | | | | *x* reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Lines. | ½ *m*, or Scale *minus* Star. | | *S–H* | Lines. | ½ *m*, or Scale *minus* Star. | | *S–H* |
| | | Schl. | Hays. | | | Schl. | Hays. | |
| 15 | 61,62 | 0.6390 | 0.6438 | ″ —0.25 | 56,58 | 0.4129 | 0.4134 | ″ —0.03 |
| 2 | 95,96 | 0.1465 | 0.1489 | — .13 | 23,24 | 0.4122 | 0.4078 | + .23 |
| 3 | 93,95 | 0.5530 | 0.5496 | + .17 | 24,25 | 0.5062 | 0.5049 | + .07 |
| 4 | 92,93 | 0.3122 | 0.3115 | + .04 | 26,27 | 0.2438 | 0.2468 | — .16 |
| 6 | 78,60 | 0.5484 | 0.5484 | .00 | 39,40 | 0.5079 | 0.5094 | — .08 |
| 8 | 72 73 | 0.2074 | 0.2076 | — .01 | 46,47 | 0.3484 | 0.3449 | + .18 |
| 10 | 71,72 | 0.3296 | 0.3339 | — .23 | 47,48 | 0.2242 | 0.2252 | — .05 |
| 11 | 70,71 | 0.4775 | 0.4796 | — .11 | 47,49 | 0.5779 | 0.5730 | + .25 |
| 14 | 61,62 | 0.8200 | 0.8219 | — .10 | 56,57 | 0.7348 | 0.7306 | + .22 |
| 16 | 60,61 | 0.7609 | 0.7619 | — .05 | 57,58 | 0.7938 | 0.7931 | + .03 |
| 17 | 59,60 | 0.3314 | 0.3268 | + .24 | 59,60 | 0.2208 | 0.2222 | — .07 |
| 18 | 57,58 | 0.7879 | 0.7915 | — .20 | 60,61 | 0.7640 | 0.7655 | — .07 |
| 20 | 57,58 | 0.4450 | 0.4424 | + .14 | 60,62 | 0.6079 | 0.6100 | — .10 |
| 22 | 55,56 | 0.4754 | 0.4781 | — .14 | 62,64 | 0.5755 | 0.5742 | + .07 |
| 23 | 54,55 | 0.1081 | 0.1092 | — .06 | 64,65 | 0.4446 | 0.4468 | — .11 |
| 24 | 51,53 | 0.5110 | 0.5112 | — .01 | 66,67 | 0.5442 | 0.5444 | — .01 |
| 25 | 51,52 | 0.4162 | 0.4139 | + .12 | 67,68 | 0 1366 | 0.1356 | + .05 |
| 26 | 51,52 | 0.3231 | 0.3251 | — .10 | 67,68 | 0.2321 | 0.2316 | + .03 |
| 27 | 50,52 | 0.5444 | 0.5456 | — .06 | 67,68 | 0.5095 | 0.5095 | .00 |
| 28 | 50,51 | 0.8028 | 0.8031 | — .01 | 67,68 | 0.7540 | 0.7515 | + .13 |
| 29 | 50,51 | 0.1946 | 0.1925 | + .11 | 68,69 | 0.3584 | 0.3595 | — .06 |
| 31 | 49,50 | 0.6379 | 0.6386 | — .04 | 68,70 | 0.4170 | 0.4178 | — .04 |
| 32 | 47,48 | 0.7781 | 0.7770 | + .06 | 70,71 | 0.7778 | 0.7756 | + .11 |
| 33 | 46,47 | 0.1226 | 0.1226 | .00 | 72,73 | 0.4316 | 0.4350 | — .18 |
| 45 | 22,24 | 0.4344 | 0.4370 | — .13 | 95,96 | 0.6214 | 0.6179 | + .19 |
| | | Schl. | Kretz | *S–K* | | Schl. | Kretz. | *S–K* |
| 15 | 61,62 | 0.6420 | 0.6444 | ″ —0.12 | 56,58 | 0.4105 | 0.4090 | ″ +0.08 |
| 1 | 96,97 | 0.1244 | 0.1286 | — .22 | 22,23 | 0.4282 | 0.4268 | + .07 |
| 2 | 95,96 | 0.1474 | 0.1480 | — .03 | 23,24 | 0.4101 | 0.4068 | + .17 |
| 5 | 83,84 | 0.2168 | 0.2158 | + .05 | 35,36 | 0.3389 | 0.3389 | .00 |
| 7 | 76,77 | 0.3461 | 0.3411 | + .26 | 42,43 | 0.2086 | 0.2081 | + .03 |
| 7A | 72,73 | 0.2332 | 0.2351 | — .10 | 46,47 | 0.3231 | 0.3216 | + .08 |
| 19 | 57.58 | 0.7251 | 0.7224 | + .14 | 60,61 | 9.8312 | 0.8338 | — .14 |
| 21 | 56,58 | 0.4262 | 0.4250 | + .06 | 61,62 | 0.6336 | 0.6280 | + .30 |
| 23A | 52,54 | 0 5909 | 0.5854 | + .28 | 65,66 | 0.4660 | 0.4674 | — .07 |
| 34 | 45,46 | 0.4486 | 0.4469 | + .09 | 73,74 | 0.1078 | 0.1046 | + .17 |
| 35 | 43,44 | 0.4162 | 0.4164 | — .01 | 75,76 | 0.1359 | 0.1390 | — .16 |
| 36 | 41,43 | 0.4652 | 0.4626 | + .14 | 76,77 | 0.5950 | 0.5931 | + .10 |
| 37 | 41,42 | 0.8426 | 0.8446 | — .12 | 76,77 | 0.7156 | 0.7064 | + .49 |
| 38 | 38,39 | 0.2091 | 0.2134 | — .23 | 80,81 | 0.3486 | 0.3459 | + .14 |
| 39 | 37,38 | 0.4620 | 0.4608 | + .06 | 80,82 | 0.5946 | 0.5924 | + .12 |
| 40 | 35,36 | 0.6735 | 0.6731 | + .02 | 82,84 | 0.3860 | 0.3824 | + .19 |
| 41 | 31,32 | 0.6124 | 0.6054 | + .37 | 86,88 | 0.4504 | 0.4526 | — .12 |
| 42 | 29,30 | 0.6276 | 0.6230 | + .24 | 88,90 | 0.4315 | 0.4300 | + .07 |
| 43 | 27,28 | 0.7438 | 0.7431 | + .04 | 90,91 | 0.8136 | 0.8128 | + .03 |
| 44 | 27,28 | 0.1826 | 0.1789 | + .20 | 91,92 | 0.3741 | 0.3744 | — .02 |
| 45 | 22,24 | 0.4362 | 0.4340 | + .11 | 95,96 | 0.6239 | 0.6222 | + .09 |

TABLE III.—(*Continued.*) PLATE VII: *y* MEASUREMENTS.

| Star. | *y* direct. | | | | *y* reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Line. | ½ *m*, or Scale *minus* Star. | | *S—K* | Line. | ½ *m*, or Scale *minus* Star. | | *S—K* |
| | | Schl. | Kretz. | | | Schl. | Kretz. | |
| 15 | 62 | 0.0196 | 0.0186 | +0.05″ | 57 | 0.5301 | 0.5302 | —0.01″ |
| 2 | 58 | 0.6448 | 0.6446 | + .01 | 60 | 0.9095 | 0.9045 | + .28 |
| 3 | 44 | 0.0536 | 0.0534 | + .01 | 75 | 0.4972 | 0.4942 | + .16 |
| 4 | 26 | 0.9754 | 0.9744 | + .07 | 92 | 0.5794 | 0.5774 | + .11 |
| 6 | 76 | 0.2415 | 0.2414 | + .01 | 43 | 0.3114 | 0.3072 | + .22 |
| 8 | 76 | 0.9804 | 0.9799 | + .02 | 42 | 0.5731 | 0.5720 | + .06 |
| 10 | 55 | 0.0164 | 0.0149 | + .08 | 64 | 0.5348 | 0.5346 | + .01 |
| 11 | 49 | 0.2788 | 0.2782 | + .03 | 70 | 0.2735 | 0.2714 | + .11 |
| 14 | 82 | 0.9624 | 0.9610 | + .06 | 36 | 0.5922 | 0.5928 | — .03 |
| 16 | 27 | 0.7882 | 0.7840 | + .23 | 91 | 0.7689 | 0.7664 | + .13 |
| 17 | 45 | 0.8736 | 0.8712 | + .14 | 73 | 0.6788 | 0.6784 | + .02 |
| 18 | 46 | 0.7182 | 0.7169 | + .07 | 72 | 0.8365 | 0.8336 | + .16 |
| 20 | 45 | 0.9394 | 0.9379 | + .10 | 73 | 0.6142 | 0.6149 | — .04 |
| 22 | 77 | 0.6870 | 0.6864 | + .03 | 41 | 0.8685 | 0.8691 | — .04 |
| 23 | 75 | 0.2095 | 0.2090 | + .03 | 44 | 0.3416 | 0.3448 | — .16 |
| 24 | 45 | 0.3472 | 0.3462 | + .05 | 74 | 0.2028 | 0.2011 | + .09 |
| 25 | 55 | 0.8854 | 0.8852 | + .02 | 63 | 0.6631 | 0.6628 | + .02 |
| 26 | 32 | 0.9052 | 0.9058 | — .02 | 86 | 0.6512 | 0.6496 | + .08 |
| 27 | 54 | 0.7488 | 0.7494 | — .03 | 64 | 0.8004 | 0.7996 | + .05 |
| 28 | 65 | 0.9808 | 0.9806 | + .01 | 53 | 0.5726 | 0.5720 | + .03 |
| 29 | 89 | 0.6049 | 0.6022 | + .14 | 29 | 0.9515 | 0.9535 | — .12 |
| 31 | 46 | 0.2505 | 0.2515 | — .05 | 73 | 0.3002 | 0.3026 | — .13 |
| 32 | 22 | 0.4230 | 0.4215 | + .08 | 97 | 0.1355 | 0.1334 | + .11 |
| 33 | 24 | 0.7514 | 0.7492 | + .11 | 94 | 0.8048 | 0.8038 | + .05 |
| | | Kretz. | Hays. | *K—H* | | Kretz. | Hays. | *K—H* |
| 15 | 62 | 0.0182 | 0.0246 | —0.34″ | 57 | 0.5318 | 0.5329 | —0.06″ |
| 1 | 77 | 0.7418 | 0.7462 | — .23 | 41 | 0.8111 | 0.8120 | — .04 |
| 5 | 90 | 0.9979 | 0.9966 | + .08 | 28 | 0.5592 | 0.5605 | — .06 |
| 7 | 43 | —.0005 | —.0001 | — .02 | 76 | 0.5508 | 0.5521 | — .06 |
| 7A | 58 | 0.2669 | 0.2690 | — .11 | 61 | 0.2860 | 0.2868 | — .04 |
| 19 | 87 | 0.9085 | 0.9064 | + .10 | 31 | 0.6464 | 0.6486 | — .12 |
| 21 | 86 | 0.3856 | 0.3829 | + .14 | 33 | 0.1770 | 0.1775 | — .02 |
| 23A | 76 | 0.7939 | 0.7956 | — .08 | 42 | 0.7582 | 0.7600 | — .10 |
| 33 | 24 | 0.7534 | 0.7530 | + .02 | 94 | 0.8038 | 0.8059 | — .12 |
| 34 | 58 | 0.1652 | 0.1675 | — .12 | 61 | 0.3841 | 0.3861 | — .11 |
| 35 | 95 | 0.4320 | 0.4320 | .00 | 24 | 0.1251 | 0.1244 | + .04 |
| 36 | 72 | 0.8776 | 0.8750 | + .14 | 46 | 0.6749 | 0.6749 | .00 |
| 37 | 48 | 0.7515 | 0.7538 | — .12 | 70 | 0.8013 | 0.8045 | — .17 |
| 38 | 65 | 0.7550 | 0.7541 | + .05 | 53 | 0.8013 | 0.8026 | — .07 |
| 39 | 72 | 0.0530 | 0.0519 | + .06 | 47 | 0.5000 | 0.5019 | — .10 |
| 40 | 27 | 0.0934 | 0.0952 | — .10 | 92 | 0.4606 | 0.4615 | — .05 |
| 41 | 54 | 0.4615 | 0.4634 | — .10 | 65 | 0.0902 | 0.0882 | + .11 |
| 42 | 54 | 0.3646 | 0.3646 | .00 | 65 | 0.1885 | 0.1909 | — .13 |
| 43 | 68 | 0.9215 | 0.9211 | + .01 | 50 | 0.6322 | 0.6345 | — .12 |
| 44 | 88 | 0.3458 | 0.3438 | + .10 | 31 | 0.2065 | 0.2076 | — .06 |
| 45 | 37 | 0.4842 | 0.4869 | — .14 | 82 | 0.0679 | 0.0672 | + .04 |

TABLE III.—(*Continued.*) PLATE VIII: $x$ MEASUREMENTS.

| Star. | $x$ direct. | | | | $x$ reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Lines. | ½ $m$, or Scale *minus* Star. | | $S-K$ | Lines. | ½ $m$, or Scale *minus* Star. | | $S-K$ |
| | | Schl. | Kretz. | | | Schl. | Kretz. | |
| | | | | ″ | | | | ″ |
| 15 | 60,61 | 0.2671 | 0.2648 | +0.12 | 58.59 | 0.2850 | 0.2819 | +0.16 |
| 15 | | | | | 58,59 | 0.2851 | 0.2828 | + .12 |
| 2 | 93.94 | 0.7701 | 0.7728 | — .14 | 24,25 | 0.7856 | 0.7825 | + .17 |
| 3 | 92,93 | 0.6742 | 0.6731 | + .06 | 25,27 | 0.3849 | 0.3842 | + .04 |
| 4 | 90,92 | 0.4280 | 0.4276 | + .02 | 27,28 | 0.6299 | 0.6285 | + .07 |
| 6 | 77,78 | 0.6768 | 0.6800 | — .17 | 40,42 | 0.3745 | 0 3741 | + .02 |
| 8 | 70,72 | 0.3415 | 0.3375 | + .21 | 47,48 | 0.7154 | 0.7150 | + .02 |
| 10 | 69 71 | 0.4545 | 0.4509 | + .19 | 48,49 | 0.6002 | 0.5968 | + .18 |
| 11 | 68,70 | 0.6009 | 0.6011 | — .01 | 49 50 | 0.4522 | 0.4505 | + .09 |
| 14 | 60 61 | 0.4509 | 0.4502 | + .04 | 57.59 | 0.5990 | 0.5988 | + .02 |
| 16 | 59,60 | 0.3821 | 0.3795 | + .14 | 59,60 | 0.1725 | 0.1725 | .00 |
| 17 | 57.59 | 0.4562 | 0.4515 | + .25 | 60,61 | 0.5979 | 0.5978 | + .01 |
| 18 | 56,57 | 0.4119 | 0.4091 | + .15 | 62,63 | 0.1374 | 0.1385 | — .06 |
| 20 | 55.57 | 0.5689 | 0.5650 | + .21 | 62,63 | 0.4841 | 0.4874 | — .18 |
| 22 | 53 55 | 0.6064 | 0.6061 | + .01 | 64,65 | 0.4450 | 0.4465 | — .08 |
| 23 | 52 53 | 0.7400 | 0.7380 | + .11 | 65,66 | 0.8161 | 0.8162 | .00 |
| 24 | 50,51 | 0.6309 | 0.6234 | + .40 | 67,69 | 0.4269 | 0.4252 | + .09 |
| 25 | 49.51 | 0.5430 | 0.5401 | + .15 | 68,69 | 0.5071 | 0.5089 | — .10 |
| 26 | 49 51 | 0.4416 | 0.4394 | + .12 | 68,69 | 0.6129 | 0 6110 | + .10 |
| 27 | 49 50 | 0.6729 | 0.6702 | + .14 | 68,70 | 0 3799 | 0.3794 | + .03 |
| 28 | 49 50 | 0.4262 | 0 4281 | — .10 | 68,70 | 0.6234 | 0.6234 | .00 |
| 29 | 48.49 | 0.8270 | 0.8258 | + .07 | 69,70 | 0.7252 | 0.7242 | + .05 |
| 31 | 48,49 | 0.2589 | 0.2556 | + .17 | 70,71 | 0.2974 | 0.2940 | + .18 |
| 45 | 21,22 | 0.5558 | 0.5545 | + .07 | 96 98 | 0.5000 | 0.4980 | + .10 |
| | | Schl. | Hays. | $S-H$ | | Schl. | Hays. | $S-H$ |
| | | | | ″ | | | | ″ |
| 15 | 60,61 | 0.2681 | 0.2700 | —0.10 | 58.59 | 0.2839 | 0.2840 | —0.01 |
| 15 | 60.61 | 0.2664 | 0.2661 | + .02 | 58,59 | 0.2852 | 0.2856 | — .02 |
| 1 | 94.95 | 0.7576 | 0.7529 | + .24 | 23,24 | 0.8044 | 0.7984 | + .32 |
| 2 | 93.94 | 0.7709 | 0.7736 | — .14 | 24.25 | 0.7872 | 0.7855 | + .08 |
| 5 | 81,82 | 0.8511 | 0.8485 | + .13 | 36,37 | 0.7059 | 0.7065 | — .03 |
| 7 | 74.76 | 0.4639 | 0.4646 | — .03 | 43.44 | 0.5938 | 0.5896 | + .22 |
| 7A | 70.72 | 0.3661 | 0.3594 | + .35 | 47,48 | 0.6921 | 0.6902 | + .10 |
| 19 | 56.57 | 0.3584 | 0.3575 | + .05 | 62 63 | 0.1961 | 0.1901 | + .31 |
| 23A | 51,52 | 0.7201 | 0.7181 | + .10 | 66.67 | 0.8364 | 0.8356 | + .05 |
| 32 | 46,47 | 0.3970 | 0.3920 | + .26 | 72,73 | 0.1592 | 0.1631 | — .21 |
| 33 | 44,45 | 0.7401 | 0.7400 | + .01 | 73.74 | 0.8152 | 0.8174 | — .11 |
| 34 | 43,45 | 0.5712 | 0.5742 | — .17 | 74.75 | 0.4800 | 0.4814 | — .07 |
| 35 | 41,43 | 0.5529 | 0.5520 | + .04 | 76 77 | 9.5016 | 0.5000 | + .08 |
| 36 | 40,41 | 0.5946 | 0.5938 | + .04 | 77.79 | 0.4630 | 0.4615 | + .08 |
| 37 | 40:41 | 0.4676 | 0.4679 | — .02 | 77.79 | 0.5885 | 0.5921 | — .19 |
| 38 | 36,37 | 0.8402 | 0.8384 | + .08 | 81,82 | 0.7172 | 0.7172 | .00 |
| 39 | 35.37 | 0.5885 | 0.5916 | — .17 | 82.83 | 0.4624 | 0.4592 | + .17 |
| 40 | 34,35 | 0.2886 | 0.2882 | + .02 | 84,85 | 0.2649 | 0.2655 | — .03 |
| 41 | 30,31 | 0.2381 | 0.2302 | + .42 | 88,89 | 0.3200 | 0.3199 | + .01 |
| 42 | 28,29 | 0.2592 | 0.2594 | — .01 | 90,91 | 0.3016 | 0.2991 | + .13 |
| 43 | 26,27 | 0.3708 | 0.3731 | — .12 | 82,93 | 0.1818 | 0.1814 | + .02 |
| 44 | 25,26 | 0.8192 | 0.8188 | + .03 | 92,93 | 0.7378 | 0.7345 | + .17 |
| 45 | 21,22 | 0.5601 | 0.5591 | + .05 | 96,98 | 0.5009 | 0.4981 | + .14 |

TABLE III.—(*Continued.*) PLATE VIII: *y* MEASUREMENTS.

| Star. | *y* direct. | | | | *y* reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Line. | ½ *m*, or Scale *minus* Star. | | *K—H* | Line. | ½ *m*, or Scale *minus* Star. | | *K—H* |
| | | Kretz. | Hays. | | | Kretz. | Hays. | |
| | | | | " | | | | " |
| 15 | 55 | 0.0068 | 0.0070 | —0.01 | 64 | 0.5411 | 0.5416 | —0.03 |
| 15 | | | | | 64 | 0 5421 | 0.5425 | — .02 |
| 2 | 51 | 0.6239 | 0.6241 | — .01 | 67 | 0.9258 | 0.9290 | — .19 |
| 3 | 37 | 0.0348 | 0.0326 | + .12 | 82 | 0.5169 | 0.5194 | — .13 |
| 4 | 19 | 0.9572 | 0.9590 | — .08 | 99 | 0.5984 | 0.6002 | — .10 |
| 6 | 69 | 0.2228 | 0.2200 | + .15 | 50 | 0.3288 | 0.3249 | + .21 |
| 8 | 69 | 0.9606 | 0.9614 | — .03 | 49 | 0.5875 | 0.5898 | — .12 |
| 10 | 48 | —.0029 | 0.0000 | — .15 | 71 | 0.5505 | 0.5512 | — .04 |
| 11 | 42 | 0.2579 | 0.2596 | — .09 | 77 | 0.2900 | 0.2915 | — .08 |
| 14 | 75 | 0.9466 | 0.9432 | + .16 | 43 | 0.6034 | 0.6072 | — .20 |
| 16 | 20 | 0.7739 | 0.7724 | + .07 | 98 | 0.7801 | 0.7820 | — .11 |
| 17 | 38 | 0.8599 | 0 8614 | — .07 | 80 | 0.6928 | 0.6949 | — .11 |
| 18 | 39 | 0.7045 | 0.7068 | — .12 | 79 | 0.8506 | 0.8478 | + .15 |
| 20 | 38 | 0.9272 | 0.9284 | — .05 | 80 | 0.6249 | 0.6264 | — .08 |
| 22 | 70 | 0.6700 | 0.6721 | — .11 | 48 | 0.8775 | 0.8769 | + .04 |
| 23 | 68 | 0.1906 | 0.1938 | — .17 | 51 | 0.3525 | 0.3596 | — .37 |
| 24 | 38 | 0.3356 | 0.3372 | — .08 | 81 | 0.2140 | 0.2150 | — .05 |
| 25 | 48 | 0 8722 | 0.8729 | — .03 | 70 | 0.6748 | 0.6775 | — .14 |
| 26 | 25 | 0 8939 | 0.8966 | — .13 | 93 | 0.6598 | 0.6611 | — .07 |
| 27 | 47 | 0.7358 | 0.7394 | — .19 | 71 | 0.8111 | 0.8096 | + .08 |
| 28 | 58 | 0.9688 | 0.9678 | + .04 | 60 | 0.5792 | 0.5779 | + .07 |
| 29 | 82 | 0.5856 | 0 5869 | — .07 | 36 | 0.9645 | 0.9650 | — .04 |
| 31 | 39 | 0.2340 | 0.2400 | — .32 | 80 | 0.3161 | 0.3192 | — .16 |
| 33 | 17 | 0.7346 | 0.7341 | + .03 | 101 | 0.8170 | 0.8195 | — .14 |
| | | Schl. | Kretz. | *S—K* | | Schl. | Kretz. | *S—K* |
| | | | | " | | | | " |
| 15 | 55 | 0 0095 | 0.0072 | +0.12 | 64 | 0.5411 | 0.5409 | +0.01 |
| 15 | 55 | 0.0105 | 0.0076 | + .15 | 64 | 0.5458 | 0.5418 | + .21 |
| 1 | 70 | 0.7176 | 0.7158 | + .09 | 48 | 0.8352 | 0.8331 | + .10 |
| 5 | 83 | 0.9740 | 0.9754 | — .09 | 35 | 0.5774 | 0.5751 | + .12 |
| 7 | 36 | —.0154 | —.0178 | + .13 | 83 | 0.5680 | 0.5670 | + .05 |
| 7A | 51 | 0.2508 | 0.2484 | + .13 | 68 | 0.3062 | 0.3025 | + .20 |
| 19 | 80 | 0.8938 | 0.8884 | + .28 | 38 | 0.6646 | 0.6609 | + .20 |
| 23A | 69 | 0.7815 | 0.7792 | + .12 | 49 | 0.7719 | 0.7688 | + .16 |
| 32 | 15 | 0.4090 | 0.4109 | — .10 | 104 | 0 1476 | 0.1456 | + .11 |
| 33 | 17 | 0.7384 | 0.7378 | + .03 | 101 | 0.8194 | 0.8171 | + .13 |
| 34 | 51 | 0.1562 | 0.1560 | + .01 | 68 | 0.3972 | 0.3955 | + .09 |
| 35 | 88 | 0.4174 | 0.4150 | + .13 | 31 | 0.1369 | 0.1330 | + .21 |
| 36 | 65 | 0.8636 | 0.8619 | + .10 | 53 | 0.6901 | 0.6880 | + .11 |
| 37 | 41 | 0.7460 | 0.7445 | + .08 | 77 | 0.8105 | 0.8101 | + .02 |
| 38 | 58 | 0.7471 | 0.7446 | + .13 | 60 | 0.8075 | 0.8049 | + .14 |
| 39 | 65 | 0.0412 | 0 0418 | — .03 | 54 | 0.5091 | 0.5089 | + .01 |
| 40 | 20 | 0.0869 | 0.0869 | .00 | 99 | 0.4692 | 0.4708 | — .08 |
| 41 | 47 | 0.4586 | 0.4596 | — .05 | 72 | 0.0951 | 0 0960 | — .05 |
| 42 | 47 | 0.3562 | 0.3532 | + .16 | 72 | 0.2010 | 0.1981 | + .15 |
| 43 | 61 | 0.9196 | 0.9135 | + .33 | 57 | 0.6349 | 0.6349 | .00 |
| 44 | 81 | 0.3348 | 0.3334 | + .07 | 38 | 0.2199 | 0.2176 | + .12 |
| 45 | 30 | 0.4771 | 0.4782 | — .06 | 89 | 0.0745 | 0.0785 | — .21 |

TABLE III.—(*Continued.*) PLATE IX: $x$ MEASUREMENTS.

| Star. | $x$ direct. | | | | $x$ reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Lines. | ½ $m$, or Scale *minus* Star. | | $S-K$ | Lines. | ½ $m$, or Scale *minus* Star | | $S-K$ |
| | | Schl. | Kretz. | | | Schl. | Kretz. | |
| | | | | " | | | | " |
| 15 | 54,55 | 0.8900 | 0.8901 | —0.01 | 63,64 | 0.6599 | 0.6628 | —0.15 |
| 2 | 88,89 | 0.3924 | 0.3978 | — .29 | 30,31 | 0.1621 | 0.1625 | — .02 |
| 3 | 87,88 | 0.3025 | 0.3008 | + .09 | 31,32 | 0.2570 | 0.2544 | + .14 |
| 4 | 85,86 | 0.5701 | 0.5648 | + .28 | 32,34 | 0.4876 | 0.4918 | — .22 |
| 6 | 72,73 | 0.2920 | 0.2899 | + .11 | 46,47 | 0.2621 | 0.2621 | .00 |
| 8 | 65,66 | 0.4511 | 0.4461 | + .26 | 53,54 | 0.1020 | 0.1029 | — .05 |
| 10 | 64,65 | 0.5751 | 0.5730 | + .11 | 53,55 | 0.4780 | 0.4776 | + .02 |
| 11 | 63,64 | 0.7320 | 0.7318 | + .01 | 54,55 | 0.8220 | 0.8205 | + .07 |
| 14 | 55,56 | 0.0608 | 0.0609 | — .01 | 63,64 | 0.4905 | 0.4886 | + .10 |
| 16 | 53,55 | 0.5259 | 0.5236 | + .12 | 64,65 | 0.5291 | 0.5299 | — .04 |
| 17 | 52,53 | 0.5848 | 0.5914 | — .35 | 65,67 | 0.4656 | 0.4661 | — .03 |
| 18 | 50,52 | 0.5451 | 0.5448 | + .01 | 67,68 | 0.5085 | 0.5105 | — .11 |
| 20 | 50,51 | 0.6969 | 0.6962 | + .04 | 67,68 | 0.8598 | 0.8592 | + .04 |
| 22 | 48,49 | 0.7159 | 0.7158 | + .01 | 69,70 | 0.8362 | 0.8382 | — .10 |
| 23 | 47,48 | 0.3495 | 0.3515 | — .11 | 71,72 | 0.2038 | 0.2044 | — .03 |
| 24 | 45,46 | 0.2512 | 0.2520 | — .04 | 73,74 | 0.2981 | 0.2989 | — .04 |
| 25 | 44,45 | 0.6609 | 0.6601 | + .04 | 73,74 | 0.8926 | 0.8914 | + .07 |
| 26 | 44,45 | 0.5798 | 0.5791 | + .04 | 73,75 | 0.4729 | 0.4739 | — .05 |
| 27 | 44,45 | 0.2938 | 0.2900 | + .20 | 74,75 | 0.2616 | 0.2608 | + .04 |
| 28 | 43,45 | 0.5416 | 0.5436 | — .11 | 74,75 | 0.5095 | 0.5086 | + .05 |
| 29 | 43,44 | 0.4295 | 0.4300 | — .03 | 75,76 | 0.1226 | 0.1228 | — .01 |
| 45 | 16,17 | 0.1870 | 0.1888 | — .10 | 102,103 | 0.3682 | 0.3689 | — .04 |

| Star. | Lines. | Kretz. | Hays. | $K-H$ | Lines. | Kretz. | Hays. | $K-H$ |
|---|---|---|---|---|---|---|---|---|
| | | | | " | | | | " |
| 15 | 54,55 | 0.8899 | 0.8898 | +0.01 | 63,64 | 0.6629 | 0.6628 | +0.01 |
| 1 | 89,90 | 0.3738 | 0.3658 | + .42 | 29,30 | 0.1809 | 0.1800 | + .05 |
| 2 | 88,89 | 0.3938 | 0.3946 | — .04 | 30,31 | 0.1600 | 0.1602 | — .01 |
| 5 | 76,77 | 0.4536 | 0.4546 | — .05 | 42,43 | 0.0996 | 0.0986 | + .05 |
| 7 | 69,70 | 0.5980 | 0.5940 | + .21 | 48,50 | 0.4599 | 0.4625 | — .13 |
| 23A | 46,47 | 0.3264 | 0.3236 | + .14 | 72,73 | 0.2242 | 0.2258 | — .08 |
| 31 | 42,43 | 0.8836 | 0.8880 | — .22 | 75,76 | 0.6685 | 0.6692 | — .04 |
| 32 | 40,42 | 0.5325 | 0.5338 | — .07 | 77,78 | 0.5216 | 0.5194 | + .12 |
| 33 | 39,40 | 0.3811 | 0.3829 | — .10 | 79,80 | 0.1719 | 0.1732 | — .07 |
| 34 | 38,39 | 0.6959 | 0.6980 | — .12 | 79,80 | 0.8624 | 0.8601 | + .13 |
| 35 | 36,37 | 0.6520 | 0.6511 | + .05 | 81,82 | 0.9028 | 0.9005 | + .13 |
| 36 | 35,36 | 0.2006 | 0.1999 | + .04 | 83,84 | 0.3488 | 0.3510 | — .12 |
| 37 | 35,36 | 0.0874 | 0.0931 | — .30 | 83,84 | 0.4661 | 0.4621 | + .21 |
| 38 | 31,32 | 0.4465 | 0.4495 | — .16 | 87,88 | 0.1064 | 0.1052 | + .06 |
| 39 | 30,31 | 0.7034 | 0.6981 | + .28 | 87,88 | 0.8530 | 0.8550 | — .10 |
| 40 | 28,29 | 0.9286 | 0.9256 | + .17 | 89,90 | 0.6300 | 0.6298 | + .01 |
| 43 | 20,22 | 0.4879 | 0.4882 | — .01 | 97,98 | 0.5671 | 0.5681 | — .05 |
| 44 | 20,21 | 0.4152 | 0.4138 | + .07 | 98,99 | 0.1415 | 0.1409 | + .03 |
| 45 | 16,17 | 0.1885 | 0.1902 | — .09 | 102,103 | 0.3685 | 0.3682 | + .02 |

TABLE III.—(*Concluded.*) PLATE IX: *y* MEASUREMENTS.

| Line. | *y* direct. | | | | *y* reversed. | | | |
|---|---|---|---|---|---|---|---|---|
| | Star. | ½ *m*, or Scale *minus* Star. | | *K—H* | Line. | ½ *m*, or Scale *minus* Star. | | *K—H* |
| | | Kretz. | Hays. | | | Kretz. | Hays. | |
| | | | | ″ | | | | ″ |
| 15 | 56 | 0.6574 | 0.6586 | —0.06 | 62 | 0.8968 | 0.8969 | 0.00 |
| 2 | 53 | 0.2924 | 0.2885 | + .21 | 66 | 0.2601 | 0.2619 | — .10 |
| 3 | 38 | 0.7025 | 0.7022 | + .02 | 80 | 0.8546 | 0.8548 | — .02 |
| 4 | 21 | 0.6201 | 0.6211 | — .05 | 97 | 0.9386 | 0.9390 | — .03 |
| 6 | 70 | 0.8824 | 0.8836 | — .05 | 48 | 0.6685 | 0.6701 | — .08 |
| 8 | 71 | 0.6176 | 0.6160 | + .08 | 47 | 0.9336 | 0.9311 | + .12 |
| 10 | 49 | 0.6535 | 0.6530 | + .02 | 69 | 0.8961 | 0.8986 | — .12 |
| 11 | 43 | 0.9194 | 0.9174 | + .10 | 75 | 0.6335 | 0.6356 | — .11 |
| 14 | 77 | 0.5956 | 0.5951 | + .03 | 41 | 0.9594 | 0.9579 | + .10 |
| 16 | 22 | 0.4234 | 0.4211 | + .12 | 97 | 0.1318 | 0.1336 | — .10 |
| 17 | 40 | 0.5092 | 0.5088 | + .02 | 79 | 0.0488 | 0.0450 | + .20 |
| 18 | 41 | 0.3556 | 0.3512 | + .23 | 78 | 0.2010 | 0.2028 | — .10 |
| 20 | 40 | 0.5775 | 0.5768 | + .04 | 78 | 0.9788 | 0.9775 | + .05 |
| 22 | 72 | 0.3186 | 0.3181 | + .03 | 47 | 0.2341 | 0.2351 | — .05 |
| 23 | 69 | 0.8454 | 0.8441 | + .06 | 49 | 0.7089 | 0.7101 | — .06 |
| 24 | 39 | 0.9861 | 0.9831 | + .17 | 79 | 0.5705 | 0.5735 | — .16 |
| 25 | 50 | 0.5185 | 0.5192 | — .04 | 69 | 0.0304 | 0.0294 | + .05 |
| 26 | 27 | 0.5389 | 0.5426 | — .20 | 92 | 0.0139 | 0.0171 | — .17 |
| 27 | 49 | 0.3845 | 0.3856 | — .06 | 70 | 0.1659 | 0.1660 | — .01 |
| 28 | 60 | 0.6129 | 0.6126 | + .02 | 58 | 0.9371 | 0.9361 | + .06 |
| 29 | 84 | 0.2345 | 0.2326 | + .10 | 35 | 0.3168 | 0.3154 | + .07 |
| 33 | 19 | 0.3819 | 0.3838 | — .10 | 100 | 0.1718 | 0.1716 | + .01 |
| | | Schl. | Hays. | *S—H* | | Schl. | Hays. | *S—H* |
| | | | | ″ | | | | ″ |
| 15 | 56 | 0.6586 | 0.6598 | —0.06 | 62 | 0.8946 | 0.8964 | —0.11 |
| 1 | 72 | 0.3909 | 0.3881 | + .15 | 47 | 0.1674 | 0.1626 | + .25 |
| 5 | 85 | 0.6366 | 0.6354 | + .06 | 33 | 0.9176 | 0.9172 | + .03 |
| 7 | 37 | 0.6385 | 0.6375 | + .05 | 81 | 0.9169 | 0.9132 | + .21 |
| 23A | 71 | 0.4271 | 0.4246 | + .13 | 48 | 0.1265 | 0.1219 | + .24 |
| 31 | 40 | 0.8852 | 0.8874 | — .13 | 78 | 0.6710 | 0.6731 | — .11 |
| 32 | 17 | 0.0584 | 0.0532 | + .28 | 102 | 0.5040 | 0.5041 | — .01 |
| 33 | 19 | 0.3802 | 0.3842 | — .21 | 100 | 0.1728 | 0.1711 | + .09 |
| 34 | 52 | 0.7965 | 0.7979 | — .07 | 66 | 0.7548 | 0.7551 | — .01 |
| 35 | 90 | 0.0624 | 0.0638 | — .07 | 29 | 0.4945 | 0.4920 | + .13 |
| 36 | 67 | 0.5094 | 0.5024 | + .37 | 52 | 0.0486 | 0.0412 | + .39 |
| 37 | 43 | 0.3850 | 0.3868 | — .10 | 76 | 0.1650 | 0.1701 | — .27 |
| 38 | 60 | 0.3900 | 0.3834 | + .35 | 59 | 0.1671 | 0.1660 | + .06 |
| 39 | 66 | 0.6850 | 0.6826 | + .13 | 52 | 0.8684 | 0.8680 | + .03 |
| 40 | 21 | 0.7210 | 0.7229 | — .10 | 97 | 0.8329 | 0.8329 | .00 |
| 43 | 63 | 0.5462 | 0.5432 | + .15 | 56 | 0.0040 | 0.0062 | — .12 |
| 44 | 82 | 0.9712 | 0.9688 | + .11 | 36 | 0.5834 | 0.5864 | — .16 |
| 45 | 32 | 0.1102 | 0.1076 | + .14 | 87 | 0.4465 | 0.4474 | — .05 |

## III.

## Instrumental Corrections.

The first step towards turning the foregoing measures into right ascensions and declinations will be to apply the following instrumental corrections, which are here considered in the order of their application.

1° *Division Errors of the Scale.*

Just before beginning the measurement of the Præsepe plates a thorough examination of the division errors of the scale was completed. The details of this investigation together with the determinations of other constants of the measuring machine are reserved for another publication from this observatory. It will suffice for present purposes to set down merely the final results.

Previous to the above investigation the scale had also been examined by the *Kaiserliche Normal Aichungs Kommission* at Berlin; the results of this determination were published in the "Annals of the New York Academy of Sciences," Vol. IX, page 206. The two determinations agree quite well, the largest difference for any line being 0.″11, and usually the agreement is much closer. As the investigation at Columbia was made with the same microscope and under the same conditions in which the plates were measured, it was thought best to use only our own results, as given in Table IV. The coördinates of a star depend upon several divisions for one plate, and the same star usually comes opposite different divisons for different plates. It follows therefore that our final positions will be nearly independent of inaccuracies in the determination of the division errors; for example, the right ascension of Star 1 depends upon eighteen different lines of the scale and its declination depends upon thirteen. In Table IV the corrections are given in millimetres, and are always to be added to observed readings.

2° *Corrections for Runs and Screw Errors.*

The screw used in the measurements is of such a pitch that two complete turns of the micrometer head correspond to one space on the scale; the micrometer head is divided into one hundred equal parts and may therefore be read directly to half-microns

TABLE IV.—DIVISION ERRORS OF THE SCALE.

| Line. | Correction in mm. | Line. | Correction in mm. | Line. | Correction in mm. |
|---|---|---|---|---|---|
| 0 | 0.0000 | 44 | +0.0029 | 88 | +0.0025 |
| 1 | +0.0011 | 45 | +0.0020 | 89 | +0.0026 |
| 2 | —0.0007 | 46 | +0.0021 | 90 | +0.0018 |
| 3 | —0.0001 | 47 | +0.0006 | 91 | +0.0027 |
| 4 | +0.0002 | 48 | +0.0013 | 92 | +0.0025 |
| 5 | —0.0004 | 49 | +0.0015 | 93 | +0.0026 |
| 6 | +0 0001 | 50 | +0.0007 | 94 | +0.0026 |
| 7 | —0.0013 | 51 | +0.0018 | 95 | +0.0026 |
| 8 | —0.0008 | 52 | +0.0030 | 96 | +0.0019 |
| 9 | —0.0009 | 53 | +0.0024 | 97 | +0.0008 |
| 10 | —0.0001 | 54 | +0.0032 | 98 | +0.0014 |
| 11 | +0.0014 | 55 | +0.0028 | 99 | +0.0004 |
| 12 | +0.0006 | 56 | +0.0030 | 100 | +0.0019 |
| 13 | +0.0014 | 57 | +0.0034 | 101 | +0.0004 |
| 14 | +0.0016 | 58 | +0.0038 | 102 | —0.0005 |
| 15 | +0.0015 | 59 | +0.0034 | 103 | +0.0002 |
| 16 | +0.0009 | 60 | +0.0034 | 104 | +0.0014 |
| 17 | +0.0008 | 61 | +0.0038 | 105 | +0.0009 |
| 18 | +0.0012 | 62 | +0.0044 | 106 | +0.0012 |
| 19 | +0.0012 | 63 | +0.0058 | 107 | +0.0002 |
| 20 | +0.0007 | 64 | +0.0050 | 108 | +0.0012 |
| 21 | +0.0015 | 65 | +0.0053 | 109 | 0.0000 |
| 22 | +0.0016 | 66 | +0.0059 | 110 | —0 0002 |
| 23 | +0.0014 | 67 | +0.0050 | 111 | +0.0002 |
| 24 | +0.0012 | 68 | +0.0052 | 112 | —0.0006 |
| 25 | +0.0007 | 69 | +0.0057 | 113 | —0.0013 |
| 26 | +0.0026 | 70 | +0.0054 | 114 | +0.0005 |
| 27 | +0.0033 | 71 | +0.0056 | 115 | —0.0003 |
| 28 | +0.0026 | 72 | +0.0047 | 116 | 0.0000 |
| 29 | +0.0020 | 73 | +0.0046 | 117 | +0.0020 |
| 30 | +0.0035 | 74 | +0.0047 | 118 | +0.0022 |
| 31 | +0.0030 | 75 | +0.0037 | 119 | +0.0026 |
| 32 | +0.0022 | 76 | +0.0052 | 120 | +0.0021 |
| 33 | +0.0024 | 77 | +0.0045 | 121 | +0.0014 |
| 34 | +0.0013 | 78 | +0.0041 | 122 | +0.0024 |
| 35 | +0.0032 | 79 | +0.0040 | 123 | +0.0015 |
| 36 | +0.0024 | 80 | +0.0033 | 124 | +0.0024 |
| 37 | +0.0025 | 81 | +0.0043 | 125 | +0.0012 |
| 38 | +0.0016 | 82 | +0.0029 | 126 | +0.0018 |
| 39 | +0.0025 | 83 | +0.0050 | 127 | +0.0014 |
| 40 | +0.0033 | 84 | +0.0034 | 128 | +0.0005 |
| 41 | +0.0020 | 85 | +0.0021 | 129 | +0.0015 |
| 42 | +0.0025 | 86 | +0.0014 | 130 | 0.0000 |
| 43 | +0.0024 | 87 | +0.0026 | | |

and by estimation to twentieths of a micron. The details of the operation of observing runs were to set the micrometer head at about $5.^r0$ and to read on the scale as follows:

Line 70, Line 65, Line 65, Line 70.

These two lines were selected because they have practically the same division errors, thus avoiding an extra correction, and also because they happen to have more accurately determined division errors than most other lines. The correction for runs need not be applied to the separate readings on the stars and on the scale but may be applied to the quantity $\frac{1}{2}m$ directly; for let us put

$2R =$ reading on Line 65, *minus* reading on Line 70, *minus* $10.^r0000$.

Dividing by 2 we obtain $R$, the quantity given in Table II; we must then add to $\frac{1}{2}m$ the correction

$$-\left(\tfrac{1}{2}m\right)\frac{R}{5}\text{ millimetres.}$$

This correction may conveniently be combined with the correction for non-periodic errors of the screw or variations in its pitch; investigation showed that the following quantities must be added to observed readings of the micrometer head in order to reduce them to what they would have been had the screw been of uniform pitch, but of the same total length:

| Reading of the Micrometer Head. r | Correction in Millimetres. |
|---|---|
| 5.0 | 0. |
| 6.0 | + 0.0005 |
| 7.0 | + 0.0002 |
| 8.0 | — 0.0003 |
| 9.0 | — 0.0012 |
| 10.0 | — 0.0017 |
| 11.0 | — 0.0022 |
| 12.0 | — 0.0021 |
| 13.0 | — 0.0022 |
| 14.0 | — 0.0014 |
| 15.0 | 0. |

The screw is actually longer than ten turns, but as only this length was used in the determination of the error of runs the rest of the screw was not investigated. It will be observed that the corrections progress uniformly in the interval from $9.^r0$ to $11.^r0$; advantage was taken of this fact to make the application of the corrections a simple matter. For if the micrometer head be set at $9.^r0$ when the microscope is pointed at a star, then the reading on the scale will lie between $9.^r0$ and $11.^r0$ because a whole space of the scale corresponds to two turns of the micrometer head; consequently the correction to the difference of the readings on scale and star will be proportionate to that difference, that is to $\frac{1}{2}m$; the correction to the latter is easily seen to be

$$-(\tfrac{1}{2}m)\times 0.0010 \text{ millimetres.}$$

Adding this to the correction for runs we obtain

$$-(\tfrac{1}{2}m)\left(0.00010+\frac{R}{5}\right)\text{ millimetres.}$$

As an example let us correct the first observation given on the specimen sheet on page 199. The date being March 25, we get from Table II,

$$R=+0.0045.$$

Consequently the correction for runs and screw errors is

$$-(\tfrac{1}{2}m)\times 0.0019 \text{ millimetres.}$$

A table may now be constructed with the argument $\frac{1}{2}m$ which applies to all observations taken on March 25.

| $\frac{1}{2}m$. | Correction. |
|---|---|
| 0.0 | 0.0000 millimetres. |
| 0.1 | — 0.0002 |
| 0.2 | — 0.0004 |
| 0.3 | — 0.0006 |
| 0.4 | — 0.0008 |
| 0.5 | — 0.0010 |
| 0.6 | — 0.0011 |
| 0.7 | — 0.0013 |
| 0.8 | — 0.0015 |
| 0.9 | — 0.0017 |
| 1.0 | — 0.0019 |

For the star given on the specimen sheet the correction is — 0.0009. During the second half of each morning's observations when the micrometer head is set at $9.^r5$ instead of at $9.^r0$ it sometimes happens that the reading on the scale exceeds $11.^r0$, in which case the correction will not be exactly proportionate to $\frac{1}{2}m$; but the error committed by using the same table throughout will never reach $0.''02$, and in most cases is entirely negligible.

3°. Having applied the corrections given above we have now to change the measures into rectangular coördinates $x$ and $y$, referred to the central star 15 as origin, one axis being parallel to the cylinder and the other at right angles to it. For this purpose we subtract the mean of all the readings on the central star for any one day from the readings of all the other stars that were measured on that day. As we wish to have positive values of $x$ for those stars which have greater right ascensions than the central star, we must subtract the reading "$x$ direct" from the reading on Star 15; but we must subtract the reading on Star 15 from the reading "$x$ reversed." Similiarly to get positive values of $y$ for those stars having greater declinations than the central star, we subtract the reading on Star 15 from each "$y$ direct" and the contrary for "$y$ reversed."

4° *Rotation Corrections.*

It was found very difficult to set the circle at exactly 90° plus the reading for the previous day. Even when this had been accomplished the circle-reading was sometimes found to have changed a little during the measurement of the stars. A correction is therefore necessary to reduce the rectangular coördinates to what they would have been had the readings of the circle for different days differed only by multiples of 90°. Let

$Q =$ the number of seconds which occurs most often in the circle readings of a particular plate.

$Q - i =$ the number of seconds in the reading for any day.

Then we have,*

$$\text{Correction for } x = -y.\ i \sin 1.''$$
$$\text{" \quad " } y = +x.\ i \sin 1.''$$

For the present measurements these corrections are very small, never exceeding 0.″05; they have however been applied throughout.

The values of $Q$ adopted for the various plates are as follows:

| | | |
|---|---|---|
| Plate | I | $Q =$ 5″ |
| | II | 0 |
| | III | 0 |
| | IV | 58 |
| | V | 7 |
| | VII | 0 |
| | VIII | 29 |
| | IX | 2 |

5° *Scale-value corrections.*

The scale being made of German silver has a greater coefficient of expansion than the glass plate, and hence it would appear that if the temperature changed during the measurement of a plate,

* "Permanence of the Rutherfurd Photographic Plates" by Harold Jacoby, Annals of the N. Y. Acad. of Sciences, Vol. IX, p. 267.

the coördinates would require a correction to reduce them to what they would have been had the temperature remained constant. Investigation shows, however, that such a correction is unnecessary by reason of its minuteness, at least within the limits of the range of temperature at which the present plates were measured. To ascertain the amount of the correction, two well defined specks, such as may be found in the film of any plate, were selected, one near either edge of the plate, and the distance between them was measured at various temperatures. On the morning of April 30, 1897, this distance was measured six times each by Mr. Kretz and myself with the following results:

| | Schlesinger: | Kretz: |
|---|---|---|
| | 104.1548 *mm.* | 104.1505 *mm.* |
| | 67 | 514 |
| | 36 | 505 |
| | 30 | 497 |
| | 50 | 540 |
| | 25 | 517 |
| Mean, | 104.1543 | 104.1513 |
| Probable Error, | ±0.00042 | ±0.00041 |

The temperature of the measuring room had been kept at 69.°3 during the measurement by means of artificial heat, the heating apparatus being at the other end of the room from that occupied by the measuring machine. The heat was now turned off and the plate allowed to assume the natural temperature of the atmosphere; on the afternoon of the same day, three hours having elapsed since the first series was completed, the distance between the specks was again measured by the same observers as follows:

| | Schlesinger: | Kretz: |
|---|---|---|
| | 104.1550 *mm.* | 104.1557 *mm.* |
| | 70 | 44 |
| | 63 | 48 |
| | 87 | 60 |
| | 90 | 53 |
| | 70 | 75 |
| Mean, | 104.1572 | 104.1556 |
| Probable Error, | ±0.00041 | ±.00031 |

The temperature for this series was 52.°2. Denoting by $v$ the increase in the measured distance due to an increase of 1° in the temperature we have

| Schlesinger: | Kretz: |
|---|---|
| $v = -0.00017$ *mm.* | $v = -0.00025$ *mm.* |
| $\pm 0.000034$ | $\pm 0.000030$ |

These two values are not very accordant, but they agree sufficiently well for present purposes. As, however, some doubts were entertained as to whether the plates had been thoroughly cooled in the intervening three hours, and as to whether it would not be better to measure the distance between the specks at a season when artificial heat could be entirely dispensed with, the following third series of observations was undertaken by myself, several days elapsing between the various measurements. No artificial heat was allowed in the measuring room during the whole period.

May 20, 1897. Temperature = 73.°6.

104.1530 *mm.*
10
18
30
58
48
25
68

Mean, 104.1536 ± 0.00047

May 22, 1897. Temperature = 69.°6.

104.1534 *mm.*
36
26
44
34
39
54
76

Mean, 104.1543 ± 0.00036

May 29, 1897. Temperature = 71.°0.

104.1548 *mm.*
26
28
64
34
28
36
34

Mean, 104.1537 ± 0.00031

July 27, 1897. Temperature $= 82.^\circ 1$.

104.1532 *mm.*
525
505
530
520
495
510
542
510
522
548
525

Mean, $104.1522 \pm 0.00031$

Denoting by $v$ as before the increase in the distance due to an increase of $1^\circ$ in the temperature, and by $L$ the distance between the specks at the temperature $69.^\circ 6$ we have the following four observation equations:

| | | |
|---|---|---|
| $L - 104.1543 = 0$ | weight | 3 |
| $L + 1.4\,v - 104.1537 = 0$ | " | 5 |
| $L + 4.0\,v - 104.1536 = 0$ | " | 2 |
| $L + 12.5\,v - 104.1522 = 0$ | " | 5 |

The weights are calculated from the probable errors given above, the probable error of an equation of weight unity being

$$\pm 0.00067$$

Solving by least squares we get

$$v = -0.00015 \pm 0.000032$$

Taking into account the two previous series, the mean by weight is

$$v = -0.00019 \ mm.$$

which very probably does not differ from its true value by as much as 0.00005.

Now the largest coördinate in the Præsepe measures is less than forty millimetres, and the greatest deviation for any single day from the mean of the temperatures for the corresponding plate is less than $5^\circ$; consequently the largest correction which it will ever be necessary to apply is

$$0.00037 \ mm.$$

which corresponds to $0.''02$. As this is so small, even in the extreme case, no appreciable error will be committed by neglecting the correction altogether. We may indeed conclude that for the scale under consideration and for the Rutherfurd plates, a correction for change in the scale-value will be unnecessary so long as the temperature does not vary more than 10° during the measurement of a single plate.

6° *Projection Errors* and *Deviation of the Cylinder from Straightness.*

In the present work corrections have been applied for neither of these; the first were discussed by Donner * and are very small in most cases; it is indeed very difficult to determine them with sufficient accuracy. Repsold has recently devised a new guiding way which is free from this source of error; the measuring machine used for the Præsepe plates had been furnished with such a guiding way in 1896. As regards the straightness of the cylinder, investigation showed that it had been admirably made †; the greatest error which we shall commit in assuming it to be straight is 0.″04; the reversal of each plate and the insertion of different plates in different positions in the measuring machine will tend to eliminate even this small error.

Having now completed the consideration of all the instrumental corrections which it is necessary to apply, I shall conclude this subject by correcting the measurements of Star 7, Plate VIII, as given on page 199, or in Table III.

| | March 25, $x$ direct: | March 24, $y$ direct: | March 18, $x$ reversed: | March 22, $y$ reversed: |
|---|---|---|---|---|
| Lines, ............. | 74,76 | 36 | 43,44 | 83 |
| $\frac{1}{2}m$; First obs'v'r., . . | 0.4646 | — 0.0154 | 0.5938 | 0.5680 |
| Second " . . | 0.4639 | — 0.0178 | 0.5896 | 0.5670 |
| Mean, ............. | 0.4643 | — 0.0166 | 0.5917 | 0.5675 |
| Cor. for Runs, etc., | — 9 | 0 | — 11 | — 11 |
| Div. Correction, .... | + 50 | + 24 | + 26 | + 50 |
| Corrected $\frac{1}{2}m$, ...... | 0.4684 | — 0.0142 | 0.5932 | 0 5714 |
| Measurement, ...... | 75.4684 | 35.9858 | 44.0932 | 83.5714 |

Where two lines have been used the division correction is the mean of the division corrections for the separate lines; the final "measurement" is then obtained by adding the mean of the numbers of the lines to the corrected $\frac{1}{2}$ $m$. The corresponding measurements for the central star 15 when similiarly corrected are:

* "Détermination des Constantes nécessaires pour la Reduction des Clichés." Acta Societatis Scientiarum Fennicae, Vol. XXI.

† "Permanence of the Rutherfurd Plates" by Harold Jacoby; Annals of the N. Y. Acad. of Sciences, Vol. IX, page 210.

| | March 25, $x$ direct: | March 24, $y$ direct: | March 18, $x$ reversed: | March 22, $y$ reversed: |
|---|---|---|---|---|
| | 60.7692 | 55.0133 | 58.7883 | 64.5497 |
| | 7695 | 0104 | 7887 | 5457 |
| | 7731 | 0100 | 7870 | 5448 |
| | 7712 | 0123 | 7871 | 5450 |
| Mean, | 60.7708 | 55.0115 | 58.7878 | 64.5463 |

Taking the differences between these and the corresponding measurements for Star 7, having regard to signs, we get:

| | | | | |
|---|---|---|---|---|
| Coördinates,........ | —14.6976 | —19.0257 | —14.6946 | —19.0251 |
| Rotation Cor.,...... | 0 | + 4 | + 2 | 0 |
| Final Coörd.,...... | —14.6976 | —19.0253 | —14.6944 | —19.0251 |

These are the quantities given in Table V, which needs no further explanation. In comparing the direct with the reversed coördinates, it should be remembered that unity in the fourth decimal place corresponds to about 0.″005 of arc of a great circle.

TABLE V.—CORRECTED COÖRDINATES. PLATE I.

| Star. | x | | | y | | |
|---|---|---|---|---|---|---|
| | Direct. | Rev'd. | Mean. | Direct. | Rev'd. | Mean. |
| 1 | —34.5052 | .5028 | —34.5040 | +15.6854 | .6850 | +15.6852 |
| 2 | —33.5104 | .5082 | —33.5093 | — 3.4200 | .4188 | — 3.4194 |
| 3 | —32.3942 | .3922 | —32.3932 | —18.0042 | .0055 | —18.0049 |
| 4 | —30.6393 | .6348 | —30.6370 | —35.0918 | .0906 | —35.0912 |
| 5 | —21.6168 | .6161 | —21.6165 | +28.9521 | .9571 | +28.9546 |
| 6 | —17.4281 | .4236 | —17.4258 | +14.2048 | .2048 | +14.2048 |
| 7 | —14.6839 | .6843 | —14.6841 | —19.0394 | .0412 | —19.0403 |
| 8 | —10.5876 | .5849 | —10.5862 | +14.9500 | .9500 | +14.9500 |
| 10 | — 9.6888 | .6886 | — 9.6887 | — 7.0204 | .0201 | — 7.0203 |
| 11 | — 8.8264 | .8270 | — 8.8267 | —12.7576 | .7577 | —12.7576 |
| 14 | — 0.2020 | .2022 | — 0.2021 | +20.9438 | .9455 | +20.9446 |
| 15 | 0.0000 | .0000 | 0.0000 | 0.0000 | .0000 | 0.0000 |
| 16 | + 0.9159 | .9173 | + 0.9166 | —34.2424 | .2429 | —34.2426 |
| 17 | + 2.3272 | .3293 | + 2.3283 | —16.1534 | .1504 | —16.1519 |
| 18 | + 3.8697 | .8712 | + 3.8705 | —15.3037 | .3022 | —15.3030 |
| 20 | + 4.2144 | .2182 | + 4.2163 | —16.0818 | .0826 | —16.0822 |
| 22 | + 6.1437 | .1546 | + 6.1541 | +15.6744 | .6760 | +15.6752 |
| 23 | + 7.5258 | .5276 | + 7.5267 | +13.2000 | .2000 | +13.2000 |
| 23A | + 8.5446 | .5478 | + 8.5462 | +14.7914 | .7874 | +14.7894 |
| 24 | + 9.6569 | .6587 | + 9.6578 | —16.6650 | .6664 | —16.6657 |
| 25 | +10.2385 | .2420 | +10.2402 | — 6.1255 | .1240 | — 6.1248 |
| 26 | +10.3560 | .3580 | +10.3570 | —29.1131 | .1110 | —29.1120 |
| 27 | +10.6100 | .6095 | +10.6098 | — 7.2644 | .2646 | — 7.2645 |
| 28 | +10.8422 | .8406 | +10.8414 | + 3.9756 | .9756 | + 3.9756 |
| 29 | +11.4264 | .4272 | +11.4268 | +27.6000 | .5983 | +27.5992 |
| 31 | +12.0292 | .0308 | +12.0300 | —15.7662 | .7623 | —15.7642 |
| 32 | +13.9115 | .9104 | +13.9110 | —39 5974 | .5944 | —39.5959 |
| 33 | +15.5667 | .5705 | +15.5686 | —37.2662 | .2662 | —37.2662 |
| 34 | +16.2032 | .2048 | +16.2040 | — 3.8424 | .8368 | — 3.8396 |
| 35 | +18.1994 | .1978 | +18.1986 | +33.4348 | .4344 | +33.4346 |
| 36 | +19.6786 | .6824 | +19.6805 | +10.8790 | .8794 | +10.8792 |
| 37 | +19.8224 | .8254 | +19.8239 | —13.2516 | .2506 | —13 2512 |
| 38 | +23.4340 | .4385 | +23.4362 | + 3.7612 | .7620 | + 3.7616 |
| 39 | +24.1815 | .1872 | +24.1844 | +10.0636 | .0626 | +10.0631 |
| 40 | +26.0190 | .0207 | +26.0198 | —34.9100 | .9092 | —34.9096 |
| 43 | +33.9119 | .9091 | +33.9105 | + 6.9450 | .9450 | + 6.9450 |
| 44 | +34.4409 | .4470 | +34.4440 | +26.3683 | .3666 | +26.3674 |

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE II.

| Star. | x | | | y | | |
|---|---|---|---|---|---|---|
| | Direct. | Rev'd. | Mean. | Direct. | Rev'd. | Mean. |
| 1 | —34.5040 | .5037 | —34.5038 | +15.6928 | .6954 | +15.6941 |
| 2 | —33.5044 | .5036 | —33.5040 | — 3.4064 | .4061 | — 3.4062 |
| 4 | —30.6440 | .6420 | —30.6430 | —35.0756 | .0789 | —35.0772 |
| 5 | —21.6032 | .6037 | —21.6035 | +28.9578 | .9610 | +28.9594 |
| 6 | —17.4227 | .4214 | —17.4221 | +14.2064 | .2055 | +14.2059 |
| 7 | —14.6867 | .6812 | —14.6840 | —19.0368 | .0348 | —19.0358 |
| 7A | —10.5894 | .5874 | —10.5884 | — 3.7603 | .7585 | — 3.7594 |
| 8 | —10.5806 | .5799 | —10.5803 | +14.9550 | .9538 | +14.9544 |
| 10 | — 9.6862 | .6838 | — 9.6850 | — 7.0164 | .0154 | — 7.0159 |
| 11 | — 8.8272 | .8259 | — 8.8266 | —12.7520 | .7530 | —12.7525 |
| 14 | — 0.2004 | .2006 | — 0.2005 | +20.9444 | .9442 | +20.9443 |
| 15 | 0.0000 | .0000 | 0.0000 | 0.0000 | .0000 | 0.0000 |
| 16 | + 0.9121 | .9122 | + 0.9122 | —34.2378 | .2359 | —34.2368 |
| 17 | + 2.3210 | .3230 | + 2.3220 | —16.1492 | .1480 | —16.1486 |
| 18 | + 3.8660 | .8664 | + 3.8662 | —15.3018 | .3032 | —15.3025 |
| 19 | + 3.8978 | .8967 | + 3.8972 | +25.8933 | .8950 | +25.8942 |
| 20 | + 4.2114 | .2147 | + 4.2130 | —16.0802 | .0786 | —16.0794 |
| 22 | + 6.1538 | .1518 | + 6.1528 | +13.1972 | .1972 | +13.1972 |
| 23A | + 8.5476 | .5505 | + 8.5490 | +14.7833 | .7834 | +14.7834 |
| 24 | + 9.6502 | .6500 | + 9.6501 | —16.6680 | .6658 | —16 6669 |
| 25 | +10.2337 | .2350 | +10.2344 | — 6.1280 | .1255 | — 6.1268 |
| 26 | +10.3454 | .3492 | +10.3473 | —29.1082 | .1090 | —29.1086 |
| 27 | +10.6000 | .6032 | +10.6016 | — 7.2620 | .2598 | — 7.2609 |
| 28 | +10.8382 | .8390 | +10.8386 | + 3.9732 | .9757 | + 3.9744 |
| 29 | +11.4256 | .4253 | +11.4254 | +27.5944 | .5926 | +27.5935 |
| 31 | +12.0266 | .0287 | +12.0276 | —15.7620 | .7641 | —15.7630 |
| 32 | +13.9074 | .9049 | +13.9061 | —39.5946 | .5894 | —39.5920 |
| 33 | +15.5584 | .5616 | +15.5600 | —37.2621 | .2607 | —37.2614 |
| 34 | +16.2032 | .2031 | +16.2031 | — 3.8444 | .8394 | — 3.8419 |
| 35 | +18.2036 | .2038 | +18.2037 | +33.4284 | .4314 | +33.4299 |
| 36 | +19.6828 | .6814 | +19.6821 | +10.8745 | .8752 | +10.8749 |
| 37 | +19.8174 | .8190 | +19.8182 | —13.2498 | .2495 | —13.2496 |
| 38 | +23.4373 | .4378 | +23.4375 | + 3.7584 | .7606 | + 3.7595 |
| 39 | +24.1793 | .1830 | +24.1812 | +10.0571 | .0604 | +10.0587 |
| 40 | +26.0170 | .0153 | +26.0162 | —34.9106 | .9091 | —34.9098 |
| 43 | +33.9056 | .9042 | +33.9049 | + 6.9342 | .9360 | + 6.9351 |
| 44 | +34.4474 | .4480 | +34.4477 | +26.3596 | .3632 | +26.3614 |
| 45 | +38.7409 | .7417 | +38.7413 | —24.5064 | .5066 | —24.5065 |

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE III.

| Star. | $x$ | | | $y$ | | |
|---|---|---|---|---|---|---|
| | Direct. | Rev'd. | Mean. | Direct. | Rev'd. | Mean. |
| 1 | —34.4942 | .4942 | —34.4942 | +15.7075 | .7076 | +15.7076 |
| 2 | —33.5073 | .5094 | —33.5084 | — 3.3957 | .3940 | — 3.3948 |
| 3 | —32.4044 | .4030 | —32.4037 | —17.9840 | .9844 | —17.9842 |
| 4 | —30.6587 | .6538 | —30.6562 | —35.0679 | .0660 | —35.0670 |
| 5 | —21.5902 | .5939 | —21.5920 | +28.9642 | .9662 | +28.9652 |
| 6 | —17.4130 | .4134 | —17.4132 | +14.2124 | .2157 | +14.2141 |
| 7 | —14.6935 | .6974 | —14.6954 | —19.0312 | .0342 | —19.0327 |
| 8 | —10.5682 | .5685 | —10.5684 | +14.9584 | .9602 | +14.9593 |
| 10 | — 9.6864 | .6859 | — 9.6862 | — 7.0159 | .0138 | — 7.0148 |
| 11 | — 8.8284 | .8312 | — 8.8298 | —12.7523 | .7510 | —12.7517 |
| 14 | — 0.1866 | .1878 | — 0.1872 | +20.9390 | .9420 | +20.9405 |
| 15 | 0.0000 | .0000 | 0.0000 | 0.0000 | .0000 | 0.0000 |
| 16 | + 0.8979 | .8959 | + 0.8969 | —34.2431 | .2410 | —34.2420 |
| 17 | + 2.3194 | .3190 | + 2.3192 | —16.1527 | .1504 | —16.1516 |
| 18 | + 3.8596 | .8590 | + 3.8593 | —15.3089 | .3060 | —15.3074 |
| 20 | + 4.2056 | .2076 | + 4.2066 | —16.0852 | .0818 | —16.0835 |
| 22 | + 6.1663 | .1653 | + 6.1658 | +15.6676 | .6737 | +15.6706 |
| 23 | + 7.5299 | .5297 | + 7.5298 | +13.1907 | .1931 | +13.1919 |
| 23A | + 8.5566 | .5554 | + 8.5560 | +14.7819 | .7820 | +14.7820 |
| 24 | + 9.6504 | .6490 | + 9.6497 | —16.6740 | .6688 | —16.6714 |
| 25 | +10.2314 | .2295 | +10.2305 | — 6.1371 | .1310 | — 6.1340 |
| 26 | +10.3361 | .3369 | +10.3365 | —29.1205 | .1154 | —29.1180 |
| 27 | +10.6036 | .6032 | +10.6034 | — 7.2689 | .2712 | — 7.2700 |
| 28 | +10.8441 | .8452 | +10.8447 | + 3.9637 | .9659 | + 3.9648 |
| 29 | +11.4440 | .4462 | +11.4451 | +27.5865 | .5912 | +27.5888 |
| 31 | +12.0134 | .0165 | +12.0150 | —15.7675 | .7700 | —15.7688 |
| 32 | +13.8892 | .8889 | +13.8891 | —39.6008 | .6048 | —39.6028 |
| 33 | +15.5390 | .5422 | +15.5406 | —37.2750 | .2731 | —37.2740 |
| 34 | +16.2035 | .2034 | +16.2034 | — 3.8514 | .8503 | — 3.8508 |
| 35 | +18.2207 | .2234 | +18.2221 | +33.4219 | .4217 | +33.4218 |
| 36 | +19.6910 | .6868 | +19.6889 | +10.8652 | .8620 | +10.8636 |
| 37 | +19.8112 | .8124 | +19.8118 | —13.2630 | .2656 | —13.2643 |
| 39 | +24.1897 | .1879 | +24.1888 | +10.0472 | .0462 | +10.0467 |
| 40 | +25.9978 | .0012 | +25.9995 | —34.9216 | .9212 | —34.9214 |
| 43 | +33.9138 | .9114 | +33.9126 | + 6.9199 | .9170 | + 6.9184 |
| 44 | +34.4648 | .4650 | +34.4649 | +26.3452 | .3448 | +26.3450 |
| 45 | +38.7302 | .7281 | +38.7292 | —24.5248 | .5266 | —24.5257 |

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE IV.

| Star. | $x$ | | | $y$ | | |
|---|---|---|---|---|---|---|
| | Direct. | Rev'd. | Mean. | Direct. | Rev'd. | Mean. |
| 1 | —34.5081 | .5005 | —34.5043 | +15.6765 | .6747 | +15.6756 |
| 2 | —33.5014 | .4986 | —33.5000 | — 3.4249 | .4234 | — 3.4241 |
| 3 | —32.3816 | .3810 | —32.3813 | —18.0095 | .0107 | —18.0101 |
| 4 | —30.6188 | .6162 | —30.6175 | —35.0890 | .0904 | —35.0897 |
| 5 | —21.6262 | .6230 | —21.6246 | +28.9437 | .9424 | +28.9430 |
| 6 | —17.4268 | .4245 | —17.4256 | +14.1982 | .2015 | +14.1999 |
| 7 | —14.6724 | .6690 | —14.6707 | —19.0377 | .0411 | —19.0394 |
| 7A | —10.5836 | .5818 | —10.5827 | — 3.7664 | .7693 | — 3.7678 |
| 8 | —10.5906 | .5902 | —10.5904 | +14.9470 | .9494 | +14.9482 |
| 10 | — 9.6824 | .6814 | — 9.6819 | — 7.0229 | .0209 | — 7.0219 |
| 11 | — 8.8172 | .8155 | — 8.8164 | —12.7601 | .7583 | —12.7592 |
| 14 | — 0.2114 | .2107 | — 0.2110 | +20.9386 | .9403 | +20.9394 |
| 15 | 0.0000 | .0000 | 0.0000 | 0.0000 | .0000 | 0.0000 |
| 16 | + 0.9326 | .9340 | + 0.9333 | —34.2394 | .2372 | —34.2383 |
| 17 | + 2.3349 | .3362 | + 2.3356 | —16.1490 | .1489 | —16.1490 |
| 18 | + 3.8712 | .8732 | + 3.8722 | —15.3017 | .3015 | —15.3016 |
| 19 | + 3.8816 | .8832 | + 3.8824 | +25.8905 | .8886 | +25.8896 |
| 20 | + 4.2190 | .2192 | + 4.2191 | —16.0778 | .0775 | —16.0777 |
| 22 | + 6.1440 | .1465 | + 6.1452 | +15.6732 | .6741 | +15.6737 |
| 23 | + 7.5157 | .5178 | + 7.5168 | +13.1976 | .1967 | +13.1971 |
| 23A | + 8.5374 | .5399 | + 8.5387 | +14.7866 | .7864 | +14.7865 |
| 24 | + 9.6622 | .6640 | + 9.6631 | —16.6652 | .6606 | —16.6629 |
| 25 | +10.2376 | .2372 | +10.2374 | — 6.1234 | .1220 | — 6.1227 |
| 26 | +10.3627 | .3652 | +10.3639 | —29.1068 | .1060 | —29.1064 |
| 27 | +10.6071 | .6077 | +10.6074 | — 7.2612 | .2614 | — 7.2613 |
| 28 | +10.8355 | .8374 | +10.8364 | + 3.9759 | .9771 | + 3.9765 |
| 29 | +11.4120 | .4129 | +11.4124 | +27.5930 | .5960 | +27.5945 |
| 31 | +12.0288 | .0305 | +12.0297 | —15.7623 | .7610 | —15.7616 |
| 32 | +13.9279 | .9289 | +13.9284 | —39.5870 | .5883 | —39.5876 |
| 33 | +15.5832 | .5771 | +15.5802 | —37.2559 | .2551 | —37.2555 |
| 34 | +16.2028 | .2030 | +16.2029 | — 3.8344 | .8350 | — 3.8347 |
| 35 | +18.1752 | .1798 | +18.1775 | +33.4338 | .4318 | +33.4328 |
| 36 | +19.6722 | .6738 | +19.6730 | +10.8808 | .8800 | +10.8804 |
| 37 | +19.8242 | .8250 | +19.8246 | —13.2450 | .2459 | —13.2454 |
| 38 | +23.4288 | .4324 | +23.4306 | + 3.7647 | .7636 | + 3.7642 |
| 39 | +24.1717 | .1728 | +24.1722 | +10.0655 | .0655 | +10.0655 |
| 40 | +26.0288 | .0312 | +26.0300 | —34.8968 | .8938 | —34.8953 |
| 43 | +33.8955 | .8986 | +33.8970 | + 6.9446 | .9455 | + 6.9450 |
| 44 | +34.4188 | .4232 | +34.4210 | +26.3714 | .3697 | +26.3706 |
| 45 | +38.7495 | .7503 | +38.7499 | —24.4909 | .4900 | —24.4904 |

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE V.

| Star. | x | | | y | | |
|---|---|---|---|---|---|---|
| | Direct. | Rev'd. | Mean. | Direct. | Rev'd. | Mean. |
| 1 | —34.4912 | .4900 | —34.4906 | +15.7164 | .7130 | +15.7147 |
| 2 | —33.5065 | .5062 | —33.5064 | — 3.3860 | .3897 | — 3.3878 |
| 3 | —32.4083 | .4072 | —32.4077 | —17.9751 | .9772 | —17.9762 |
| 4 | —30.6656 | .6644 | —30.6650 | —35.0600 | .0620 | —35.0610 |
| 5 | —21.5824 | .5810 | —21.5817 | +28.9692 | .9680 | +28.9686 |
| 6 | —17.4077 | .4090 | —17.4084 | +14.2193 | .2187 | +14.2190 |
| 7 | —14.6985 | .6980 | —14.6982 | —19.0254 | .0321 | —19.0288 |
| 8 | —10.5690 | .5682 | —10.5686 | +14.9581 | .9598 | +14.9589 |
| 10 | — 9.6874 | .6894 | — 9.6884 | — 7.0102 | .0116 | — 7.0109 |
| 11 | — 8.8342 | .8320 | — 8.8331 | —12.7484 | .7500 | —12.7492 |
| 14 | — 0.1788 | .1805 | — 0.1797 | +20.9386 | .9374 | +20.9380 |
| 15 | 0.0000 | .0000 | 0.0000 | 0.0000 | .0000 | 0.0000 |
| 16 | + 0.8868 | .8872 | + 0.8870 | —34.2418 | .2394 | —34.2406 |
| 17 | + 2.3130 | .3152 | + 2.3141 | —16.1528 | .1520 | —16.1524 |
| 18 | + 3.8581 | .8571 | + 3.8576 | —15.3042 | .3044 | —15.3043 |
| 19 | + 3.9180 | .9201 | + 3.9190 | +25.8858 | .8814 | +25.8836 |
| 20 | + 4.2016 | .2034 | + 4.2025 | —16.0850 | .0826 | —16.0838 |
| 22 | + 6.1697 | .1684 | + 6.1690 | +15.6671 | .6672 | +15.6672 |
| 23 | + 7.5392 | .5374 | + 7.5383 | +13.1906 | .1916 | +13.1911 |
| 23A | + 8.5584 | .5599 | + 8.5592 | +14.7780 | .7756 | +14.7768 |
| 24 | + 9.6428 | .6431 | + 9.6429 | —16.6726 | .6745 | —16.6736 |
| 25 | +10.2291 | .2308 | +10.2299 | — 6.1376 | .1352 | — 6.1364 |
| 26 | +10.3236 | .3257 | +10.3246 | —29.1198 | .1210 | —29.1204 |
| 27 | +10.6022 | .6037 | +10.6030 | — 7.2723 | .2700 | — 7.2711 |
| 28 | +10.8461 | .8451 | +10.8456 | + 3.9626 | .9622 | + 3.9624 |
| 29 | +11.4492 | .4498 | +11.4495 | +27.5812 | .5812 | +27.5812 |
| 31 | +12.0096 | .0100 | +12.0098 | —15.7728 | .7723 | —15.7726 |
| 32 | +13.8710 | .8778 | +13.8744 | —39.6013 | .6038 | —39.6025 |
| 34 | +16.1957 | .1977 | +16.1967 | — 3.8561 | .8526 | — 3.8543 |
| 35 | +18.2316 | .2267 | +18.2292 | +33.4117 | .4098 | +33.4108 |
| 37 | +19.8083 | .8070 | +19.8077 | —13.2664 | .2697 | —13.2680 |
| 39 | +24.1869 | .1882 | +24.1876 | +10.0364 | .0376 | +10.0370 |
| 40 | +25.9806 | .9837 | +25.9822 | —34.9250 | .9260 | —34.9255 |
| 43 | +33.9056 | .9072 | +33.9064 | + 6.9073 | .9062 | + 6.9068 |
| 44 | +34.4653 | .4661 | +34.4657 | +26.3334 | .3336 | +26.3335 |
| 45 | +38.7196 | .7170 | +38.7183 | —24.5324 | .5328 | —24.5326 |

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE VII.

| Star. | $x$ | | | $y$ | | |
|---|---|---|---|---|---|---|
| | Direct. | Rev'd. | Mean. | Direct. | Rev'd. | Mean. |
| 1 | —34.4817 | .4843 | —34.4830 | +15.7221 | .7231 | +15.7226 |
| 2 | —33.5043 | .5043 | —33.5043 | — 3.3759 | .3763 | — 3.3761 |
| 3 | —32.4086 | .4100 | —32.4093 | —17.9669 | .9658 | —17.9664 |
| 4 | —30.6694 | .6673 | —30.6684 | —35.0474 | .0472 | —35.0473 |
| 5 | —21.5742 | .5714 | —21.5728 | +28.9724 | .9737 | +28.9730 |
| 6 | —17.4069 | .4056 | —17.4062 | +14.2230 | .2216 | +14.2223 |
| 7 | —14.7014 | .7022 | —14.7018 | —19.0236 | .0206 | —19.0221 |
| 7A | —10.5922 | .5894 | —10.5908 | — 3.7542 | .7547 | — 3.7545 |
| 8 | —10.5673 | .5687 | —10.5680 | +14.9603 | .9586 | +14.9595 |
| 10 | — 9.6920 | .6904 | — 9.6912 | — 7.0050 | .0060 | — 7.0055 |
| 11 | — 8.8388 | .8402 | — 8.8395 | —12.7439 | .7446 | —12.7443 |
| 14 | — 0.1793 | .1816 | — 0.1805 | +20.9396 | .9388 | +20.9392 |
| 15 | 0.0000 | .0000 | 0.0000 | 0.0000 | .0000 | 0.0000 |
| 16 | + 0.8806 | .8805 | + 0.8806 | —34.2354 | .2364 | —34.2359 |
| 17 | + 2.3125 | .3090 | + 2.3108 | —16.1506 | .1493 | —16.1500 |
| 18 | + 3.8524 | .8514 | + 3.8519 | —15.3052 | .3057 | —15.3054 |
| 19 | + 3.9198 | .9222 | + 3.9210 | +25.8832 | .8854 | +25.8843 |
| 20 | + 4.1979 | .1962 | + 4.1971 | —16.0844 | .0854 | —16.0849 |
| 21 | + 4.7178 | .7213 | + 4.7196 | +24.3594 | .3554 | +24.3574 |
| 22 | + 6.1656 | .1624 | + 6.1640 | +15.6664 | .6633 | +15.6648 |
| 23 | + 7.5330 | .5340 | + 7.5335 | +13.1890 | .1872 | +13.1881 |
| 23A | + 8.5558 | .5590 | + 8.5574 | +14.7731 | .7745 | +14.7738 |
| 24 | + 9.6320 | .6332 | + 9.6326 | —16.6755 | .6736 | —16.6745 |
| 25 | +10.2276 | .2252 | +10.2264 | — 6.1370 | .1348 | — 6.1359 |
| 26 | +10.3185 | .3214 | +10.3199 | —29.1174 | .1180 | —29.1177 |
| 27 | +10.5986 | .5979 | +10.5982 | — 7.2726 | .2710 | — 7.2718 |
| 28 | +10.8415 | .8406 | +10.8410 | + 3.9608 | .9590 | + 3.9599 |
| 29 | +11.4500 | .4474 | +11.4487 | +27.5814 | .5797 | +27.5806 |
| 31 | +12.0062 | .0064 | +12.0063 | —15.7710 | .7727 | —15.7718 |
| 32 | +13.8671 | .8658 | +13.8664 | —39.6006 | .6022 | —39.6014 |
| 33 | +15.5207 | .5220 | +15.5214 | —37.2730 | .2721 | —37.2726 |
| 34 | +16.1972 | .1980 | +16.1976 | — 3.8560 | .8536 | — 3.8548 |
| 35 | +18.2277 | .2290 | +18.2284 | +33.4081 | .4088 | +33.4084 |
| 36 | +19.6808 | .6854 | +19.6831 | +10.8540 | .8588 | +10.8564 |
| 37 | +19.8020 | .8021 | +19.8020 | —13.2730 | .2723 | —13.2726 |
| 38 | +23.4334 | .4379 | +23.4356 | + 3.7330 | .7316 | + 3.7323 |
| 39 | +24.1835 | .1831 | +24.1833 | +10.0310 | .0340 | +10.0325 |
| 40 | +25.9716 | .9742 | +25.9729 | —34.9286 | .9282 | —34.9284 |
| 41 | +30.0359 | .0402 | +30.0381 | — 7.5610 | .5599 | — 7.5605 |
| 42 | +32.0193 | .0197 | +32.0195 | — 7.6587 | .6003 | — 7.6595 |
| 43 | +33.9009 | .9016 | +33.9012 | + 6.8994 | .9014 | + 6.9004 |
| 44 | +34.4624 | .4636 | +34.4630 | +26.3208 | .3246 | +26.3227 |
| 45 | +38.7094 | .7085 | +38.7090 | —24.5388 | .5361 | —24.5374 |

TABLE V.—(*Continued.*) CORRECTED COÖRDINATES. PLATE VIII.

| Star. | $x$ | | | $y$ | | |
|---|---|---|---|---|---|---|
| | Direct. | Rev'd. | Mean. | Direct. | Rev'd. | Mean. |
| 1 | —34.4857 | .4866 | —34.4862 | +15.7100 | .7124 | +15.7112 |
| 2 | —33.5032 | .5024 | —33.5028 | — 3.3848 | .3846 | — 3.3847 |
| 3 | —32.4060 | .4011 | —32.4036 | —17.9734 | .9738 | —17.9736 |
| 4 | —30.6600 | .6560 | —30.6580 | —35.0517 | .0524 | —35.0520 |
| 5 | —21.5811 | .5808 | —21.5809 | +28.9670 | .9680 | +28.9675 |
| 6 | —17.4127 | .4101 | —17.4114 | +14.2171 | .2192 | +14.2182 |
| 7 | —14.6976 | .6944 | —14.6960 | —19.0253 | .0251 | —19.0252 |
| 7A | —10.5962 | .5969 | —10.5966 | — 3.7603 | .7626 | — 3.7615 |
| 8 | —10.5749 | .5718 | —10.5733 | +14.9556 | .9570 | +14.9563 |
| 10 | — 9.6885 | .6880 | — 9.6882 | — 7.0098 | .0096 | — 7.0097 |
| 11 | — 8.8362 | .8352 | — 8.8357 | —12.7488 | .7488 | —12.7488 |
| 14 | — 0.1844 | .1852 | — 0.1848 | +20.9374 | .9392 | +20.9383 |
| 15 | 0.0000 | .0000 | 0.0000 | 0.0000 | .0000 | 0.0000 |
| 16 | + 0.8857 | .8885 | + 0.8871 | —34.2371 | .2353 | —34.2362 |
| 17 | + 2.3126 | .3134 | + 2.3130 | —16.1488 | .1500 | —16.1494 |
| 18 | + 3.8562 | .8560 | + 3.8561 | —15.3028 | .3060 | —15.3044 |
| 19 | + 3.9104 | .9097 | + 3.9100 | +25.8812 | .8832 | +25.8822 |
| 20 | + 4.2000 | .2031 | + 4.2016 | —16.0818 | .0820 | —16 0819 |
| 22 | + 6.1610 | .1636 | + 6.1623 | +15.6656 | .6687 | +15.6672 |
| 23 | + 7.5284 | .5337 | + 7.5310 | +13.1874 | .1886 | +13 1880 |
| 23A | + 8.5506 | .5521 | + 8.5513 | + 14.7729 | .7760 | +14.7744 |
| 24 | + 9.6418 | .6438 | + 9.6428 | —16.6723 | .6726 | —16.6724 |
| 25 | +10.2268 | .2256 | +10.2262 | — 6.1372 | .1347 | — 6.1360 |
| 26 | +10.3278 | .3292 | +10.3285 | —29.1152 | .1163 | —29.1158 |
| 27 | +10.5974 | .5974 | +10.5974 | — 7.2728 | .2689 | — 7.2708 |
| 28 | +10.8416 | .8408 | +10.8412 | + 3.9608 | .9648 | + 3.9628 |
| 29 | +11.4424 | .4426 | +11.4425 | +27.5784 | .5800 | +27.5792 |
| 31 | +12.0110 | .0137 | +12.0124 | —15.7707 | .7748 | —15.7727 |
| 32 | +13.8756 | .8780 | +13.8768 | —39.6012 | .6014 | —39.6013 |
| 33 | +15.5298 | .5320 | +15.5309 | —37.2751 | .2712 | —37.2732 |
| 34 | +16.1969 | .1962 | +16.1966 | — 3.8543 | .8544 | — 3.8544 |
| 35 | +18.2171 | .2166 | +18.2168 | +33.4060 | .4086 | +33.4073 |
| 36 | +19.6751 | .6778 | +19.6764 | +10.8545 | .8562 | +10.8554 |
| 37 | +19.8014 | .8057 | +19.8035 | —13.2662 | .2670 | —13.2666 |
| 38 | +23.4306 | .4318 | +23.4312 | + 3.7362 | .7382 | + 3.7372 |
| 39 | +24.1790 | .1761 | +24.1776 | +10.0346 | .0351 | +10.0348 |
| 40 | +25.9807 | .9800 | +25.9804 | —34.9247 | .9232 | —34.9240 |
| 41 | +30.0339 | .0342 | +30.0340 | — 7.5534 | .5538 | — 7.5536 |
| 42 | +32.0097 | .0144 | +32.0120 | — 7.6577 | .6576 | — 7.6576 |
| 43 | +33.8966 | .8960 | +33.8963 | + 6.9064 | .9093 | + 6.9079 |
| 44 | +34.4516 | .4494 | +34.4505 | +26.3255 | .3264 | +26.3259 |
| 45 | +38.7120 | .7129 | +38.7124 | —24.5322 | .5326 | —24.5324 |

TABLE V.—(*Concluded.*) CORRECTED COÖRDINATES. PLATE IX.

| Star. | $x$ | | | $y$ | | |
|---|---|---|---|---|---|---|
| | Direct. | Rev'd. | Mean. | Direct. | Rev'd. | Mean |
| 1 | —34.4800 | .4842 | —34.4821 | +15.7316 | .7334 | +15.7325 |
| 2 | —33.5050 | .5025 | —33.5037 | — 3.3680 | .3664 | — 3.3672 |
| 3 | —32.4120 | .4079 | —32.4100 | —17.9574 | .9570 | —17.9572 |
| 4 | —30.6766 | .6746 | —30 6756 | —35.0392 | .0384 | —35.0388 |
| 5 | —21.5667 | .5659 | —21.5663 | +28.9755 | .9802 | +28.9778 |
| 6 | —17.4034 | .4030 | —17.4032 | +14 2269 | .2304 | +14.2286 |
| 7 | —14.7092 | .7056 | —14.7074 | —19.0220 | .0194 | —19.0208 |
| 8 | —10.5617 | .5612 | —10.5614 | +14.9613 | .9682 | +14.9648 |
| 10 | — 9.6866 | .6860 | — 9.6863 | — 7.0064 | .0018 | — 7.0041 |
| 11 | — 8.8444 | .8424 | — 8.8434 | —12.7406 | .7372 | —12.7389 |
| 14 | — 0.1718 | .1718 | — 0.1718 | +20.9388 | .9407 | +20 9397 |
| 15 | 0.0000 | .0000 | 0.0000 | 0.0000 | .0000 | 0.0000 |
| 16 | + 0.8652 | .8684 | + 0.8668 | —34.2368 | .2330 | —34.2349 |
| 17 | + 2.3019 | .3048 | + 2.3033 | —16.1486 | .1504 | —16.1495 |
| 18 | + 3.8459 | .8481 | + 3.8470 | —15.3053 | .3054 | —15.3054 |
| 20 | + 4.1952 | .1981 | + 4.1966 | —16.0804 | .0809 | —16.0807 |
| 22 | + 6.1756 | .1759 | + 6.1758 | +15.6626 | .6655 | +15.6640 |
| 23 | + 7.5408 | .5429 | + 7.5418 | +13.1893 | .1902 | +13.1898 |
| 23A | + 8.5656 | .5620 | + 8.5638 | +14.7698 | .7735 | +14.7716 |
| 24 | + 9.6386 | 6369 | + 9.6378 | —16.6742 | .6750 | —16 6746 |
| 25 | +10.2299 | .2300 | +10.2300 | — 6.1412 | .1352 | — 6.1382 |
| 26 | +10.3108 | .3114 | +10.3111 | —29.1168 | .1175 | —29.1171 |
| 27 | +10.5979 | .5991 | +10.5985 | — 7.2740 | .2707 | — 7.2724 |
| 28 | +10.8479 | .8466 | +10.8473 | + 3.9552 | .9610 | + 3.9581 |
| 29 | +11.4602 | .4605 | +11.4603 | +27.5766 | .5815 | +27.5790 |
| 31 | +12.0046 | .0050 | +12.0048 | —15.7726 | .7764 | —15.7745 |
| 32 | +13 8562 | .8568 | +13.8565 | —39.6046 | .6040 | —39.6043 |
| 33 | +15.5071 | .5086 | +15.5079 | —37.2773 | .2739 | —37.2756 |
| 34 | +16.1936 | .1964 | +16.1950 | — 3.8618 | .8610 | — 3.8614 |
| 35 | +18.2386 | .2367 | +18.2376 | +33.4038 | .4042 | +33.4040 |
| 36 | +19.6886 | .6863 | +19.6875 | +10.8493 | .8510 | +10.8502 |
| 37 | +19.7985 | .8004 | +19.7994 | —13.2732 | .2738 | —13.2735 |
| 38 | +23.4416 | .4410 | +23.4413 | + 3.7287 | .7290 | + 3.7289 |
| 39 | +24.1886 | .1881 | +24.1884 | +10.0280 | .0287 | +10.0284 |
| 40 | +25 9634 | .9639 | +25.9637 | —34.9383 | .9338 | —34.9360 |
| 43 | +33.9029 | .9006 | +33.9018 | + 6.8892 | .8907 | + 6.8899 |
| 44 | +34.4765 | .4747 | +34.4756 | +26.3112 | .3123 | +26.3117 |
| 45 | +38.7025 | .7012 | +38.7018 | —24.5497 | .5502 | —24.5499 |

IV.

## Method of Reduction.

The measured coördinates having been cleared of instrumental errors, it remains to convert them into right ascensions and declinations. For this purpose the following constants must be known for each plate:

1°. The right ascension of the centre of the plate, in this case the central star 15.

2°. The declination of the same star.

3°. The scale-value, or the number of seconds corresponding to one space on the scale.

4°. The orientation correction, or the angle through which we must rotate the coördinate axes in order that they may point respectively in the directions of a parallel of declination and a circle of declination through the central star.

The first plan that suggested itself for determining these constants was to employ the two existing heliometer researches upon the group. In 1856 to 1858 Professor Winnecke of Bonn measured the position angles and distances of forty-four stars from the central star 15; and in 1889 to 1892 Professor Schur of Göttingen triangulated thirty-eight stars and derived the places of seven more by measuring the position angles and distances from stars in the triangulation. The results of both researches were published in one volume by Professor Schur, part IV of the "Astronomische Mittheilungen von der K. Sternwarte zu Göttingen." The stars whose positions are there given include almost all those appearing on the photographs, and consequently very accurate values of the four constants could be obtained by comparing the measured coördinates of a large number of stars with their heliometer places. Another plan is to determine the constants by comparison with meridian observations. While this is not as accurate as the preceding, it has the advantage of being independent of the heliometer results, thus rendering a comparison with the latter more instructive.

The course that I have actually pursued is this: the constants were first determined for each plate separately by comparing the coördinates of some of the stars with meridian observations. For a star which appears on all the plates we have thus eight determinations of its right ascension, and eight of its declination, and a catalogue of the group may now be formed by taking the means. Finally a least square solution was made to determine how much the constants would have to be changed on the average, so as to secure the best possible agreement with the heliometer places. It is evident that if we now apply to our catalogue positions the corrections which result from these average changes in the constants we shall obtain the same results as though we had used the heliometer places to determine the constants for the separate plates, and had then taken the means.

The meridian observations used are those quoted by Professor Schur in the work mentioned above; they were used by him to help fix the place of his triangulation in the sky. Five stars were observed, the central star and four others distributed symmetrically over the plate; they are admirably fitted for our purpose, being at sufficiently large distances from the central star to insure accurate determinations of the scale-value and orientation, and yet not so distant as to have their photographic images much distorted. Their magnitudes are such that they appear on all of the plates with good images. The stars were observed both at Berlin and Göttingen;* the positions obtained at the former observatory and reduced to the A. G. catalogue system are as follows:

| Star. | Epoch. | Equinox of 1890.0. | |
|---|---|---|---|
| 4 | 1890.26 | $8^h31^m28.^s444$, | $+19°39'00''.65$ |
| 5 | .51 | 32 02. 359 | 20 35 28 .43 |
| 15 | .26 | 33 23. 463 | 20 09 55 .38 |
| 40 | .51 | 35 00. 573 | 19 39 04 .35 |
| 44 | .26 | 35 33. 417 | 20 33 03 .28 |

Each star was observed four times, and the probable error of a single observation is given as

$\pm 0.^s012$ in right ascension,
$\pm 0.''25$ in declination.

At Göttingen each star was observed six times with these results:

* "Astronomische Mittheilungen von der K. Sternwarte zu Göttingen," Part IV, pages 139 et seq.

| Star. | Epoch. | Equinox of 1890.0. | |
|---|---|---|---|
| 4 | 1891.52 | $8^h31^m$ 28.425, | +19°38′59″.83 |
| 5 | .37 | 32 02.388 | 20 35 27 .75 |
| 15 | .55 | 33 23.462 | 20 09 55 .52 |
| 40 | .89 | 35 00.607 | 19 39 04 .03 |
| 44 | .89 | 35 33.447 | 20 33 03 .40 |

Giving these observations the weight $\frac{1}{3}$, and those at Berlin the weight unity, as was done by Professor Schur, we get finally:

| Star. | Epoch. | Equinox of 1890 o. | |
|---|---|---|---|
| 4 | 1890.58 | $8^h31^m$ 28.440, | +19 39′00″.45 |
| 5 | .72 | 32 02.366 | 20 35 28 .26 |
| 15 | .58 | 33 23.463 | 20 09 55 .42 |
| 40 | .86 | 35 00.582 | 19 39 04 .27 |
| 44 | .67 | 35 33.425 | 20 33 03 .31 |

As the epochs of these observations are from thirteen to twenty years later than the dates of our plates, it is necessary to apply proper motions, for which the following values have been adopted:

| | | |
|---|---|---|
| 4 | —0.$^s$0054 | +0″.007 |
| 5 | —0. 0005 | +0 .038 |
| 15 | —0. 0049 | +0 .017 |
| 40 | —0. 0040 | +0 .011 |
| 44 | —0. 0044 | +0 .015 |

These are the values given by Professor Schur in his catalogue of the group, but they are not derived directly from a comparison of his places with those of Winnecke. Systematic corrections have been added to make the proper motion of the group as a whole conform with observations by Bradley and by Tobias Mayer; these corrections are:

—0.$^s$0003 +0″.039.

The necessity for such a large correction in declination is accounted for by Professor Schur, by assuming that either in the Bonn or in the Göttingen observations, or perhaps in both, the declination of the group as a whole was incorrectly determined; we shall have occasion to refer to this circumstance later.

The plates were taken at practically only two dates, 1870.3 and 1877.3; applying the corresponding proper motions to the meridian observations and reducing them to the equinox of 1875.0, we get:

For Plates I, II, III and IV,

| | $\Delta\alpha$ | $\Delta\delta$ |
|---|---|---|
| 4 | —1723″.34 | —1856″.74 |
| 5 | —1220 .23 | +1531 .02 |
| 15 | 0 | 0 |
| 40 | +1459 .38 | —1849 .36 |
| 44 | +1948 .13 | +1390 .16 |
| | $\alpha_0$ | $\delta_0$ |
| 15 | 128°07′55″.26 | +20°13′01″.26 |

For Plates V, VII, VIII and IX,

| | $\Delta\alpha$ | $\Delta\delta$ |
|---|---|---|
| 4 | —1723″.40 | —1856″.81 |
| 5 | —1219 .75 | +1531 .17 |
| 15 | 0 | 0 |
| 40 | +1459 .48 | —1849 .40 |
| 44 | +1948 .19 | +1390 .15 |
| | $\alpha_0$ | $\delta_0$ |
| 15 | 128°07′51″.75 | +20°13′01″.38 |

$\Delta\alpha$ and $\Delta\delta$ are obtained by subtracting the right ascension and declination of Star 15 from those of the five comparison stars.

The numerical work in the problem before us, namely, to determine the constants of the plates, will be greatly decreased by first assuming an approximate scale-value and then determining how much this is in error. Such an approximate value is furnished by the reduction of Rutherfurd's photographs of the Pleiades where it was found that

$$1 \text{ millimetre} = 52.''87$$

Let us suppose that this scale-value has been applied to the measured coördinates $x$ and $y$ of each of the comparison stars, giving $X$ and $Y$; then the quantities $X$ sec $\delta_0$ and $Y$ will be nearly equal to the corresponding $\Delta\alpha$ and $\Delta\delta$ respectively. The causes of difference are the following:

*a. Transformation Corrections* (see below), *Refraction*, *Precession*, etc.

*b. Orientation*, use of incorrect *scale-value*, etc.

*c. Errors of observation*, both in the measured coördinates and in the meridian places.

Let us first consider the causes of difference under *a*; we shall then determine the orientation, true scale-value etc., by comparing the corrected coördinates with the corresponding values of $\Delta\alpha$

and $\Delta\delta$, eliminating the errors of observation as far as possible by means of a least-square solution.

## I. Transformation Corrections.

An astronomical photograph may be regarded as a central projection of a portion of the celestial sphere upon a tangent plane. The point on the plate which corresponds to the point of tangency is the foot of the perpendicular let fall from the optical centre of the object glass upon the plane of the plate. The rigorous relations between the rectilinear coördinates referred to this point as origin, and the right ascension and declination of a star, were given in simple form by Professor Turner in Vol. XVI, of "Observatory," page 374. Previous to this, however, Ball and Rambaut gave these relations in the form of series in their paper "On the Relative Positions of 223 stars in $\chi$ Persei," Transactions of the Royal Irish Academy, Vol. XXX, page 247. In our notation these formulas would be

$$\begin{aligned} \Delta\alpha - X\sec\delta_0 &= (X\sec\delta_0)\,Y\tan\delta_0 - \tfrac{1}{3}(X\sec\delta_0)^3 + (X\sec\delta_0)\,Y\tan^2\delta_0 \\ \Delta\delta - Y &= -\tfrac{1}{4}(X\sec\delta_0)^2\sin 2\delta_0 - \tfrac{1}{3}Y^3 - \tfrac{1}{2}(X\sec\delta_0)^2\,Y \end{aligned}$$

The elegance of these formulas lies in the fact that the coefficients of the powers and products of $X$ and $Y$, are functions of $\delta_0$ only, and are therefore constant for a plate, or indeed for an entire zone. For most plates these series are sufficiently accurate, but when the declination or the measured coördinates are large they fail; in such cases we do not need to resort to the rigorous formulas but we have merely to extend the series to higher terms, as was done by Professor Jacoby in a review of a paper by Professor Donner, in the Vierteljahrschrift for 1895, page 114. In the same place, formulas are also given in which $\Delta\alpha$ and $\Delta\delta$ appear in the second members, instead of $X$ and $Y$ as above. Omitting terms of higher degree than the third, which is permissible for the Præsepe plates, these formulas may be written

$$\begin{aligned} \Delta\alpha - X\sec\delta_0 &= \Delta\alpha\cdot\Delta\delta\cdot\tan\delta_0 - \tfrac{1}{3}\Delta\alpha^3\left(1 - \tfrac{3}{2}\sin^2\delta_0\right) \\ \Delta\delta - Y &= -\tfrac{1}{4}\Delta\alpha^2\cdot\sin 2\delta_0 - \tfrac{1}{2}\Delta\alpha^2\cdot\Delta\delta\cdot\cos 2\delta_0 - \tfrac{1}{3}\Delta\delta^3 \end{aligned}$$

The use of these formulas presupposes a knowledge of the approximate values of $\Delta\alpha$ and $\Delta\delta$ for each star. They possess two points of advantage over the inverse forms: first, there is one term less in the expression for $\Delta\alpha - X\sec\delta_0$; and second, they give slightly more accurate values for the corrections as they do not involve errors of orientation, scale-value, etc., such as would be incurred through the use of the measured $X$ and $Y$ in the second members. I have therefore used the latter expressions for computing the transformation corrections given in Table VI, employing the heliometer values of $\Delta\alpha$ and $\Delta\delta$ given by Professor Schur. It will be remembered that Rutherfurd was careful to make the central star 15 coincide with the foot of the perpendicular let fall from the optical centre of the object glass upon the plane of the plate. As our measured coördinates are referred to this star as origin, Table VI applies equally to all the plates.

TABLE VI.—TRANSFORMATION CORRECTIONS.

| Star. | $\Delta\alpha - X \sec \delta_0$ | $\Delta\delta - Y$ | Star. | $\Delta\alpha - X \sec \delta_0$ | $\Delta\delta - Y$ |
|---|---|---|---|---|---|
| | ″ | ″ | | ″ | ″ |
| 1 | —2.83 | —3.01 | 24 | —0.85 | —0.22 |
| 2 | +0.66 | —2.80 | 25 | —0.34 | —0.26 |
| 3 | +3.15 | —2.58 | 26 | —1.60 | —0.23 |
| 4 | +5.75 | —2.23 | 27 | —0 41 | —0.28 |
| 5 | —3.33 | —1.22 | 28 | +0.23 | —0.29 |
| 6 | —1.31 | —0.77 | 29 | +1.68 | —0.36 |
| 7 | +1.49 | —0.52 | 31 | —1.01 | —0.35 |
| 7A | +0.21 | —0.27 | 32 | —2.92 | —0.39 |
| 8 | —0.84 | —0.29 | 33 | —3.08 | —0.53 |
| 10 | +0.36 | —0.23 | 34 | —0.34 | —0.65 |
| 11 | +0.60 | —0.19 | 35 | +3.24 | —0.89 |
| 14 | —0.02 | —0.01 | 36 | +1.13 | —0.98 |
| 15 | 0.00 | 0.00 | 37 | —1.41 | —0.97 |
| 16 | —0.16 | +0.05 | 38 | +0.45 | —1.38 |
| 17 | —0.20 | —0.01 | 39 | +1.28 | —1.47 |
| 18 | —0.31 | —0.03 | 40 | —4.84 | —1.59 |
| 19 | +0.54 | —0.06 | 41 | —1.24 | —2.24 |
| 20 | —0.36 | —0.04 | 42 | —1.35 | —2.54 |
| 22 | +0.51 | —0.10 | 43 | +1.19 | —2.89 |
| 23 | +0.53 | —0.15 | 44 | +4 79 | —3.05 |
| 23A | +0.67 | —0.18 | 45 | —5.12 | —3.66 |

## II. CORRECTIONS FOR REFRACTION.

Formulas for clearing rectangular coördinates of the effects of refraction were first published by Dr. Rambaut in the "Astronomische Nachrichten," No. 3125. Professor Turner has shown how these may be much simplified by employing the coördinates of the zenith as projected upon the plate.* His formulas, however, will not serve in the transformation of rectangular coördinates into right ascensions and declinations unless we apply an

* Monthly Notices, R.A.S., November, 1893.

extra correction for orientation. (See note at the end of this paper.) The formulas that I have preferred to use are those given by Professor Jacoby;* while these are not quite so simple as those of Professor Turner, they take into account the orientation correction mentioned. Let

$\varphi$ = the latitude, $+40^\circ 44'$ in this case.

$\theta - \alpha_0$ = the hour angle of the centre of the plate, from Table I.

$\delta_0$ = the declination of the centre, $+20^\circ 13'$

$\beta$ = the constant of refraction, computed in the usual way and then multiplied by $\frac{66}{65}$ to allow for the increased refrangibility of photographic rays.†

Now let us compute:

$$\begin{aligned} \tan N &= \cos(\theta - \alpha_0)\cot\varphi \\ G &= \cot(\delta_0 + N) \\ H &= \tan(\theta - \alpha_0)\sin N \operatorname{cosec}(\delta_0 + N) \\ M_x &= \beta(1 + H^2) \\ N_x &= \beta(G - \tan\delta_0) H \sec\delta_0 \\ M_y &= \beta(G + \tan\delta_0) H \cos\delta_0 \\ N_y &= \beta(1 + G^2) \end{aligned}$$

Then the corrections for refraction take the form:

$$\text{Correction for } X\sec\delta_0 = M_x \cdot X\sec\delta_0 + N_x \cdot Y$$
$$\text{“ \quad “ \quad } Y = M_y \cdot X\sec\delta_0 + N_y \cdot Y$$

The coefficients of $X \sec \delta_0$ and of $Y$ in the second members are constant for an entire plate. We may then construct Table VII, in which the number of the plate is the argument.

TABLE VII.—REFRACTION COEFFICIENTS.

| Plate. | $M_x$ | $N_x$ | $M_y$ | $N_y$ |
|---|---|---|---|---|
| I. | 0.000356 | 0.000017 | 0.000114 | 0.000349 |
| II. | 0.000423 | 0.000042 | 0.000174 | 0.000375 |
| III. | 0.000404 | 0.000031 | 0.000153 | 0.000373 |
| IV. | 0.000523 | 0.000086 | 0.000255 | 0.000424 |
| V. | 0.000357 | 0.000015 | 0.000110 | 0.000354 |
| VII. | 0.000423 | 0.000042 | 0.000174 | 0.000375 |
| VIII. | 0.000491 | 0.000074 | 0.000233 | 0.000404 |
| IX. | 0.000377 | 0.000023 | 0.000131 | 0.000360 |

All the coefficients are positive.

* Astronomical Journal, No. 387.

† Bulletin du Comité Permanent, I, 464; and Scheiner and Rambaut, Astron. Nach. 3255.

### III. Precession and Nutation.

These merely change the position of the axes to which the group is referred; it follows therefore that their *differential* effect upon $X$ and $Y$ is simply to rotate the coördinate axes through a small angle. When we determine the constants of a plate by comparing the measures of some of the stars with their true positions, it is evident that we need apply no corrections for precession and nutation to the measures of the comparison stars. Thus if we employ the places of the latter as referred to the equinox of 1875.0, then the value for the orientation which we shall get will include the necessary correction for precession and nutation. On the other hand, if we correct the places of the comparison stars for precession and nutation, then it would not only be necessary to apply the resulting orientation correction to the *other* stars, but we should also have to apply to them additional corrections for precession and nutation.

### IV. Aberration.

It was shown by Bessel* that aberration changes the position angles around a point equally, and changes the distances by a constant factor, no matter in what direction the distance is measured. Consequently, as in the case of precession and nutation, we need apply no correction for aberration to the measures of the comparison stars, since the resulting orientation and scale-value corrections will be appropriately modified to include its whole effect.

Thus we see that the coördinates of our five comparison stars need be corrected only for transformation and refraction. We must bear in mind, however, that the orientation and the scale-value which we shall then obtain are not the true values of these constants: the former must be corrected for precession, nutation and aberration, and the latter simply for aberration.

We are now ready to find the constants of the plates. Let

$p$ = the correction to the scale-value, so that the true scale-value is $52''.87\ (1 + p)$.

$r$ = the orientation correction, or the small angle through which the axes are to be rotated in the direction of decreasing position angles.

* "Astronomische Untersuchungen," Vol. I, page 207.

$k$ = the number of seconds of arc of a great circle through which the axes are to be translated in the direction of decreasing right ascensions.

$c$ = the number of seconds of arc of a great circle through which the axes are to be translated in the direction of decreasing declinations.

The corrections to the rectangular coördinates arising from $p$ are then:

$$\begin{array}{ll} \text{For } X, & +p \cdot X \\ \text{`` } Y, & +p \cdot Y \end{array}$$

On account of the orientation corrections, remembering that $r$ is small, we have the corrections:

$$\begin{array}{ll} \text{For } X, & +r \cdot Y \\ \text{`` } Y, & -r \cdot X \end{array}$$

Finally, $k$ and $c$ give the corrections:

$$\begin{array}{ll} \text{For } X, & +k \\ \text{`` } Y, & +c \end{array}$$

Combining all these corrections, we have:

$$\begin{array}{ll} \text{For } X, & +p \cdot X + r \cdot Y + k \\ \text{`` } Y, & +p \cdot Y - r \cdot X + c \end{array}$$

Let us now compute $n_x$ and $n_y$ for each comparison star, from the following equations:

$n_x \sec \delta_0 = X \sec \delta_0$ *plus* corrections for transformation and refraction, *minus* $\Delta\alpha$.

$n_y = Y$ *plus* corrections for transformation and refraction, *minus* $\Delta\delta$.

Then for each comparison star we have two equations of the following form from which to determine $p$, $r$, $k$ and $c$:

$$pX + rY + k + n_x = 0$$

$$pY - rX + c + n_y = 0$$

Owing to the way in which the coefficients of the unknowns are repeated in these equations we do not need to make the least square solution in the usual manner, but as Professor Jacoby has pointed out,* we may find the unknowns very simply. Thus, let $\nu$ = the number of comparison stars, and let us denote by square brackets the sum of $\nu$ quantities.

* Monthly Notices of the Royal Astronomical Society, May, 1896.

Put

$$A = [XX] + [YY] - \frac{1}{\nu}\,([X]^2 + [Y]^2)$$

$$C = [X \cdot n_x] + [Y \cdot n_y] - \frac{1}{\nu}\,([X][n_x] + [Y][n_y])$$

$$E = [Y \cdot n_x] - [X \cdot n_y] - \frac{1}{\nu}\,([Y][n_x] - [X][n_y])$$

Then we have:

$$p = -\frac{C}{A}, \text{ with the weight } A.$$

$$r = -\frac{E}{A}, \quad \text{“} \quad \text{“} \quad \text{“} \quad A.$$

$$k \quad -\frac{1}{\nu}([X]p + [Y]\,r + [n_x]), \text{ with the weight, } \nu - \frac{[X]^2 + [Y]^2}{[XX] + [YY]}$$

$$c = -\frac{1}{\nu}([Y]p - [X]\,r + [n_y]), \quad \text{“} \quad \text{“} \quad \text{“} \quad \nu - \frac{[X]^2 + [Y]^2}{[XX] + [YY]}$$

The following will be found a convenient check on the computations: the sum of the residuals for the right ascension equations is equal to zero, and similarly for the declination equations.*

The above method of solution is rendered still simpler in the present case, as we are going to use the same comparison stars for all the plates. Hence all the terms in the expressions for $A$, $C$ and $E$ are constant except those which involve $n_x$ or $n_y$. Thus, selecting the coördinates of the comparison stars from any plate in Table V, and multiplying them by 52.87 we have, with sufficient accuracy:

| | $X$ | $Y$ |
|---|---|---|
| 4 | —1620″ | —1850″ |
| 5 | —1140 | +1530 |
| 15 | 0 | 0 |
| 40 | +1370 | —1850 |
| 44 | +1820 | +1390 |

Consequently, for all the plates,

* This is indeed a general check for any set of observation equations in which one of the unknowns enters with a constant coefficient; if this unknown is missing from some of the equations, then the sum of the residuals for those equations in which it does appear is equal to zero. The theorem may be easily modified to include the case of unequal weights.

$$A = 20{,}080{,}000$$

$$C = [X \cdot n_x] + [Y \cdot n_y] - 86\,[n_x] + 156\,[n_y]$$

$$E = [Y \cdot n_x] - [X \cdot n_y] + 156\,[n_x] - 86\,[n_y]$$

$$p = -\frac{C}{20{,}080{,}000}\,; \text{ weight, } 20{,}080{,}000$$

$$r = -\frac{E}{20{,}080{,}000}\,; \quad \text{“} \quad 20{,}080{,}000$$

$$k = -86p + 156r - 0.20\,[n_x]\,; \text{ weight, } 4.96$$

$$c = +156p + 86r - 0.20\,[n_y]\,; \quad \text{“} \quad 4.96$$

It now remains to show how the right ascensions and declinations of all the stars may be computed. The constants of the plate give rise to the corrections:

$$\begin{array}{llll} \text{For } X \sec \delta_0, & +p \cdot X \sec \delta_0 & + r \sec \delta_0 \cdot Y & + k \sec \delta_0 \\ \text{“} \quad Y \quad , & +p \cdot Y & - r \cdot X & + c \end{array}$$

The corrections for refraction are:

$$\begin{array}{ll} \text{For } X \sec \delta_0, & + M_x \cdot X \sec \delta_0 + N_x \cdot Y \\ \text{“} \quad Y \quad , & + M_y \cdot X \sec \delta_0 + N_y \cdot Y \end{array}$$

We have still to add corrections for transformation, which vary from star to star, but are the same for different plates. Now let us define $a_1$ and $\delta_1$ as the *projected* right ascension and declination respectively of a star, the true right ascension and declination being given thus:

$a = a_1$ *plus* the correction for transformation.

$\delta = \delta_1$ *plus* the correction for transformation.

Then collecting the corrections given above:

$$\begin{array}{l} a_1 = (1 + p + M_x)\,X \sec \delta_0 + (N_x + r \sec \delta_0)\,Y + (a_0 + k \sec \delta_0) \\ \delta_1 = (1 + p + N_y)\,Y + (M_y - r \cos \delta_0)\,X \sec \delta_0 + (\delta_0 + c) \end{array}$$

Hence, to get the projected right ascension and declination of any star, the constants of the plate having been determined, we need only compute the six coefficients in the parentheses and perform the simple operations indicated. These coefficients, it is needless to remark, are constant for an entire plate.

As an example of the above methods I have set down the details of the computations for the constants of Plate VIII.

Right Ascensions.

| Star | 4 | 5 | 15 | 40 | 44 |
|---|---|---|---|---|---|
| $x$ : (Table V), | —30.6580 | —21.5809 | 0 | +25.9804 | +34.4505 |
| $X \sec \delta_0 = 52.87 \sec \delta_0 \cdot x$, | —1727.″31 | —1215.″89 | 0″ | +1463.″77 | +1940.″98 |
| $M_x \cdot X \sec \delta_0$ : (Tab. VII), | — 0.85 | — .60 | 0 | + 0.72 | + 0.95 |
| $N_x \cdot Y$ : (See below), | — 0.14 | + .12 | 0 | — 0.14 | + 0.11 |
| $\varDelta a - X \sec \delta_0$ : (Tab. VI), | + 5.75 | — 3.33 | 0 | — 4.84 | + 4.79 |
| $- \varDelta a$ : (Page 237), | +1723.40 | +1219.75 | 0 | —1459.48 | —1948.19 |
| $n_x \sec \delta_0$ : | + 0.85 | + 0.05 | 0 | + 0.03 | — 1.36 |
| $n_x$ : | + 0.80 | + 0.05 | 0 | + 0.03 | — 1.28 |

Declinations.

| Star. | 4 | 5 | 15 | 40 | 44 |
|---|---|---|---|---|---|
| $y$ : (Table V), | —35.0520 | +28.9675 | 0 | —34.9240 | +26.3259 |
| $Y = 52.87\, y$ : | —1853.″20 | +1531.″51 | 0″ | —1846.″43 | +1391.″85 |
| $N_y \cdot Y$ : (Table VII), | — 0.75 | + 0.62 | 0 | — 0.75 | + 0.56 |
| $N_x \cdot X \sec \delta_0$ : (See above), | — 0.40 | — 0.28 | 0 | + 0.34 | + 0.46 |
| $\varDelta\delta - Y$ : (Table VI), | — 2.23 | — 1.22 | 0 | — 1.59 | — 3.05 |
| $- \varDelta\delta$ : (Page 237), | +1856.81 | —1531.17 | 0 | +1849.40 | —1390.15 |
| $n_y$ : | + 0.23 | — 0.54 | 0 | + 0.97 | — 0.33 |

$$[X \cdot n_x] = -3650 \quad [Y \cdot n_x] = -3240 \quad [n_x] = -0''.40$$
$$[X \cdot n_y] = +980 \quad [Y \cdot n_y] = -3510 \quad [n_y] = +0''.33$$

$$p = +0.000352 \qquad \pm 0.000030$$
$$r = +0.000211 \qquad \pm 0.000030$$
$$k = +0.''08 \qquad \pm 0.''061$$
$$c = +0.''01 \qquad \pm 0.''061$$

Having found the constants, we may now proceed to get the right ascension and declination of each star on the plate. For this purpose we compute the coefficients :

For Right Ascensions. For Declinations.

$$52.87\,(1 + p + M_x) \sec \delta_0 = 56.3887 \qquad 52.87\,(1 + p + N_y) = 52.9100$$

$$N_x + r \sec \delta_0 = +0.000299 \qquad M_y - r \cos \delta_0 = +0.000035$$
$$a_0 + k \sec \delta_0 = 128°07'54''.84 \qquad \delta_0 + c = 20°13'01''.39$$

A slight change has been made in the two coefficients in the first line, our formulas requiring $(1+p+M_x)$ and $(1+p+N_y)$. This change, however, merely amounts to combining two multiplications into one; thus, instead of first computing $X \sec \delta_0$ and then multiplying this by $(1+p+M_x)$, we may apply the factor $52.87(1 + p + M_x) \sec \delta_0$ to $x$ directly. The formulas require that we know $X$ sec $\delta_0$ in computing the correction to the declination, but for this purpose we may use $52.87(1 + p + M_x) \sec \delta_0 \cdot x$, the quantity which we have just computed and which is practically equal to $X$ sec $\delta_0$ for this purpose. Similarly in the declination we may compute at once $52.87(1 + p + N_y)$.

Employing these coefficients for Star 7 we have:

| Right Ascension: | | Declination: | |
|---|---|---|---|
| $x$: (Tab. V), | $-$ 14.6960 | $y$: (Tab. V), | $-$ 19.0252 |
| $52.87(1+p+M_x) \sec \delta_0 \cdot x$: | $-$ 828.″69 | $52.87(1+y+N_y) \cdot y$: | $-$ 1006″.62 |
| | $= -$ 13′48.69 | | $= -$16′46″.62 |
| $(N_x + r \sec \delta_0) \cdot Y$: | $-$ 0.30 | $(M_y - r \sec \delta_0) \cdot X \sec \delta_0$: | $-$ 0.03 |
| $\alpha_0 + k \sec \delta_0$: | 128°07 54 .84 | $\delta_0 + c$: | +20°13 01 .39 |
| $\alpha_1 =$ | 127°54′05″.85 | $\delta_1 =$ | +19°56′14″.74 |

These give the projected position; the true right ascension and declination are found by adding the transformation corrections from Table VI, giving:

$$\alpha = 127°54'7''.34\,,\ \delta = +\,19°56'14''.22,$$

which are corrected for refraction, precession, nutation and aberration, and are referred to the mean equinox of 1875.0.

## V.

## Results.

Least-square solutions entirely similar to that given in detail in the last section lead to the following values of $p$, $r$, etc., for the various plates:

CONSTANTS OF THE PLATES.

| Plate. | $p$ | $r$ | Probable Error of $p$ or $r$. | $k$ | $c$ | Probable Error of $k$ or $c$. |
|---|---|---|---|---|---|---|
| | | | | $''$ | $''$ | $''$ |
| I. | +0.000100 | +0.001054 | ±0.000037 | —0.06 | 0.00 | ±0.075 |
| II. | + 125 | + 844 | ± 45 | —0.18 | —0.15 | ±0.092 |
| III. | + 125 | + 409 | ± 32 | —0.22 | —0.06 | ±0.066 |
| IV. | + 209 | + 1435 | ± 41 | 0.00 | —0.03 | ±0.082 |
| V. | + 261 | + 172 | ± 22 | —0.01 | +0.01 | ±0.044 |
| VII. | + 342 | — 35 | ± 24 | +0.02 | —0.04 | ±0.049 |
| VIII. | + 352 | + 211 | ± 30 | +0.08 | +0.01 | ±0.061 |
| IX. | + 365 | — 326 | ± 24 | —0.06 | —0.01 | ±0.048 |

The average probable error of $p$ or $r$ is

±0.000032

which corresponds to an uncertainty of about 0''.06 in the coördinates of the outlying stars. The great diversity in the values of $r$ is due in small part to corrections for precession, nutation and aberration, but chiefly to the accidental position in which the plate was inserted in the measuring machine.

The following are the residuals for the five comparison stars, used in computing the values of $p$, $r$, $k$ and $c$ given above.

Residuals from the Right Ascension Equations:

| Plate. | Star 4. | Star 5. | Star 15. | Star 40. | Star 44. |
|---|---|---|---|---|---|
| | $''$ | $''$ | $''$ | $''$ | $''$ |
| I | 0.00 | +0.03 | —0.01 | +0.07 | —0.09 |
| II | — .24 | + .31 | — .18 | + .42 | — .31 |
| III | — .14 | + .20 | — .23 | + .28 | — .11 |
| IV | — .19 | + .13 | .00 | + .39 | — .33 |
| V | — .01 | + .13 | — .06 | + .25 | — .31 |
| VII | — .07 | + .09 | + .02 | + .14 | — .18 |
| VIII | — .08 | + .05 | + .08 | + .21 | — .26 |
| IX | + .10 | — .09 | — .06 | + .12 | — .08 |
| Means, | — .08 | + .11 | — .06 | + .24 | —.21 |

Residuals from the Declination Equations:

| Plate. | Star 4. | Star 5. | Star 15. | Star 40. | Star 44. |
|---|---|---|---|---|---|
| | $''$ | $''$ | $''$ | $''$ | $''$ |
| I | —0.13 | +0.20 | +0.01 | +0.10 | —0.18 |
| II | — .03 | + .20 | — .15 | + .11 | — .13 |
| III | — .07 | + .13 | — .06 | + .16 | — .16 |
| IV | — .00 | + .23 | — .04 | + .07 | — .26 |
| V | — .09 | + .34 | .00 | — .01 | — .24 |
| VII | — .10 | + .22 | — .04 | + .08 | — .16 |
| VIII | — .08 | + .25 | + .01 | + .04 | — .22 |
| IX | — .02 | + .23 | — .01 | + .03 | — .23 |
| Means, | — .06 | + .22 | — .03 | + .07 | — .20 |

Employing the constants in the manner described at length in the last section, we obtain the quantities $\alpha_1$ and $\delta_1$ which have been tabulated in the following pages. It will be remembered that $\alpha_1$ and $\delta_1$ are the projected right ascension and declination of a star respectively; the transformation correction being the same for all the plates, may just as well be applied to the means; and it is evident that this procedure does not affect in any way the comparison of the right ascensions or declinations of a star as derived from different plates. The columns headed "At Epoch of Plate" give the coördinates uncorrected for proper motion. The calculation of the latter is very simple in this case as the plates were taken at practically only two dates, 1870.3 and 1877.3; hence the annual proper motion is obtained by subtracting the mean of the places on plates of the earlier date from the mean for the later date, and dividing the difference by 7. The columns marked "P. M." give the correction for proper motion necessary to reduce the place of the star to the epoch 1875.0.

Probable errors are given for the right ascension and the declination of each star, and also for the proper motions; they were calculated thus:

Let $m =$ the number of plates of date 1870.3 on which the star was measured.

$n =$ the number of date 1877.3.

$[vv] =$ the sum of the squares of the residuals obtained by subtracting the mean from the separate observations reduced to the epoch 1875.0.

Then the probable error of a quantity having the weight unity is:

$$\pm 0.6745 \sqrt{\frac{[vv]}{m+n-2}}$$

The weight of a right ascension or a declination at the epoch 1875.0 is

$$\frac{49mn}{22.1\,m + 5.3\,n}$$

For a proper motion the weight is

$$\frac{49mn}{m+n}$$

Most of the stars appear on all eight plates ; for such we have simply,

$$\text{Probable error of } \alpha_1 \text{ or of } \delta_1 = \pm 0.103 \sqrt{[vv]}$$
$$\text{“ “ of proper motion} = \pm 0.028 \sqrt{[vv]}$$

Two of the stars were observed only on plates taken in 1877, and consequently it was not possible to reduce them to the epoch 1875.0 by using proper motions determined from the plates themselves, as has been done for all the other stars. The proper motions used for these two stars are those given by Professor Schur on page 298 of his memoir, and are as follows :

| Star. | P. M. in Right Ascension. | P. M. in Declination. |
|---|---|---|
| 41 | —0″.042 | +0″.012 |
| 42 | —0 .066 | +0 .036 |

These were used for an interval of only 2.3 years.

## Star 1.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 127°35′31″.25 | −0″.43 | 30″.82 | 20°26′52″.60 | +0″.15 | 52″.75 |
| II | 30 .80 | − .43 | .37 | .47 | + .15 | .62 |
| III | 30 .94 | − .43 | .51 | .52 | + .15 | .67 |
| IV | 31 .16 | − .43 | .73 | .64 | + .15 | .79 |
| V | 30 .46 | + .21 | .67 | .84 | − .07 | .77 |
| VII | 30 .47 | + .21 | .68 | .79 | − .07 | .72 |
| VIII | 30 .45 | + .21 | .66 | .60 | − .07 | .53 |
| IX | 30 .22 | + .21 | .43 | .90 | − .07 | .83 |
| Mean, | 127°35′30″.61 | | | Mean, 20°26′52″.71 | | |
| Probable Error, | ±.041 | | | Probable Error, ±.026 | | |
| Proper Motion, | −0.091 ±0.011 | | | Proper Motion, +0.032 ±0.007 | | |

## Star 2.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 127°36′26″.17 | −0″.31 | 25″.86 | 20°10′02″.04 | +0″.15 | 2″.19 |
| II | 26 .21 | − .31 | .90 | .10 | + .15 | .25 |
| III | 26 .03 | − .31 | .72 | .06 | + .14 | .20 |
| IV | 26 .15 | − .31 | .84 | .14 | + .14 | .28 |
| V | 25 .74 | + .15 | .89 | .26 | − .07 | .19 |
| VII | 25 .65 | + .15 | .80 | .32 | − .07 | .25 |
| VIII | 25 .60 | + .15 | .75 | .24 | − .07 | .17 |
| IX | 25 .71 | + .15 | .86 | .40 | − .07 | .33 |
| Mean, | 127°36′25″.83 | | | Mean, 20°10′02″.23 | | |
| Probable Error, | ±.018 | | | Probable Error, ±.015 | | |
| Proper Motion, | −0.066 ±0.005 | | | Proper Motion, +0.031 ±0.004 | | |

## Star 3.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 127°37′28″.20 | —0″.38 | 27″.82 | 19°57′10″.51 | +0″.01 | 10″.52 |
| III | 27 .95 | — .38 | .57 | .32 | + .01 | .33 |
| IV | 27 .98 | — .38 | .60 | .42 | + .01 | .43 |
| V | 27 .53 | + .19 | .72 | .50 | .00 | .50 |
| VII | 27 .39 | + .19 | .58 | .39 | .00 | .39 |
| VIII | 27 .36 | + .19 | .55 | .34 | .00 | .34 |
| IX | 27 .62 | + .19 | .81 | .49 | — .01 | .48 |
| Mean, | | | 127°37′27″.66 | Mean, | | 19°57′10″.43 |
| Probable Error, | | | ±.032 | Probable Error, | | ±.021 |
| Proper Motion, | | | —0.081 ±0.009 | Proper Motion, | | +0.002 ±0.006 |

## Star 4.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 127°39′06″.16 | —0″.29 | 5″.87 | 19°42′06″.67 | +0″.01 | 6″.68 |
| II | 5 .92 | — .29 | .63 | .72 | + .01 | .73 |
| III | 6 .04 | — .29 | .75 | .68 | + .01 | .69 |
| IV | 5 .97 | — .29 | .68 | .74 | + .01 | .75 |
| V | 5 .60 | + .14 | .74 | .66 | .00 | .66 |
| VII | 5 .54 | + .14 | .68 | .70 | .00 | .70 |
| VIII | 5 .52 | + .14 | .66 | .73 | .00 | .73 |
| IX | 5 .71 | + .14 | .85 | .77 | — .01 | .76 |
| Mean, | | | 127°39′05″.73 | Mean, | | 19°42′06″.71 |
| Probable Error, | | | ±.024 | Probable Error, | | ±.010 |
| Proper Motion, | | | —0.061 ±0.007 | Proper Motion, | | +0.002 ±0.003 |

## Star 5.

| Plate. | Right Ascension: | | | Declination: | | |
|---|---|---|---|---|---|---|
| | At Epoch of Plate. | P. M. | At Epoch 1875.0. | At Epoch of Plate. | P. M. | At Epoch 1875.0. |
| I | 127°47′38″.48 | —0″.14 | 8″.34 | 20°38′33″.84 | +0″.17 | 34″.01 |
| II | .68 | — .14 | .54 | 33 .71 | + .17 | 33 .88 |
| III | .57 | — .14 | .43 | 33 .64 | + .17 | 33 .81 |
| IV | .48 | — .14 | .34 | 33 .74 | + .17 | 33 .91 |
| V | .35 | + .07 | .42 | 33 .97 | — .08 | 33 .89 |
| VII | .41 | + .07 | .48 | 33 .99 | — .09 | 33 .90 |
| VIII | .38 | + .07 | .45 | 34 .01 | — .09 | 33 .92 |
| IX | .22 | + .07 | .29 | 34 .01 | — .09 | 33 .92 |
| | Mean, | | 127°47′38″.41 | Mean, | | 20°38′33″.91 |
| | Probable Error, | | ±.022 | Probable Error, | | ±.015 |
| | Proper Motion, | | —0.030 ±0.006 | Proper Motion, | | +0.037 ±0.004 |

## Star 6.

| Plate. | Right Ascension: | | | Declination: | | |
|---|---|---|---|---|---|---|
| | At Epoch of Plate. | P. M. | At Epoch 1875.0. | At Epoch of Plate. | P. M. | At Epoch 1875.0. |
| I | 127°51′33″.81 | —0″.32 | 33″.49 | 20°25′33″.46 | +0″.21 | 33″.67 |
| II | .66 | — .32 | .34 | .16 | + .21 | .37 |
| III | .77 | — .32 | .45 | .30 | + .21 | .51 |
| IV | .97 | — .32 | .65 | .52 | + .21 | .73 |
| V | .47 | + .16 | .63 | .66 | — .10 | .56 |
| VII | .34 | + .16 | .50 | .61 | — .10 | .51 |
| VIII | .26 | + .16 | .42 | .64 | — .10 | .54 |
| IX | .20 | + .16 | .36 | .76 | — .10 | .66 |
| | Mean, | | 127°51′33″.48 | Mean, | | 20°25′33″.57 |
| | Probable Error, | | ±.031 | Probable Error, | | ±.031 |
| | Proper Motion, | | —0.069 ±0.009 | Proper Motion, | | +0.044 ±0.009 |

STAR 7.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 127°54′06″.35 | —0″.33 | 6″.02 | 19°56′14″.87 | —0″.03 | 14″.84 |
| II | 6 .36 | — .33 | 6 .03 | .70 | — .03 | .67 |
| III | 6 .16 | — .33 | 5 .83 | .63 | — .03 | .60 |
| IV | 6 .46 | — .33 | 6 .13 | .88 | — .03 | .85 |
| V | 5 .91 | + .16 | 6 .07 | .76 | + .01 | .77 |
| VII | 5 .81 | + .16 | 5 .97 | .74 | + .01 | .75 |
| VIII | 5 .85 | + .16 | 6 .01 | .74 | + .01 | .75 |
| IX | 5 .77 | + .17 | 5 .94 | .66 | + .01 | .67 |
| Mean, | 127°54′06″.00 | | | Mean, 19°56′14″.74 | | |
| Probable Error, | ±.025 | | | Probable Error, ±.024 | | |
| Proper Motion, | —0.071 ±0.007 | | | Proper Motion, —0.006 ±0.007 | | |

STAR 7A.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| II | 127°57′58″.00 | —0″.47 | 57″.53 | 20°09′42″.62 | —0″.09 | 42″.53 |
| IV | 58 .26 | — .47 | .79 | .55 | — .09 | .46 |
| VII | 57 .61 | + .23 | .84 | .57 | + .04 | .61 |
| VIII | 57 .25 | + .23 | .48 | .34 | + .04 | .38 |
| Mean, | 127°57′57″.66 | | | Mean, 20°09′42″.50 | | |
| Proper Motion, | —0.100 | | | Proper Motion, —0.019 | | |

## Star 8.

| Plate. | Right Ascension: At Epoch of Plate. | Right Ascension: P. M. | Right Ascension: At Epoch 1875.0. | Declination: At Epoch of Plate. | Declination: P. M. | Declination: At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 127°57′59″.38 | —0″.34 | 9″.04 | 20°26′12″.54 | +0″.12 | 12″.66 |
| II | 59 .38 | — .34 | .04 | .51 | + .12 | .63 |
| III | 59 .64 | — .34 | .30 | .63 | + .12 | .75 |
| IV | 59 .42 | — .34 | .08 | .69 | + .12 | .81 |
| V | 59 .08 | + .17 | .25 | .79 | — .06 | .73 |
| VII | 58 .90 | + .17 | .07 | .69 | — .06 | .63 |
| VIII | 58 .86 | + .17 | .03 | .70 | — .06 | .64 |
| IX | 58 .95 | + .17 | .12 | .88 | — .06 | .82 |
| | Mean, | | 127°57′59″.12 | Mean, | | 20°26′12″.71 |
| | Probable Error, | | ±.028 | Probable Error, | | ±.022 |
| Proper Motion, | | | —0.072 ±0.008 | Proper Motion, | +0.025 | ±0.006 |

## Star 10.

| Plate. | Right Ascension: At Epoch of Plate. | Right Ascension: P. M. | Right Ascension: At Epoch 1875.0. | Declination: At Epoch of Plate. | Declination: P. M. | Declination: At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 127°58′48″.65 | —0″.19 | 48″.46 | 20°06′50″.40 | +0″.14 | 50″.54 |
| II | .76 | — .19 | .57 | .33 | + .14 | .47 |
| III | .83 | — .19 | .64 | .27 | + .14 | .41 |
| IV | .77 | — .19 | .58 | .34 | + .14 | .48 |
| V | .47 | + .09 | .56 | .52 | — .07 | .45 |
| VII | .34 | + .09 | .43 | .58 | — .07 | .51 |
| VIII | .42 | + .09 | .51 | .48 | — .07 | .41 |
| IX | .67 | + .09 | .76 | .56 | — .07 | .49 |
| | Mean, | | 127°58′48″.56 | Mean, | | 20°06′50″.47 |
| | Probable Error, | | ±.028 | Probable Error, | | ±.012 |
| Proper Motion, | | | —0.040 ±0.008 | Proper Motion, | +0.029 | ±0.003 |

STAR 11.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 127°59′36″.89 | —0″.35 | 36″.54 | 20°01′46″.90 | +0″.10 | 47″.00 |
| II | 36 .86 | — .35 | .51 | 46 .86 | + .10 | 46 .96 |
| III | 36 .96 | — .35 | .61 | 46 .80 | + .10 | 46 .90 |
| IV | 37 .08 | — .35 | .73 | 46 .76 | + .10 | 46 .86 |
| V | 36 .63 | + .17 | .80 | 46 .95 | — .05 | 46 .90 |
| VII | 36 .36 | + .17 | .53 | 46 .96 | — .05 | 46 .91 |
| VIII | 36 .40 | + .17 | .57 | 46 .83 | — .05 | 46 .78 |
| IX | 36 .29 | + .17 | .46 | 47 .16 | — .05 | 47 .11 |
| | Mean, | | 127°59′36″.59 | Mean, | | 20°01′46″.93 |
| | Probable Error, | | ±.032 | Probable Error, | | ±.027 |
| Proper Motion, | | | —0.075 ±0.009 | Proper Motion, | | +0.021 ±0.008 |

STAR 14.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°07′45″.06 | —0″.20 | 44″.86 | 20°31′29″.10 | +0″.13 | 29″.23 |
| II | 44 .81 | — .20 | .61 | 29 .00 | + .13 | .13 |
| III | 44 .98 | — .20 | .78 | 28 .88 | + .13 | .01 |
| IV | 45 .15 | — .20 | .95 | 29 .01 | + .13 | .14 |
| V | 44 .82 | + .10 | .92 | 29 .07 | — .06 | .01 |
| VII | 44 .60 | + .10 | .70 | 29 .19 | — .06 | .13 |
| VIII | 44 .75 | + .10 | .85 | 29 .23 | — .06 | .17 |
| IX | 44 .64 | + .10 | .74 | 29 .26 | — .06 | .20 |
| | Mean, | | 128°07′44″.80 | Mean, | | 20°31′29″.13 |
| | Probable Error, | | ±.031 | Probable Error, | | ±.022 |
| Proper Motion, | | | —0.042 ±0.009 | Proper Motion, | | +0.027 ±0.006 |

## Star 15.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°07′55″.19 | —0″.25 | 54″.94 | 20°13′01″.26 | +0″.12 | 1″.38 |
| II | 55 .07 | — .25 | 54 .82 | .11 | + .12 | .23 |
| III | 55 .02 | — .25 | 54 .77 | .20 | + .12 | .32 |
| IV | 55 .26 | — .25 | 55 .01 | .23 | + .12 | .35 |
| V | 54 .74 | + .12 | 54 .86 | .39 | — .06 | .33 |
| VII | 54 .77 | + .12 | 54 .89 | .34 | — .06 | .28 |
| VIII | 54 .84 | + .12 | 54 .96 | .39 | — .06 | .33 |
| IX | 54 .69 | + .13 | 54 .82 | .37 | — .06 | .31 |
| | Mean, | | 128°07′54″.88 | Mean, | | 20°13′01″.32 |
| | Probable Error, | | ±.022 | Probable Error, | | ±.012 |
| Proper Motion, | | | —0.054 ±0.006 | Proper Motion, | | +0.025 ±0.003 |

## Star 16.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°08′44″.80 | —0″.34 | 44″.46 | 19°42′50″.00 | +0″.03 | 50″.03 |
| II | .79 | — .34 | .45 | 50 .08 | + .03 | 50 .11 |
| III | .73 | — .34 | .39 | 49 .91 | + .03 | 49 .94 |
| IV | .98 | — .34 | .64 | 49 .85 | + .03 | 49 .88 |
| V | .38 | + .17 | .55 | 49 .97 | — .01 | 49 .96 |
| VII | .41 | + .17 | .58 | 50 .00 | — .01 | 49 .99 |
| VIII | .32 | + .17 | .49 | 49 .95 | — .01 | 49 .94 |
| IX | .15 | + .17 | .32 | 50 .08 | — .01 | 50 .07 |
| | Mean, | | 128°08′44″.48 | Mean, | | 19°42′49″.99 |
| | Probable Error, | | ±.028 | Probable Error, | | ±.021 |
| Proper Motion, | | | —0.073 ±0.008 | Proper Motion, | | +0.006 ±0.006 |

## STAR 17.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°10′05″.46 | —0″.27 | 5″.19 | 19°48′46″.81 | +0″.09 | 46″.90 |
| II | 5 .17 | — .27 | 4 .90 | .83 | + .09 | .92 |
| III | 5 .36 | — .27 | 5 .09 | .81 | + .08 | .89 |
| IV | 5 .57 | — .27 | 5 .30 | .75 | + .08 | .83 |
| V | 5 .03 | + .13 | 5 .16 | .88 | — .04 | .84 |
| VII | 5 .06 | + .13 | 5 .19 | .90 | — .04 | .86 |
| VIII | 5 .01 | + .13 | 5 .14 | .93 | — .04 | .89 |
| IX | 4 .83 | + .14 | 4 .97 | .99 | — .04 | .95 |
| Mean, | 128°10′05″.12 | | | Mean, 19°48′46″.89 | | |
| Probable Error, | ±.035 | | | Probable Error, ±.011 | | |
| Proper Motion, | —0.058 ±0.010 | | | Proper Motion, +0.018 ±0.003 | | |

## STAR 18.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°11′32″.44 | —0″.22 | 32″.22 | 19°59′31″.64 | +0″.10 | 31″.74 |
| II | 32 .26 | — .22 | 32 .04 | .53 | + .10 | .63 |
| III | 32 .20 | — .21 | 31 .99 | .44 | + .10 | .54 |
| IV | 32 .28 | — .21 | 32 .07 | .48 | + .10 | .58 |
| V | 32 .05 | + .11 | 32 .16 | .74 | — .05 | .69 |
| VII | 31 .95 | + .11 | 32 .06 | .60 | — .05 | .55 |
| VIII | 32 .04 | + .11 | 32 .15 | .64 | — .05 | .59 |
| IX | 31 .86 | + .11 | 31 .97 | .69 | — .05 | .64 |
| Mean, | 128°11′32″.08 | | | Mean, 19°59′31″.62 | | |
| Probable Error, | ±.024 | | | Probable Error, ±.019 | | |
| Proper Motion, | —0.046 ±0.007 | | | Proper Motion, +0.021 ±0.005 | | |

STAR 19.

| Plate. | Right Ascension: At Epoch of Plate. | Right Ascension: P. M. | Right Ascension: At Epoch 1875.0 | Declination: At Epoch of Plate. | Declination: P. M. | Declination: At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| II | 128°11′36″.06 | —0″.25 | 35″.81 | 20°35′50″.68 | +0″.09 | 50″.77 |
| IV | 36 .37 | — .25 | 36 .12 | .64 | + .09 | .73 |
| V | 35 .95 | + .12 | 36 .07 | .69 | — .04 | .65 |
| VII | 35 .86 | + .12 | 35 .98 | .87 | — .04 | .83 |
| VIII | 35 .72 | + .12 | 35 .84 | .82 | — .04 | .78 |
| Mean, | | 128°11′35″.96 | | Mean, | | 20°35′50″.75 |
| Proper Motion, | | | —0.053 | Proper Motion, | | +0.019 |

STAR 20.

| Plate. | Right Ascension: At Epoch of Plate. | Right Ascension: P. M. | Right Ascension: At Epoch 1875.0 | Declination: At Epoch of Plate. | Declination: P. M. | Declination: At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°11′51″.88 | —0″.20 | 51″.68 | 19°58′50″.40 | +0″.08 | 50″.48 |
| II | .77 | — .20 | .57 | .42 | + .08 | .50 |
| III | .75 | — .20 | .55 | .39 | + .08 | .47 |
| IV | .77 | — .20 | .57 | .40 | + .08 | .48 |
| V | .49 | + .10 | .59 | .50 | — .04 | .46 |
| VII | .42 | + .10 | .52 | .37 | — .04 | .33 |
| VIII | .51 | + .10 | .61 | .50 | — .04 | .46 |
| IX | .58 | + .10 | .68 | .68 | — .04 | .64 |
| Mean, | | 128°11′51″.60 | | Mean, | | 19°58′50″.48 |
| Probable Error, | | | ±.016 | Probable Error, | | ±.023 |
| Proper Motion, | | | —0.042 ±0.004 | Proper Motion, | | +0.016 ±0.006 |

STAR 22.

| Plate. | Right Ascension: | | | Declination: | | |
|---|---|---|---|---|---|---|
| | At Epoch of Plate. | P. M. | At Epoch 1875.0. | At Epoch of Plate. | P. M. | At Epoch 1875.0. |
| I | 128°12′43″.03 | —0″.32 | 42″.71 | 20°26′50″.07 | +0″.13 | 50″.20 |
| II | 42 .70 | — .32 | .38 | .12 | + .13 | .25 |
| III | 42 .98 | — .32 | .66 | .04 | + .13 | .17 |
| IV | 43 .08 | — .32 | .76 | .04 | + .13 | .17 |
| V | 42 .36 | + .16 | .52 | .20 | — .06 | .14 |
| VII | 42 .33 | + .16 | .49 | .20 | — .06 | .14 |
| VIII | 42 .57 | + .16 | .73 | .35 | — .06 | .29 |
| IX | 42 .63 | + .16 | .79 | .28 | — .06 | .22 |
| | Mean, | | 128°12′42″.63 | Mean, | | 20°26′50″.20 |
| | Probable Error, | | ±.040 | Probable Error, | | ±.015 |
| | Proper Motion, | | —0.068 ±0.011 | Proper Motion, | | +0.027 ±0.004 |

STAR 23.

| Plate. | Right Ascension: | | | Declination: | | |
|---|---|---|---|---|---|---|
| | At Epoch of Plate. | P. M. | At Epoch 1875.0. | At Epoch of Place. | P. M. | At Epoch 1875.0. |
| I | 128°14′60″.24 | —0″.23 | 60″.01 | 20°34′39″.08 | +0″.19 | 39″.27 |
| II | 59 .92 | — .23 | 59 .69 | 38 .93 | + .19 | .12 |
| III | 59 .81 | — .23 | 59 .58 | 38 .91 | + .19 | .10 |
| IV | 60 .20 | — .23 | 59 .97 | 38 .94 | + .19 | .13 |
| V | 59 .85 | + .11 | 59 .96 | 39 .21 | — .09 | .12 |
| VII | 59 .54 | + .11 | 59 .65 | 39 .18 | — .09 | .09 |
| VIII | 59 .71 | + .11 | 59 .82 | 39 .18 | — .09 | .09 |
| IX | 59 .69 | + .11 | 59 .80 | 39 .41 | — .09 | .32 |
| | Mean, | | 128°14′59″.81 | Mean, | | 20°34′39″.16 |
| | Probable Error, | | ±.044 | Probable Error, | | ±.025 |
| | Proper Motion, | | —0.049 ±0.012 | Proper Motion, | | +0.040 ±0.007 |

## Star 23A.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°15′57″.80 | —0″.32 | 57″.48 | 20°26′03″.10 | +0″.09 | 3″.19 |
| II | .74 | — .32 | .42 | 2 .80 | + .09 | 2 .89 |
| III | .70 | — .32 | .38 | 3 .00 | + .09 | 3 .09 |
| IV | .96 | — .32 | .64 | 2 .96 | + .09 | 3 .05 |
| V | .42 | + .16 | .58 | 3 .10 | — .05 | 3 .05 |
| VII | .28 | + .16 | .44 | 3 .09 | — .05 | 3 .04 |
| VIII | .27 | + .16 | .43 | 3 .12 | — .05 | 3 .07 |
| IX | .29 | + .16 | .45 | 3 .12 | — .05 | 3 .07 |
| | Mean, | | 128°15′57″.48 | Mean, | | 20°26′03″.06 |
| | Probable Error, | | ±.024 | Probable Error, | | ±.022 |
| | Proper Motion, | | —0.069 ±0.007 | Proper Motion, | | +0.020 ±0.006 |

## Star 24.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°16′58″.57 | —0″.21 | 58″.36 | 19°58′19″.27 | +0″.07 | 19″.34 |
| II | 58 .24 | — .21 | 58 .03 | .16 | + .07 | .23 |
| III | 58 .57 | — .21 | 58 .36 | .22 | + .07 | .29 |
| IV | 58 .67 | — .21 | 58 .46 | .11 | + .07 | .18 |
| V | 58 .19 | + .10 | 58 .29 | .29 | — .03 | .26 |
| VII | 57 .89 | + .10 | 57 .99 | .24 | — .03 | .21 |
| VIII | 58 .32 | + .10 | 58 .42 | .27 | — .03 | .24 |
| IX | 58 .38 | + .10 | 58 .48 | .38 | — .04 | .34 |
| | Mean, | | 128°16′58″.30 | Mean, | | 19°58′19″.26 |
| | Probable Error, | | ±.051 | Probable Error, | | ±.016 |
| | Proper Motion, | | —0.045 ±0.014 | Proper Motion, | | +0.015 ±0.004 |

### Star 25.

| Plate. | Right Ascension: | | | Declination: | | |
|---|---|---|---|---|---|---|
| | At Epoch of Plate. | P. M. | At Epoch 1875.0. | At Epoch of Plate. | P. M. | At Epoch 1875.0. |
| I | 128°17′32″.03 | —0″.25 | 31″.78 | 20°07′36″.79 | +0″.07 | 36″.86 |
| II | 31 .70 | — .25 | .45 | .67 | + .07 | .74 |
| III | 31 .57 | — .25 | .32 | .60 | + .07 | .67 |
| IV | 31 .95 | — .25 | .70 | .69 | + .07 | .76 |
| V | 31 .39 | + .12 | .51 | .73 | — .03 | .70 |
| VII | 31 .38 | + .12 | .50 | .82 | — .03 | .79 |
| VIII | 31 .38 | + .12 | .50 | .75 | — .03 | .72 |
| IX | 31 .59 | + .13 | .72 | .86 | — .04 | .82 |
| | Mean, | | 128°17′31″.56 | Mean, | | 20°07′36″.76 |
| | Probable Error, | | ±.043 | Probable Error, | | ±.016 |
| | Proper Motion, | | —0.054 ±0.012 | Proper Motion, | | +0.015 ±0.004 |

### Star 26.

| Plate. | Right Ascension: | | | Declination: | | |
|---|---|---|---|---|---|---|
| | At Epoch of Plate. | P. M. | At Epoch 1875.0. | At Epoch of Plate. | P. M. | At Epoch 1875.0 |
| I | 128°17′37″.23 | —0″.30 | 36″.93 | 19°47′20″.91 | +0″.03 | 20″.94 |
| II | 36 .92 | — .30 | .62 | 21 .01 | + .03 | 21 .04 |
| III | 36 .98 | — .29 | .69 | 20 .83 | + .03 | 20 .86 |
| IV | 37 .12 | — .29 | .83 | 20 .76 | + .03 | 20 .79 |
| V | 36 .49 | + .14 | .63 | 20 .82 | — .02 | 20 .80 |
| VII | 36 .64 | + .15 | .79 | 20 .90 | — .02 | 20 .88 |
| VIII | 36 .79 | + .15 | .94 | 20 .89 | — .02 | 20 .87 |
| IX | 36 .56 | + .15 | .71 | 21 .09 | — .02 | 21 .07 |
| | Mean, | | 128°17′36″.77 | Mean, | | 19°47′20″.91 |
| | Probable Error, | | ±.034 | Probable Error, | | ±.028 |
| | Proper Motion, | | —0.063 ±0.009 | Proper Motion, | | +0.007 ±0.008 |

## Star 27.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°17′52″.80 | —0″.17 | 52″.63 | 20°06′36″.49 | +0″.15 | 36″.64 |
| II | .35 | — .17 | .18 | .67 | + .15 | .82 |
| III | .56 | — .16 | .40 | .50 | + .15 | .65 |
| IV | .71 | — .16 | .55 | .43 | + .15 | .58 |
| V | .42 | + .08 | .50 | .70 | — .07 | .63 |
| VII | .34 | + .08 | .42 | .73 | — .07 | .66 |
| VIII | .30 | + .08 | .38 | .71 | — .07 | .64 |
| IX | .39 | + .08 | .47 | .86 | — .08 | .78 |
| | Mean, | | 128°17′52″.44 | Mean, | | 20°06′36″.68 |
| | Probable Error, | | ±.037 | Probable Error, | | ±.022 |
| | Proper Motion, | | —0.035 ±0.010 | Proper Motion, | | +0.032 ±0.006 |

## Star 28.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°18′06″.53 | —0″.19 | 6″.34 | 20°16′31″.01 | +0″.07 | 31″.08 |
| II | .26 | — .19 | .07 | 30 .96 | + .07 | 31 .03 |
| III | .44 | — .19 | .25 | 30 .78 | + .07 | 30 .85 |
| IV | .58 | — .19 | .39 | 30 .93 | + .07 | 31 .00 |
| V | .21 | + .09 | .30 | 30 .98 | — .03 | 30 .95 |
| VII | .03 | + .09 | .12 | 30 .97 | — .03 | 30 .94 |
| VIII | .22 | + .09 | .31 | 31 .08 | — .03 | 31 .05 |
| IX | .22 | + .09 | .31 | 31 .06 | — .04 | 31 .02 |
| | Mean, | | 128°18′06″.26 | Mean, | | 20°16′30″.99 |
| | Probable Error, | | ±.030 | Probable Error, | | ±.020 |
| | Proper Motion, | | —0.040 ±0.008 | Proper Motion, | | +0.015 ±0.006 |

## STAR 29.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°18′40″.95 | —0″.29 | 40″.66 | 20″.52 | +0″.17 | 20″.69 |
| II | 40 .52 | — .29 | .23 | .31 | + .17 | .48 |
| III | 40 .87 | — .29 | .58 | .40 | + .17 | .57 |
| IV | 41 .08 | — .29 | .79 | .37 | + .17 | .54 |
| V | 40 .50 | + .14 | .64 | .48 | — .08 | .40 |
| VII | 40 .30 | + .14 | .44 | .71 | — .08 | .63 |
| VIII | 40 .50 | + .14 | .64 | .62 | — .08 | .54 |
| IX | 40 .38 | + .14 | .52 | .81 | — .08 | .73 |
| Mean, | 128°18′40″.56 | | | Mean, | 20°37′20″.57 | |
| Probable Error, | ±.046 | | | Probable Error, | ±.030 | |
| Proper Motion, | —0.062 0.012 | | | Proper Motion, | +0.036 ±0.008 | |

## STAR 31.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°19′12″.34 | —0″.27 | 12″.07 | 19°59′06″.84 | +0″.10 | 6″.94 |
| II | 12 .31 | — .27 | 12 .04 | 6 .88 | + .10 | 6 .98 |
| III | 11 .93 | — .27 | 11 .66 | 6 .93 | + .10 | 7 .03 |
| IV | 12 .18 | — .27 | 12 .91 | 6 .64 | + .10 | 6 .74 |
| V | 11 .64 | + .13 | 11 .77 | 6 .94 | — .05 | 6 .89 |
| VII | 11 .73 | + .13 | 11 .86 | 7 .02 | — .05 | 6 .97 |
| VIII | 11 .95 | + .13 | 12 .08 | 6 .88 | — .05 | 6 .83 |
| IX | 11 .83 | + .13 | 11 .96 | 7 .07 | — .05 | 7 .02 |
| Mean, | 128°19′11″.92 | | | Mean, | 19°59′06″.92 | |
| Probable Error, | ±.041 | | | Probable Error, | ±.027 | |
| Proper Motion, | —0.057 ±0.011 | | | Proper Motion, | +0.022 ±0.008 | |

## Star 32.

| Plate. | Right Ascension: At Epoch of Plate. | Right Ascension: P. M. | Right Ascension: At Epoch 1875.0. | Declination: At Epoch of Plate. | Declination: P. M. | Declination: At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°20′56″.93 | —0″.28 | 56″.65 | 19°38′06″.20 | +0″.03 | 6″.23 |
| II | 57 .02 | — .28 | .74 | .35 | + .03 | .38 |
| III | 56 .98 | — .28 | .70 | .17 | + .03 | .20 |
| IV | 57 .20 | — .28 | .92 | .05 | + .03 | .08 |
| V | 56 .51 | + .14 | .65 | .28 | — .02 | .26 |
| VII | 56 .61 | + .14 | .75 | .27 | — .02 | .25 |
| VIII | 56 .71 | + .14 | .85 | .11 | — .02 | .09 |
| IX | 56 .64 | + .14 | .78 | .32 | — .02 | .30 |
| | Mean, | | 128°20′56″.76 | Mean, | | 19°38′06″.22 |
| | Probable Error, | | ±.026 | Probable Error, | | ±.028 |
| | Proper Motion, | | —0.059 ±0.007 | Proper Motion, | | +0.007 ±0.008 |

## Star 33.

| Plate. | Right Ascension: At Epoch of Plate. | Right Ascension: P. M. | Right Ascension: At Epoch 1875.0. | Declination: At Epoch of Plate. | Declination: P. M. | Declination: At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°22′30″.50 | —0″.34 | 30″.16 | 19°40′09″.34 | +0″.04 | 9″.38 |
| II | 30 .37 | — .34 | 30 .03 | .57 | + .04 | .61 |
| III | 30 .14 | — .34 | 29 .80 | .34 | + .04 | .38 |
| IV | 30 .53 | — .34 | 30 .19 | .32 | + .04 | .36 |
| VII | 29 .92 | + .17 | 30 .09 | .50 | — .02 | .48 |
| VIII | 30 .02 | + .17 | 30 .19 | .29 | — .02 | .27 |
| IX | 29 .71 | + .17 | 29 .88 | .57 | — .02 | .55 |
| | Mean, | | 128°22′30″.05 | Mean, | | 19°40′09″.43 |
| | Probable Error, | | ±.048 | Probable Error, | | ±.037 |
| | Proper Motion, | | —0.072 ±0.013 | Proper Motion, | | +0.009 ±0.010 |

STAR 34.

| Plate. | Right Ascension: | | | Declination: | | |
|---|---|---|---|---|---|---|
| | At Epoch of Plate. | P. M. | At Epoch 1875.0. | At Epoch of Plate. | P. M. | At Epoch 1875.0. |
| I | 128°23′08″.33 | —0″.27 | 8″.06 | 20°09′37″.37 | +0″.10 | 37″.47 |
| II | 8 .29 | — .27 | 8 .02 | .32 | + .10 | .42 |
| III | 8 .33 | — .27 | 8 .06 | .30 | + .10 | .40 |
| IV | 8 .49 | — .27 | 8 .22 | .36 | + .10 | .46 |
| V | 7 .80 | + .13 | 7 .93 | .44 | — .05 | .39 |
| VII | 8 .06 | + .13 | 8 .19 | .58 | — .05 | .53 |
| VIII | 8 .08 | + .13 | 8 .21 | .48 | — .05 | .43 |
| IX | 7 .88 | + .14 | 8 .02 | .47 | — .05 | .42 |
| | Mean, | | 128°23′08″.09 | Mean, | | 20°09′37″.44 |
| | Probable Error, | | ±.029 | Probable Error, | | ±.012 |
| Proper Motion, | | | —0.058 ±0.008 | Proper Motion, | | +0.022 ±0.003 |

STAR 35.

| Plate. | Right Ascension: | | | Declination: | | |
|---|---|---|---|---|---|---|
| | At Epoch of Plate. | P. M. | At Epoch 1875.0. | At Epoch of Plate. | P. M. | At Epoch 1875.0. |
| I | 128°25′03″.01 | —0″.27 | 2″.74 | 20°42′28″.84 | +0″.14 | 28″.98 |
| II | 2 .92 | — .27 | .65 | 28 .80 | + .14 | 28 .94 |
| III | 3 .04 | — .27 | .77 | 28 .86 | + .14 | 29 .00 |
| IV | 3 .01 | — .27 | .74 | 28 .82 | + .14 | 28 .96 |
| V | 2 .78 | + .13 | .91 | 28 .86 | — .07 | 28 .79 |
| VII | 2 .58 | + .13 | .71 | 29 .12 | — .07 | 29 .05 |
| VIII | 2 .59 | + .13 | .72 | 29 .00 | — .07 | 28 .93 |
| IX | 2 .41 | + .14 | .55 | 29 .17 | — .07 | 29 .10 |
| | Mean, | | 128°25′02″.72 | Mean, | | 20°42′28″.97 |
| | Probable Error, | | ±.028 | Probable Error, | | ±.025 |
| Proper Motion, | | | —0.058 ±0.008 | Proper Motion, | | +0.030 ±0.007 |

## Star 36.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°26′25″.18 | —0″.45 | 24″.73 | 20°22′35″.73 | +0″.16 | 35″.89 |
| II | 25 .14 | — .45 | .69 | .67 | + .16 | .83 |
| III | 25 .17 | — .44 | .73 | .59 | + .15 | .74 |
| IV | 25 .40 | — .44 | .96 | .63 | + .15 | .78 |
| VII | 24 .59 | + .22 | .81 | .96 | — .08 | .88 |
| VIII | 24 .54 | + .22 | .76 | .78 | — .08 | .70 |
| IX | 24 .54 | + .22 | .76 | .92 | — .08 | .84 |
| Mean, | | | 128°26′24″.78 | Mean, | | 20°22′35″.81 |
| Probable Error, | | | ±.028 | Probable Error, | | ±.022 |
| Proper Motion, | | | —0.095 +0.007 | Proper Motion, | | +0.033 ±0.006 |

## Star 37.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°26′31″.81 | —0″.28 | 31″.53 | 20°01′19″.38 | +0″.05 | 19″.43 |
| II | .61 | — .28 | .33 | .56 | + .05 | .61 |
| III | .50 | — .28 | .22 | .31 | + .05 | .36 |
| IV | .89 | — .28 | .61 | .28 | + .05 | .33 |
| V | .28 | + .14 | .42 | .42 | — .02 | .40 |
| VII | .29 | + .14 | .43 | .34 | — .03 | .31 |
| VIII | .32 | + .14 | .46 | .49 | — .03 | .46 |
| IX | .27 | + .14 | .41 | .58 | — .03 | .55 |
| Mean, | | | 128°26′31″.43 | Mean, | | 20°01′19″.43 |
| Probable Error, | | | ±.032 | Probable Error, | | ±.029 |
| Proper Motion, | | | —0.059 ±0.006 | Proper Motion, | | +0.011 ±0.008 |

## Star 38.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°29′56″.44 | —0″.21 | 56″.23 | 20°16′19″.07 | +0″.08 | 19″.15 |
| II | .48 | — .21 | .27 | 19 .16 | + .08 | .24 |
| IV | .66 | — .21 | .45 | 18 .93 | + .07 | .00 |
| VII | .17 | + .10 | .27 | 19 .08 | — .04 | .04 |
| VIII | .15 | + .10 | .25 | 19 .17 | — .04 | .13 |
| IX | .32 | + .10 | .42 | 19 .24 | — .04 | .20 |

| | Right Ascension | | Declination | |
|---|---|---|---|---|
| Mean, | 128°29′56″.32 | Mean, | 20°16′19″.13 |
| Probable Error, | ±.031 | Probable Error, | ±.030 |
| Proper Motion, | —0.045 ±0.008 | Proper Motion, | +0.016 ±0.008 |

## Star 39.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°30′39″.00 | —0″.35 | 38″.65 | 20°21′52″.34 | +0″.07 | 52″.41 |
| II | 38 .72 | — .35 | .37 | .34 | + .07 | .41 |
| III | 38 .82 | — .35 | .47 | .32 | + .07 | .39 |
| IV | 39 .01 | — .35 | .66 | .24 | + .07 | .31 |
| V | 38 .44 | + .17 | .61 | .30 | — .03 | .27 |
| VII | 38 .33 | + .17 | .50 | .42 | — .03 | .39 |
| VIII | 38 .34 | + .17 | .51 | .38 | — .03 | .35 |
| IX | 38 .33 | + .17 | .50 | .56 | — .04 | .52 |

| | Right Ascension | | Declination |
|---|---|---|---|
| Mean, | 128°30′38″.53 | Mean, | 20°21′52″.38 |
| Probable Error, | ±.027 | Probable Error, | ±.021 |
| Proper Motion, | —0.075 ±0.008 | Proper Motion, | +0.015 ±0.006 |

## STAR 40.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°32′19″.74 | —0″.42 | 19″.32 | 19°42′13″.48 | +0″.05 | 13″.53 |
| II | .92 | — .42 | .50 | .60 | + .05 | .65 |
| III | .78 | — .42 | .36 | .65 | + .05 | .70 |
| IV | .92 | — .42 | .50 | .54 | + .05 | .59 |
| V | .14 | + .21 | .35 | .67 | — .02 | .65 |
| VII | .22 | + .21 | .43 | .65 | — .02 | .63 |
| VIII | .29 | + .21 | .50 | .61 | — .02 | .59 |
| IX | .20 | + .21 | .41 | .61 | — .02 | .59 |
| | Mean, | | 128°32′19″.42 | Mean, | | 19°42′13″.62 |
| | Probable Error, | | ±.020 | Probable Error, | | ±.014 |
| | Proper Motion, | | —0.090 ±0.006 | Proper Motion, | | +0.010 ±0.004 |

## STAR 41.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| VII | 128°06′08″.44 | +0″.10 | 8″.54 | 20°06′21″.68 | —0″.03 | 21″.65 |
| VIII | .30 | + .10 | .40 | .78 | — .03 | .75 |
| | Mean, | | 128°06′08″.47 | Mean, | | 20°06′21″.70 |

## STAR 42.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| VII | 128°38′00″.16 | +0″.15 | 00″.31 | 20°06′16″.46 | —0″.08 | 16″.38 |
| VIII | 59 .83 | + .15 | 59 .98 | .29 | — .08 | .21 |
| | Mean, | | 128°38′00″.14 | Mean, | | 20°06′16″.30 |

STAR 43.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°39′47″.04 | —0″.46 | 46″.58 | 20°19′06″.94 | +0″.03 | 6″.97 |
| II | 46 .71 | — .46 | .25 | .77 | + .03 | .80 |
| III | 46 .88 | — .45 | .43 | .72 | + .03 | .75 |
| IV | 47 .05 | — .45 | .60 | .56 | + .03 | .59 |
| V | 46 .32 | + .22 | .54 | .68 | — .02 | .66 |
| VII | 46 .27 | + .22 | .49 | .82 | — .02 | .80 |
| VIII | 46 .32 | + .22 | .54 | .95 | — .02 | .93 |
| IX | 46 .06 | + .23 | .29 | .74 | — .02 | .72 |
| Mean, | | | 128°39′46″.46 | Mean, | | 20°19′06″.78 |
| Probable Error, | | | ±.036 | Probable Error, | | ±.035 |
| Proper Motion, | | | —0.097 ±0.010 | Proper Motion, | | +0.007 ±0.010 |

STAR 44.

| Plate. | Right Ascension: At Epoch of Plate. | P. M. | At Epoch 1875.0. | Declination: At Epoch of Plate. | P. M. | At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| I | 128°40′18″.28 | —0″.23 | 18″.05 | 20°36′14″.23 | +0″.07 | 14″.30 |
| II | 18 .27 | — .23 | 18 .04 | .33 | + .07 | .40 |
| III | 18 .49 | — .22 | 18 .27 | .31 | + .07 | .38 |
| IV | 18 .26 | — .22 | 18 .04 | .21 | + .07 | .28 |
| V | 18 .05 | + .11 | 18 .16 | .40 | — .03 | .37 |
| VII | 17 .95 | + .11 | 18 .06 | .42 | — .03 | .39 |
| VIII | 17 .87 | + .11 | 17 .98 | .36 | — .03 | .33 |
| IX | 18 .08 | + .11 | 18 .19 | .33 | — .04 | .29 |
| Mean, | | | 128°40′18″.10 | Mean, | | 20°36′14″.34 |
| Probable Error, | | | ±.027 | Probable Error, | | ±.013 |
| Proper Motion, | | | —0.048 ±0.008 | Proper Motion, | | +0.015 ±0.004 |

STAR 45.

| Plate. | Right Ascension: At Epoch of Plate. | Right Ascension: P. M. | Right Ascension: At Epoch 1875.0. | Declination: At Epoch of Plate. | Declination: P. M. | Declination: At Epoch 1875.0. |
|---|---|---|---|---|---|---|
| II | 128°44′17″.78 | —0″.33 | 17″.45 | 19°51′23″.45 | +0″.08 | 23″.53 |
| III | .62 | — .33 | .29 | .38 | + .08 | .46 |
| IV | .98 | — .33 | .65 | .22 | + .08 | .30 |
| V | .26 | + .16 | .42 | .44 | — .04 | .40 |
| VII | .34 | + .16 | .50 | .56 | — .04 | .52 |
| VIII | .39 | + .16 | .55 | .45 | — .04 | .41 |
| IX | .23 | + .16 | .39 | .43 | — .04 | .39 |
| | Mean, | | 128°44′17″.46 | Mean, | | 19°51′23″.43 |
| | Probable Error, | | ±.032 | Probable Error, | | ±.022 |
| Proper Motion, | | | —0.070 ±0.009 | Proper Motion, | | +0.017 ±0.006 |

The final results of the measurements have been collected on the next page; the right ascensions and declinations are obtained from $\alpha_1$ and $\delta_1$, which are printed in the foregoing pages in slightly bolder type, by adding the transformation corrections given in Table VI, page 239. The magnitudes are those of the Bonn Durchmusterung.

## Catalogue of the Relative Positions and Proper Motions of 42 Stars in the Præsepe Group.

**Mean Equinox of 1875.0.** **Epoch 1875.0.**

| Star. | Mag. B. D. | Right Ascension. | Proper Motion. | Declination. | Proper Motion. | No. of Plates. |
|---|---|---|---|---|---|---|
| | | ° ′ ″ | ″ | ° ′ ″ | ″ | |
| 1 | 8.8 | 127 35 27.78 | —0.091 | +20 26 49.70 | +0.032 | 8 |
| 2 | 8.2 | 36 26.49 | — .066 | +20 09 59.43 | + .031 | 8 |
| 3 | 8.4 | 37 30.81 | — .081 | +19 57 07.85 | + .002 | 7 |
| 4 | 7.2 | 39 11.48 | — .061 | +19 42 04.48 | + .002 | 8 |
| 5 | 8.0 | 47 35.08 | — .030 | +20 38 32.69 | + .037 | 8 |
| 6 | 8.4 | 51 32.17 | — .069 | +20 25 32.80 | + .044 | 8 |
| 7 | 9.0 | 54 07.49 | — .071 | +19 56 14.22 | — .006 | 8 |
| 7A | 8.9 | 57 57.87 | | +20 09 42.23 | | 4 |
| 8 | 9.0 | 57 58.28 | — .072 | +20 26 12.42 | + .025 | 8 |
| 10 | 8.0 | 58 48.92 | — .040 | +20 06 50.24 | + .029 | 8 |
| 11 | 8.8 | 127 59 37.19 | — .075 | +20 01 46.74 | + .021 | 8 |
| 14 | 8.0 | 128 07 44.78 | — .042 | +20 31 29.12 | + .027 | 8 |
| 15 | 7.0 | 07 54.88 | — .054 | +20 13 01.32 | + .025 | 8 |
| 16 | 8.0 | 08 44.32 | — .073 | +19 42 50.04 | + .006 | 8 |
| 17 | 7.2 | 10 04.92 | — .058 | +19 48 46.88 | + .018 | 8 |
| 18 | 8.2 | 11 31.77 | — .046 | +19 59 31.59 | + .021 | 8 |
| 19 | 9.0 | 11 36.50 | | +20 35 50.69 | | 5 |
| 20 | 8.2 | 11 51.24 | — .042 | +19 58 50.44 | + .016 | 8 |
| 22 | 7.0 | 12 43.14 | — .068 | +20 26 50.10 | + .027 | 8 |
| 23 | 7.3 | 15 00.34 | — .049 | +20 34 39.01 | + .040 | 8 |
| 23A | 9.0 | 15 56.81 | — .069 | +20 26 02.88 | + .020 | 8 |
| 24 | 8.2 | 16 57.45 | — .045 | +19 58 19.04 | + .015 | 8 |
| 25 | 8.5 | 17 31.22 | — .054 | +20 07 36.50 | + .015 | 8 |
| 26 | 7.0 | 17 35.17 | — .063 | +19 47 20.68 | + .007 | 8 |
| 27 | 7.3 | 17 52.03 | — .035 | +20 06 36.40 | + .032 | 8 |
| 28 | 8.5 | 18 06.49 | — .040 | +20 16 30.70 | + .015 | 8 |
| 29 | 8.8 | 18 42.24 | — .062 | +20 37 20.21 | + .036 | 8 |
| 31 | 7.2 | 19 10.91 | — .057 | +19 59 06.57 | + .022 | 8 |
| 32 | 9.0 | 20 53.84 | — .059 | +19 38 05.83 | + .007 | 8 |
| 33 | 8.2 | 22 26.97 | — .072 | +19 40 08.90 | + .009 | 7 |
| 34 | 7.1 | 23 07.75 | — .058 | +20 09 36.79 | + .022 | 8 |
| 35 | 8.7 | 25 05.96 | — .058 | +20 42 28.08 | + .030 | 8 |
| 36 | 9.0 | 26 25.91 | — .095 | +20 22 34.83 | + .033 | 7 |
| 37 | 7.7 | 26 30.02 | — .059 | +20 01 18.46 | + .011 | 8 |
| 38 | 9.0 | 29 56.77 | — .045 | +20 16 17.75 | + .016 | 6 |
| 39 | 8.6 | 30 39.81 | — .075 | +20 21 50.91 | + .015 | 8 |
| 40 | 8.7 | 32 14.58 | — .090 | +19 42 12.03 | + .010 | 8 |
| 41 | 9.5 | 36 07.23 | | +20 06 19.46 | | 2 |
| 42 | 9.3 | 37 58.79 | | +20 06 13.76 | | 2 |
| 43 | 7.5 | 39 47.65 | — .097 | +20 19 03.89 | + .007 | 8 |
| 44 | 8.9 | 40 22.88 | — .048 | +20 36 11.29 | + .015 | 8 |
| 45 | 8.4 | 128 44 12.34 | — .070 | +19 51 19.77 | + .017 | 7 |

## VI.

### Discussion of Results.

Let us first ascertain what is the probable error of a measured coördinate, being careful not to let personalities in the observing enter into our result. Each coördinate was measured completely, that is in both the direct and in the reversed positions, by two observers. The difference between the two complete measurements will be free from personalities and may be ascribed to errors of observation. This difference, which I shall call $v$, may easily be computed from Table III; say the two observers are Schlesinger and Kretz, then subtract $(S—K)$ *direct*, from $(S—K)$ *reversed* and the difference is double the amount by which one observer's complete measurement differs from the other's, or $2v$. The probable error of a final coördinate is then given by,

$$\pm \frac{0.6745}{2} \sqrt{\frac{[vv]}{n}}$$

Proceeding in this way for all the plates we obtain the following probable errors. Only those stars were used, thirty-three in number, which appear on all the plates.

| | Probable Error of a final $x$. | Probable Error of a final $y$. |
|---|---|---|
| Plate I | $\pm 0''.034$ | $\pm 0''.031$ |
| II | .036 | .029 |
| III | .023 | .023 |
| IV | .024 | .020 |
| V | .020 | .027 |
| VII | .034 | .020 |
| VIII | .032 | .025 |
| IX | .037 | .027 |
| Means, | $\pm 0''.030$ | $\pm 0''.025$ |

The greater uncertainty in right ascension is due to the fact that the images are usually elongated in that direction and are therefore more difficult to bisect. The elongation was caused by the failure of Rutherfurd's clock to keep pace exactly with the diurnal motion of the group, sometimes lagging slightly or sometimes moving too rapidly.

In the tabulation of results the probable error of each right ascension and declination is given. We may compute the probable error of right ascension of a star as derived from a single plate by the expression

$$\pm 0.6745\sqrt{\frac{[vv]}{264-66}}\cos\delta_0$$

where $[vv]$ is the sum of the squares of all the residuals in right ascension for the thirty-three stars which appear on all eight plates; the factor $\cos\delta_0$ serves to reduce the probable error to arc of a great circle. The expression for the probable error of a single declination is identical with the above except that $\cos\delta_0$ is omitted. In this way we obtain the probable errors,

| In Right Ascension. | In Declination. |
|---|---|
| $\pm 0''.081$ | $\pm 0''.058$ |

If we do not confine ourselves to the thirty-three stars as above, but use all the stars, we get

| | |
|---|---|
| $\pm 0''.080$ | $\pm 0''.060$ |

Thus it appears that the uncertainty in a right ascension or in a declination is considerably greater than that in the corresponding measured coördinate. We may conclude from this that when a large number of plates is available, better results will be attained, for a given expenditure of time and labor, by measuring a large number of plates rather than measuring a few with all the elaboration used in the present research. But for the Rutherfurd photographs such elaboration is amply justified by the very limited number of existing photographs of so early a date.

It might appear at first as though a large part of the discrepancy between the two sets of probable errors, namely, those for the measured coördinates, and those for the resulting right ascension and declination, could be accounted for by the uncertainty of the constants used for the several plates. That such is not the case appears from the following considerations: the residuals for the five comparison stars, given on pages 247 and 248, exhibit a remarkable uniformity, showing that the greater part of these residuals is due to inaccuracies in the meridian observations. It follows, therefore, that the probable errors given for the constants $p$, $r$, $k$ and $c$, are due not so much to errors in measuring the plate as to errors in the meridian places. To obtain more precise information on this point, let us correct the meridian places of each of the comparison stars by the mean of the residuals for that star, and suppose we have effected thes leat-square solutions anew, using now the corrected meridian places. It can easily be shown that the new solutions would lead to exactly the same values of the constants as had been first obtained, but now each residual will be altered by a certain quantity, namely, the amount of the corresponding correction to the meridian place. We may then subtract at once the mean of the residuals for a star, from the corresponding residual in each least-square solution and then compute the probable errors of the constants. The results of such a computation are as follows:

| | Probable Error of $p$ or $r$. | Probable Error of $k$ or $c$ |
|---|---|---|
| Plate I | ±0.000013 | ±0″.026 |
| II | 24 | .049 |
| III | 16 | .032 |
| IV | 16 | .032 |
| V | 15 | .030 |
| VII | 08 | .016 |
| VIII | 11 | .022 |
| IX | 20 | .041 |
| Means, | ±0.000015 | ±0″.031 |

The former means were

| | | |
|---|---|---|
| | ±0.000032 | ±0″.065 |

and these must be regarded as indicating the uncertainty in the absolute values of the constants; if the constants which we have obtained are in error, then there will be a decided tendency to error in the same direction on *different* plates, and the smaller probable errors given above indicate how much we should expect the adopted values of the constants to differ from each other as obtained for different plates. Consequently only a small part of the discrepancy between the probable errors of the measured coördinates and of the right ascensions and declinations can be due to uncertainties in the adopted constants.

The discrepancy is probably caused by inaccuracies, and in some cases neglect, of instrumental corrections. For example, the difference between the two complete measurements of a coördinate is independent of errors in the determination of the division corrections, because the two observers always used the same lines; but not so with the differences of the right ascensions or declinations as derived from different plates. Similarly, the corrections for temperature and straightness of the scale, which we have neglected, do not affect the agreement of the measured coördinates. Possibly too, there have been distortions of the film, but the smallness of the probable errors on the whole must rather be taken as evidence against such distortions. It is important to note that the close agreement of the right ascensions and declinations for different plates affords a striking confirmation of the permanence of the Rutherfurd plates, which in the present case have been measured a quarter of a century after they were made.*

If we consider the probable errors of the measured coördinates, we see that the uncertainty is considerably greater upon some plates than upon others. Notwithstanding, equal weights have been assigned to all the plates, since it appears that the uncertainty in a measured coördinate forms only a small part of the uncertainty in the corresponding right ascension or declination.

Let us now compare the photographic results with those of the heliometer. In his memoir upon the group, Professor Schur has given the places of forty-five stars referred to the mean equinox and epoch of 1875.0, which are the same as those used in the present paper. Of these stars all but five appear on the photographs. The following table gives first the uncorrected or direct differences obtained by subtracting the right ascension, declination and proper motion of each star in our catalogue, from the corresponding quantities in Schur's. The differences in right ascension and in proper motion in right ascension have been multiplied by cos $\delta_0$ to reduce them to arc of a great circle.

* See, in this connection, "On the Permanence of the Rutherfurd Photographs," by Harold Jacoby, Annals of the N. Y. Acad. of Sciences, Vol. IX.

## Comparison with Heliometer Results.
## Heliometer *minus* Photographs.

| Star. | Right Ascension. | | Declination. | | Proper Motion. | | No. of Plates. |
|---|---|---|---|---|---|---|---|
| | Direct Diff's. | Corr'd. Diff's. | Direct Diff's. | Corr'd. Diff's. | Diff's in R. As. | Diff's in Decl. | |
| | " | " | " | " | " | " | |
| 1 | —0.04 | +0.07 | +0.40 | —0.08 | +0.016 | —0.015 | 8 |
| 2 | — .03 | — .02 | + .46 | — .04 | — .014 | — .020 | 8 |
| 3 | — .17 | — .24 | + .61 | + .10 | + .011 | + .004 | 7 |
| 4 | + .24 | + .09 | + .73 | + .20 | — .019 | + .005 | 8 |
| 5 | — .15 | + .03 | + .67 | + .13 | + .021 | + .001 | 8 |
| 6 | — .05 | + .06 | + .55 | — .02 | — .011 | — .032 | 8 |
| 7 | + .12 | + .06 | + .67 | + .07 | — .004 | + .018 | 8 |
| 8 | — .11 | + .01 | + .50 | — .10 | — .004 | — .020 | 8 |
| 10 | + .11 | + .12 | + .72 | + .10 | — .030 | — .022 | 8 |
| 11 | — .01 | — .03 | + .67 | + .04 | + .003 | — .013 | 8 |
| 14 | — .26 | — .10 | + .74 | + .08 | — .032 | — .008 | 8 |
| 15 | — .11 | — .06 | + .52 | — .15 | — .019 | — .008 | 8 |
| 16 | + .38 | + .25 | + .57 | — .12 | — .007 | + .001 | 8 |
| 17 | + .22 | + .18 | + .70 | + .01 | — .017 | — .019 | 8 |
| 18 | + .16 | + .13 | + .62 | — .08 | — .023 | — .028 | 8 |
| 19 | — .27 | — .09 | + .71 | + .04 | | | 5 |
| 20 | + .03 | .00 | + .66 | — .04 | — .035 | — .022 | 8 |
| 22 | — .20 | — .07 | + .67 | — .02 | — .007 | — .017 | 8 |
| 23 | — .08 | + .04 | + .79 | + .09 | — .020 | — .031 | 8 |
| 24 | — .06 | — .09 | +1.04 | + .31 | — .016 | — .011 | 8 |
| 25 | — .02 | .00 | + .62 | — .10 | — .016 | — .011 | 8 |
| 26 | + .20 | + .10 | + .69 | — .05 | — .014 | — .006 | 8 |
| 27 | + .08 | + .10 | + .87 | + .14 | — .032 | — .033 | 8 |
| 28 | — .25 | — .18 | + .68 | — .04 | — .028 | — .014 | 8 |
| 29 | — .51 | — .31 | + .73 | + .02 | — .004 | — .026 | 8 |
| 31 | + .01 | — .02 | + .80 | + .06 | — .007 | — .017 | 8 |
| 32 | + .32 | + .17 | + .80 | + .04 | — .014 | — .002 | 8 |
| 33 | + .07 | — .07 | + .74 | — .02 | + .009 | — .011 | 7 |
| 34 | + .07 | + .11 | + .94 | + .19 | + .002 | — .010 | 8 |
| 35 | — .32 | — .09 | + .66 | — .08 | — .009 | — .026 | 8 |
| 36 | — .13 | — .02 | + .79 | + .03 | + .037 | — .030 | 7 |
| 37 | — .06 | — .07 | + .68 | — .10 | — .001 | — .006 | 8 |
| 38 | — .05 | + .03 | + .93 | + .14 | — .018 | — .008 | 6 |
| 39 | — .14 | — .03 | + .77 | — .02 | + .008 | — .010 | 8 |
| 40 | + .08 | — .04 | + .57 | — .25 | + .028 | + .001 | 8 |
| 41 | — .11 | — .09 | + .78 | — .05 | | | 2 |
| 42 | — .23 | — .20 | + .66 | — .18 | | | 2 |
| 43 | — .16 | — .06 | + .91 | + .07 | + .031 | — .002 | 8 |
| 44 | — .11 | + .09 | + .71 | — .12 | — .017 | .000 | 8 |
| 45 | — .07 | — .13 | + .58 | — .30 | + .018 | + .011 | 7 |

The corrected differences in right ascension and declination were obtained by adding systematic corrections and also by modifying the scale-value and orientation of the photographs. That is, a least-square solution was made to determine how much the constants of the plates would have to be changed so as to secure the best possible agreement between the two catalogues. Each star gives two equations of the form,

$$Xdp + Ydr + dk + da = 0$$
$$Ydp - Xdr + dc + d\delta = 0$$

where $da$ and $d\delta$ are the uncorrected or direct differences in the table. The least-square solution may be carried out in a manner entirely similar to that previously used. The differences for stars 18, 20, 24 and 25 were not used because these stars were not included in Schur's triangulation, but each was merely located by position angle and distance from the nearest star in the triangulation. Stars 19, 41 and 42 were also excluded in making the least-square solution because of the small number of plates on which they appear. The remaining stars, thirty-three in number, give the following corrections to the contents:

$$dp = +\,0.000011 \pm 0.000009$$
$$dr = +\,0.000098 \pm 0.000009$$
$$dk = +\,0''.047 \quad \pm 0''.014$$
$$dc = -\,0''.667 \quad \pm 0''.014$$

The probable error of one equation is

$$\pm\, 0''.080$$

a quantity which speaks well for the accuracy of all three researches concerned. The corrected differences in the table are now obtained by adding to each uncorrected difference

$X{\cdot}dp + Y{\cdot}dr + dk$ in the right ascensions,

and $Y{\cdot}dp - X{\cdot}dr + dc$ in the declinations.

From the above value for $dp$ we see that the meridian observations gave a scale-value which agrees very closely with that obtained from the heliometer places; the largest effect that $dp$ has on either coördinate of any star is only about $0''.02$. On the other hand the value of $dr$, or the change in the orientation constant is quite large, corresponding to a correction of about $0''.20$ in the coördinates of outlying stars. The meridian observations which we used to determine the orientation of the group, were also employed by Schur for the same purpose, and were found by him to give results which practically agreed with those obtained by an independent method. As we have adopted Schur's proper motions for the comparison stars, to reduce their places to the epochs of the plates, we can only conclude that the somewhat large value of $dr$ is due to the fact that the relative positions of these stars with respect to the rest of the group have been differently determined by the photographs on the one hand, and the heliometers on the other. This explanation is borne out by the comparatively large values of the corrected differences for the comparison stars, numbers 4, 5, 15, 40 and 44.

The large value for $dk$, or the systematic correction in declination, was to be expected. We have already remarked (see page 236) that the proper motions used for the comparison stars were not derived by Schur from the direct differences between the two heliometer determinations of the places of these stars, but that systematic corrections,

$$+0^{s}.0003 \text{ and } -0''.039$$

were added to the proper motions in right ascension and declination respectively. Hence we must expect the photographic places to differ from those of the heliometer for the epoch of 1875.0, by

$$+0''.071 \text{ and } -0''.612,$$

the proper motion having been used for an interval of 15.7 years. These corrections agree quite well with the values of $dk$ and $dc$ respectively, as obtained above.

## VII.

### Orientation by Trails. Scale-Value.

An independent method for orienting a stellar photograph is furnished by the " trails " or third images of some of the brighter stars. The Rutherfurd photographs previously reduced depend upon this mode of orientation, and the present research offers an admirable opportunity for testing its accuracy. Four trails have been measured and reduced on each Præsepe plate, and the resulting values of the orientation corrections were compared with the results obtained from a comparison with meridian observations, and also with those obtained with the use of the heliometer places. On Plate II the trails were too faint to admit of measurement, and on Plate V they were missing altogether.

The trails were measured in a different manner from that used for the other images. The plate was first set in the position which it occupied when "$y$ direct" had been measured for the stars, and the micrometer was set and read on the east image of a star whose trail was to be measured. Then, without touching the microscope, the plate was moved along the cylinder till the corresponding trail came into view. This was always possible because the plate had been approximately oriented when first set in the machine. Two readings were made upon the trail and the plate was then moved back to the east image, which was read a second time. The same operations were gone through for the west image, and the mean of all the readings on the images was subtracted from the mean of the readings on the trail, thus giving the *offset* in declination by which the trail differed from the middle point between the two images. All the above operations were repeated in the opposite position of the plate, namely that corresponding to "$y$ reversed," except that in the latter case the mean of the readings on the trail was subtracted from that for the images, so as to get the same sign for the offset as before. Each trail was thus measured by two observers separately, so that in all, sixteen readings were made on each trail, and eight upon each of the images. The resulting offsets are tabulated below in millimetres.

TRAIL MEASUREMENTS.

| Plate. \ Star. | 15. | 22. | 23. | 27. | 31. | 37. |
|---|---|---|---|---|---|---|
| I | —.0443 | | —.0193 | | —.0084 | +.0183 |
| III | —.0676 | | —.0404 | —.0398 | —.0292 | |
| IV | —.0535 | | —.0312 | | —.0169 | +.0070 |
| VII | —.0772 | —.0422 | —.0499 | | —.0294 | |
| VIII | —.1054 | —.0766 | —.0718 | | —.0510 | |
| IX | —.0850 | | —.0568 | | —.0356 | —.0070 |

The distance from each trail to the middle point between the corresponding images was measured approximately as follows, being practically the same for all the stars upon a plate :

| Plate, | I | III | IV | VII | VIII | IX | |
|---|---|---|---|---|---|---|---|
| $s$, | 35.0, | 35.1, | 35.0, | 39.3, | 48.1, | 39.4 | millimetres. |

We shall now consider what corrections must be applied to the above offsets in order that the true orientations of the plates may be computed from them.

**Instrumental Corrections.** The only correction of this kind is that for rotation, the data for which have already been given in Table II. Using the same notation as before the correction to the offset is

$$-s.\ i.\ \sin 1''$$

which is the same for all four stars. Having applied this connection, the offset may now be converted into seconds of arc by multiplying by the approximate scale value, 52.87.

**Transformation Corrections.** For the present purpose it will be convenient to use Ball and Rambaut's formulas quoted on page 238, in which $X \sec \delta_0$ and $Y$ appear in the second members instead of $\varDelta a$ and $\varDelta \delta$. We need only the second of these formulas :

$$\Delta\delta - y = -\tfrac{1}{4}(X \sec \delta_0)^2 \sin 2\delta_0 - \tfrac{1}{3} Y^3 - (X \sec \delta_0)^2\, Y$$

For the trail, $X \sec \delta_0$ is diminished by

$$z = 52.87 \cdot s \cdot \sec \delta_0,$$

while $Y$ remains practically unchanged. Hence the correction to the offset is,

$$+\tfrac{1}{4} \sin 2\delta_0 \cdot z \cdot (z - 2X \sec \delta_0) + z \cdot (z - 2X \sec \delta_0)\, Y$$

**Refraction Corrections.** The trails were taken somewhat later than the principal images of the group, and as the zenith distance changed in the interval, the refraction-coefficients will also be changed. Denoting by $M_y{}'$ and $N_y{}'$ what these coefficients be come for the trails, we have the correction to the offset,

$$M' \cdot z + (M_y - M_y') X \sec \delta_0 + (N_y - N_y') Y$$

The first term is constant for all four stars, and the two remaining terms are small. To calculate $M_y{}'$ and $N_y{}'$ we must know how much the hour angle has changed in the interval between the exposures for the principal images and that for the trail. As each of the former lasted six minutes and as the exposure for the trail was much shorter, we may safely adopt seven minutes of time as the change in the hour-angle. $M_y{}'$ and $N_y{}'$ may then be calculated with sufficient accuracy by interpolating in Table VII.

After these corrections have been applied it will be convenient to transform the offsets into position angles, which may be done by the formula

$$p = 270^\circ + \sin^{-1} \left\{ \frac{\text{offset}}{z \cdot \cos \delta_0} \right\}$$

**Precession, Nutation and Aberration.** Formulas for correcting position angles for these were deduced in convenient form by Bessel* ; let

$$\alpha' = 20'' \sec \delta_0 \sin \alpha_0$$

$$\beta' = \sec \delta_0 \cos \alpha_0$$

$$\gamma' = \tan \delta \cos \alpha_0$$

$$\delta' = \tan \delta_0 \sin \alpha_0$$

$A, B, C, D =$ Bessel's star-numbers, tabulated for each day in the year in the ephemerides.

The true position angle at the beginning of the *same* year is found by adding to the observed position angle the correction,

$$(-A\alpha' + B\beta' + C\gamma' + D\delta')$$

Then to reduce this to beginning of *another* year we add

$$+ 20''.06 \sec \delta_0 \sin \alpha_0 \cdot t$$

where $t$ is the integer corresponding to the difference of the years, and must be considered positive if we are reducing an observation to a later year than that in which it was made.

As an example of the reduction of trail measurements, I have set down the calculations in detail for the trail of Star 23, Plate I.

* "Astronomische Untersuchungen" Vol. I., pg. 202.

| | | |
|---|---|---|
| Offset, | $-0.0193$ | millimetres |
| Rotation Corr'n., | $+0.0005$ | |
| | $-0.0188$ | |
| In arc, | $-0''.99$ | |
| Transf. Corr'n., | $+1\ .75$ | |
| Refraction | $+0\ .24$ | |
| Corrected offset | $+1''.00$ | |
| Position Angle, | | $270 + 111''.9$ |
| $-(A\alpha' + B\beta' + C\gamma' + D\delta')$, | | $+\ 2\ .6$ |
| $20.06''$ sec $\delta_0$ sin $\alpha_0 \cdot t$, | | $+\ 84\ .0$ |
| True Position Angle, | | $270° + 198''.5$ |

Consequently we have from this star,

$$r = +0.000963$$

Similar calculations for all the trails gave the following results in which $r$ has been multiplied by $10^6$ throughout.

ORIENTATION BY TRAILS. VALUES OF $r \times 10^6$.

| Plate \ Star. | 15. | 22. | 23. | 27. | 31. | 37. |
|---|---|---|---|---|---|---|
| I | +954 | | +963 | | +840 | +873 |
| III | +334 | | +390 | +118 | +288 | |
| IV | +851 | | +777 | | +757 | +706 |
| VII | −128 | +186 | −140 | | − 52 | |
| VIII | +122 | +152 | +111 | | +113 | |
| IX | −360 | | −341 | | −248 | −254 |

Taking the mean for the four stars on each plate and setting down again the values of $r$ previously obtained by comparison with the meridian observations, we have,

| | Orientation by Trails. | Orientation by Merid. Obs. |
|---|---|---|
| Plate I | + 0.000908 | + 0.001054 |
| III | + 282 | + 409 |
| IV | + 773 | + 1435 |
| VII | − 34 | − 35 |
| VIII | + 124 | + 211 |
| IX | − 301 | − 326 |
| Means | + 292 | + 458 |

In comparing these it will be remembered that a difference of 0.000100 corresponds to about $0''.20$ in the coördinates of the outlying stars of the group. The results are decidedly adverse to the accuracy of this mode of orientation, especially as a comparison with the heliometer places indicates a further correction of

$$+0.000098$$

to the orientations obtained by using the meridian places. T! large discrepancies are probably due to jarring of the plate duri g exposure, caused by stopping and starting the clock-work severa. times; the large difference for Plate IV admits of no other obvious explanation.

Let us now examine the scale-values of the different plates. The values of $p$ given at the beginning of Section V include aberration and temperature effects. Formulas for the former correction are thus given by Bessel:*

$$\gamma = -(\cos\delta_0 \sin\alpha_0 + \tan\omega \sin\delta_0)$$
$$\delta = +(\cos\delta_0 \cos\alpha_0)$$

Then the true distance is found by adding to the observed distance $s$,

$$-s(C\gamma + D\delta),$$

$C$ and $D$ being as before, the Besselian star numbers.

We may also correct the values of $p$ for the temperature at which the plates were measured by adding

$$+0.0000017\,(T - 65°),$$

$T$ being the temperature in Fahrenheit degrees at which the plate was measured, given in Table II. This expression is easily derived from the value of $v$ on page 223. Corrections for the temperature at which the plate was exposed ought also to be applied, but sufficient data to establish a connection between this quantity and the scale-value are lacking. After a greater number of Rutherfurd's photographs have been reduced we may have more definite information on this point.

The true scale-value $S$ (so far as it can be obtained without the last correction), is given thus,

$$S = 52''.87\,[1 + p - C\gamma - D\delta + 0.0000017\,(T° - 65°)]$$

The following table gives the corrections and the resulting scale value for each plate. The corrections for temperature are very small and might well have been neglected. The last two columns give the readings of the thermometer attached to the telescope and of the "focus," which have been copied from Table I for convenience of reference.

* "Astronomische Untersuchungen," Vol. I, page 208.

SCALE-VALUE.

| Plate. | Cor. for Aberration. | Cor. for Temp. | Corrected Scale-Value. | Tel. Therm. | Focus. |
|---|---|---|---|---|---|
| I | —0.000099 | 0.000000 | 52.8701 | +58° | 8.4 |
| II | — 99 | + 2 | 52.8715 | 58 | 8.4 |
| III | — 100 | — 3 | 52.8712 | 53 | 8.4 |
| IV | — 100 | + 4 | 52.8760 | 53 | 8.4 |
| V | — 98 | + 3 | 52.8788 | 48 | 7.8 |
| VII | — 99 | — 2 | 52.8827 | 58 | 7.7 |
| VIII | — 99 | — 5 | 52.8831 | 58 | 7.7 |
| IX | — 98 | — 2 | 52.8840 | 48 | 7.8 |

The mean of the scale-values is

$$52''.8772$$

and if we adopt the correction of + 0.000009 as indicated by comparison with the heliometer places, this becomes

$$52''.8776.$$

However, either of these must still be regarded as only an approximate value, since the separate values for the different plates, as given above, vary in a way that cannot be fully explained by a connection with the readings either of the telescope thermometer or of the "focus."

The above investigations on the orientation and on the scale-value lead to the same conclusion; it will usually be better to determine all the constants of a plate by comparing the measures of some of the stars with their positions as known through meridian observations or otherwise, than to attempt to reduce them by means of a predetermined scale-value and orientation. In any case it is necessary to appeal to such known positions to determine the values of $k$ and $c$, or the absolute place of the group in the sky. The positions of two stars are theoretically sufficient to determine all four constants, but in most cases it will be possible to find enough stars to eliminate errors of observation to a large extent.

In conclusion, I wish to acknowledge my indebtedness to Messrs. Kretz and Hays for assisting me in the measurement of the plates, and to Professor Jacoby, who has kindly explained to me the methods used by him in the measurement and reduction of stellar photographs, and who has also suggested some improve-

ments in the paper in reading over the proofs. Finally I desire to express my thanks to Professor Rees, Director of the Observatory, for the interest he has shown in my work, and for securing its publication.

## Note on Refraction Formulas for Photographic Plates.

Formulas for correcting the measured rectangular coördinates of a star upon a photographic plate for refraction, may be easily derived from the well known general formulas of Bessel. On page 166, Vol. 1. of his "Astronomische Untersuchungen" he gives the following corrections to the differences of right ascension and declination:

$$\Delta\,(a'-a) = s \cdot k\,[\tan^2\zeta\cos(p-q)\sin q - \tan\zeta\sin q\tan\delta_0\cos p + \sin p]\sec\delta_0$$

$$\Delta\,(\delta'-\delta) = s \cdot k\,[\tan^2\zeta\cos(p-q)\cos q + \tan\zeta\sin q\tan\delta_0\sin p + \cos p]$$

Substituting

$$X = s\sin p$$
$$Y = s\cos p$$
$$G = \tan\zeta\sin q$$
$$H = \tan\zeta\cos q$$

we obtain

$$\Delta\,(a'-a) = k\,X\sec\delta_0\,(I+H^2) \quad + k\,Y\,(G-\tan\delta_0)\,H\sec\delta_0$$
$$\Delta\,(\delta'-\delta) = k\,X\,(G+\tan\delta)\,H \quad + k\,Y\,(I+G^2)$$

These formulas become identical with those of Professor Jacoby when we change $k$ into $\beta$ in order to allow for the increased refrangibility of photographic rays.

One point in the above deduction deserves mention; the quantities $\delta_0$, etc., were intended by Bessel to be the means of corresponding quantities for the two stars whose distance along the arc of the great circle joining them has been measured. We have treated them as though they referred to one end of that arc; however, this merely amounts to neglecting terms in the second and higher powers of $s$, which may be done for most photographic plates.

If we omit the middle term in each bracket in Bessel's formulas we obtain the formulas given by Professor Turner; the omission of these terms, as has been repeatedly pointed out, corresponds to a rotation of the axes, and is, therefore, of no importance when we determine the constants of a plate by comparing the measured coördinates of some of the stars with their known places. Turner's formulas are

$$\begin{aligned} \Delta X &= kX \cdot (1 + H^2) + kY \cdot GH \\ \Delta Y &= kX \cdot GH \qquad\quad + kY \cdot (1 + G^2) \end{aligned}$$

These formulas may be simplified when we use the above method for determining the constants, as I pointed out in the *Astronomical Journal*, No. 430; rejecting so much of the correction for refraction as may be regarded as either an orientation correction or a scale-value correction, we have remaining

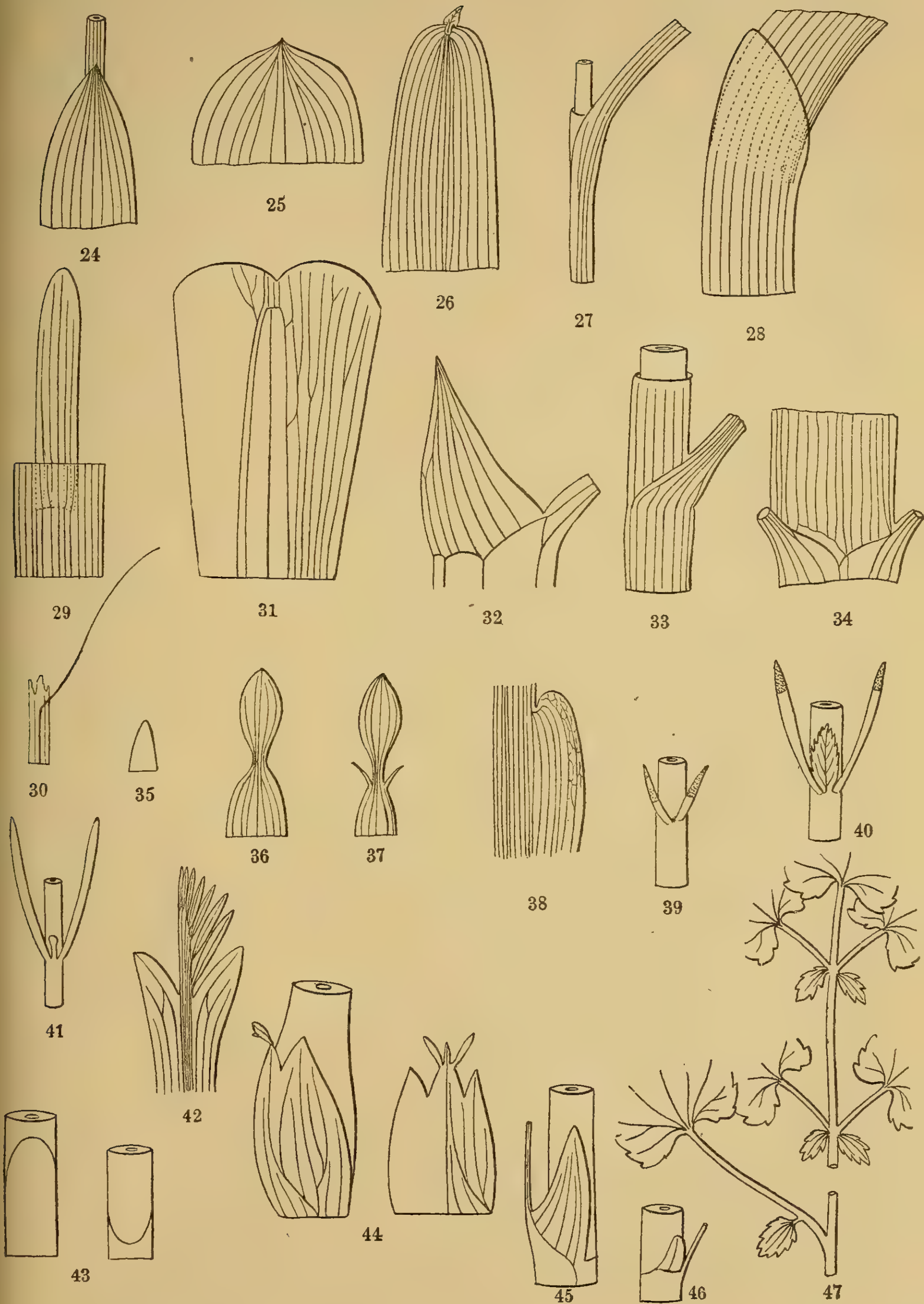
$$\begin{aligned} \Delta X &= kX \cdot (H^2 - G^2) \\ \Delta Y &= kX \cdot 2\,GH \end{aligned}$$

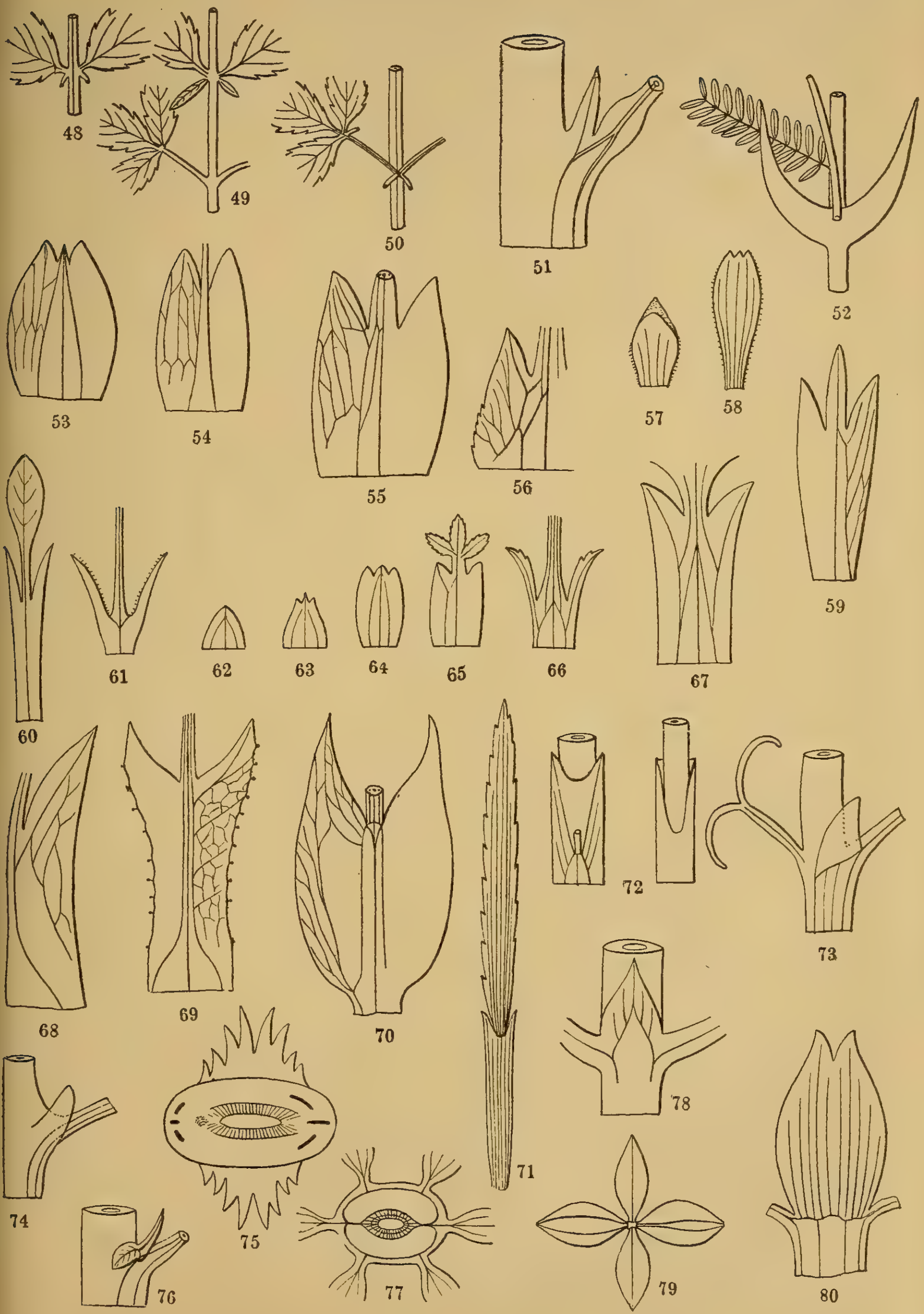
These formulas might have been used for the reduction of the Præsepe plates, but as we wished to know the true orientation and scale-value for each plate, extra corrections to these constants would have been necessary. Only four of the comparison stars used need corrections for refraction; so that in the present case nothing would have been gained by the use of the last formulas. When, however, the number of comparison stars is greater, or when we do not care especially to know the true orientation and scale-value of a plate, these formulas will save some labor.

# GENERAL INDEX TO VOLUME X.

Names of authors are in **heavy face type**. Generic and specific names in *italics*.


1
2
3
4
11
12
13
14
5
6
7
8
9
10
15
16
17
18
19
20
21
22
23


24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47


48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80

I

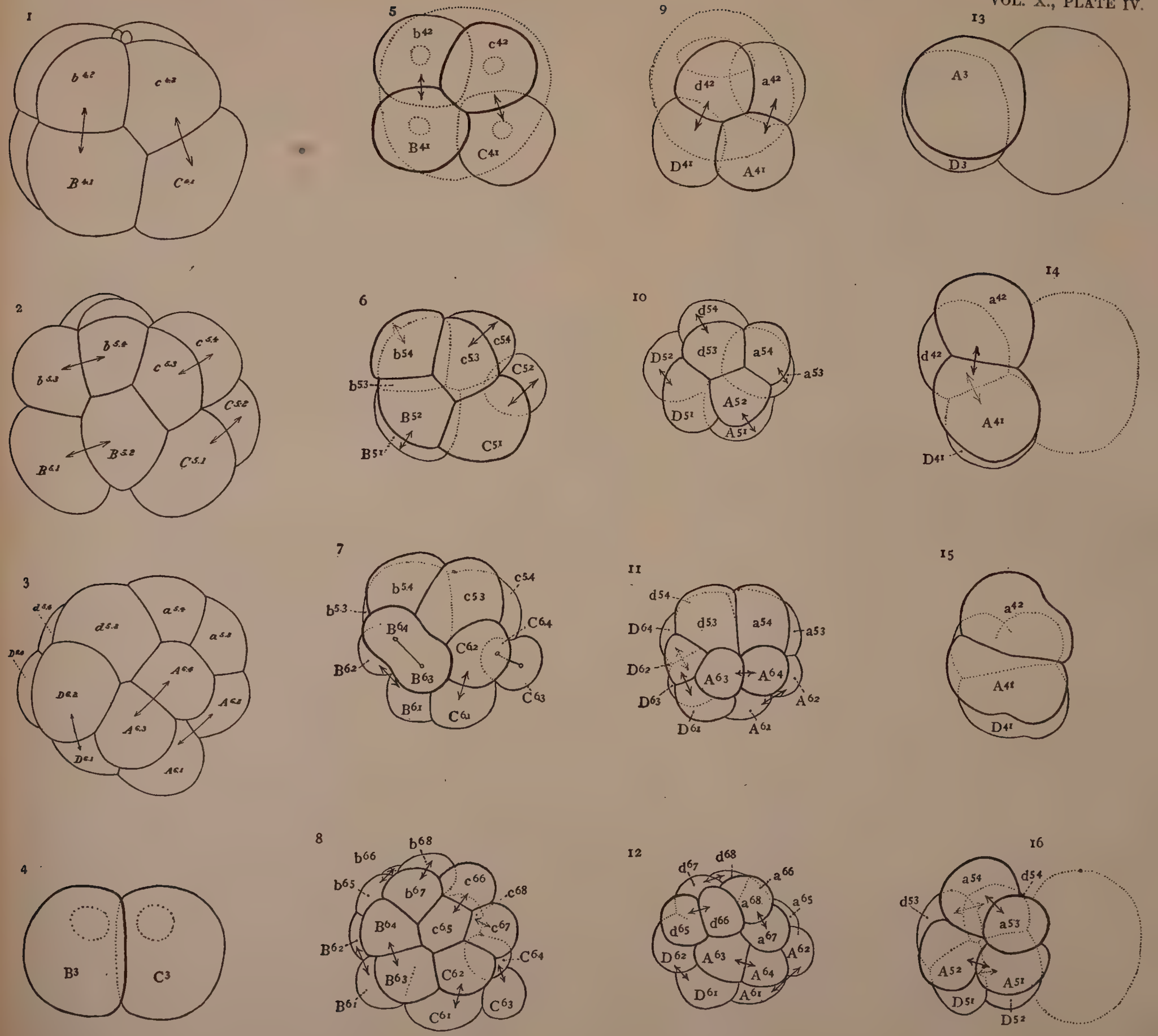
2


3

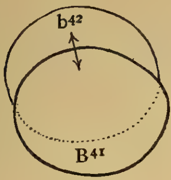

4

67

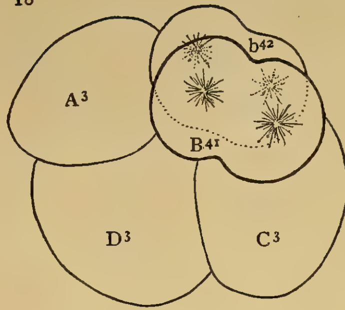
78


1
b4.2
c4.2
B4.1
C4.1
2
b5.4
b5.3
c5.4
c5.3
C5.2
B5.2
B6.1
C5.1
3
d5.4
d5.3
a5.4
a5.3
D6.2
A6.4
A6.2
D6.1
A6.3
A6.1
4
B3
C3
5
b42
c42
B41
C41
6
b54
c53
c54
C52
b53
B52
B51
C51
7
b5.4
c53
c54
b5.3
B64
C64
C62
B62
B63
C63
B61
C61
8
b66
b68
b65
b67
c66
c68
B64
c65
c67
B62
C64
B63
C62
B61
C63
C61
9
d42
a42
D41
A41
10
d54
D52
d53
a54
a53
A52
D51
A51
11
d54
d53
a54
D64
a53
D62
A63
A64
D63
A62
D61
A61
12
d67
d68
a66
a68
a65
d65
d66
a67
D62
A63
A62
A64
D61
A61
13
A3
D3
14
a42
d42
A41
D41
15
a42
A41
D41
16
a54
d54
d53
a53
A52
A51
D51
D52

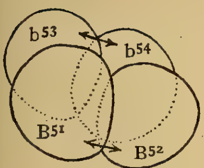
17



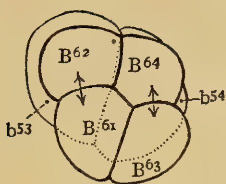

18



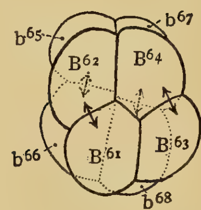

19



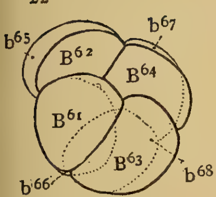

20



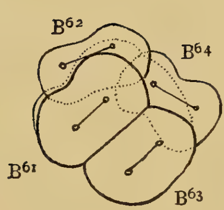

21



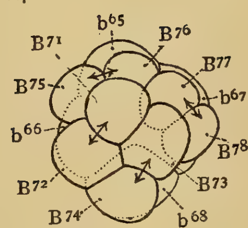

22



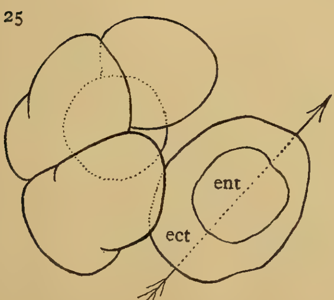

23




24




25




26

Vol. X. October, 1898. Nos. 1–12.

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# CONTENTS OF VOLUME X.

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