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Definitive Orbit of Comet 1894 IV (E. Swift).

By

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By *Frederick H. Seares.*

1. Introductory.

Comet 1894 IV was discovered by Edward Swift at Echo Mountain, California, on Nov. 20, 1894 at $8^h 30^m$ p.m. The comet was then very faint and had a short tail. The first observations were obtained by Barnard with the 12 inch Equatorial of the Lick Observatory on Nov. 21, 22, and 23, and by Javelle at Nice on Nov. 22 and 23.

A rapidly increasing deviation from the positions predicted by means of the preliminary parabolic elements gave indication of decided ellipticity which was soon confirmed by later elements.

A great similarity between the elements of the new comet and those of De Vico 1844 I was soon noted and the possibility of identity was suggested by Berberich as early as Nov. 23. On Dec. 1 Tisserand announced that Schulhof had found the two comets to be identical.

Owing to the extreme faintness of the object observations were obtained with the greatest difficulty as is sufficiently evident from the notes by the various observers, and in many places bad weather made observing quite impossible. This was especially the case at Mt. Hamilton where in spite of constant watchfulness on the part of Barnard the comet was not seen from Nov. 30, 1894 until Jan. 25, 1895. As a consequence the total number of positions is only 64 for right ascension and 63 for declination.

The first set of elements approximating a definitive solution were by Chandler from 27 observations grouped into 6 normal places. Basing himself upon this system of elements Chandler undertook a preliminary investigation of the question of identity with De Vico's comet, carrying the perturbations back through the conjunction with Jupiter in 1885. It seemed useless on account of the necessary indeterminateness of the value used for the mean motion to carry the calculation of the perturbations farther, but enough had been done to accomplish a partial adjustment of the discrepancies between the two comets and to show that the effect of the conjunctions with Jupiter in 1874 and 1862 would be in the right direction to produce a still better agreement. Notwithstanding the definiteness of the announcement concerning Schulhof's conclusions they were only provisional and were derived from a consideration of the perturbations of De Vico's comet throughout a long series of years. They were substantially the same as those arrived it by Chandler and may be found in A. N. No. 3267. With this encouragement the calculation of the definitive elements of comet Swift was begun, and the results are here presented as a part of an investigation of the question of identity with De Vico's comet which the writer has undertaken.

2. Calculation of Ephemeris.

The following elements by Chandler in A. J. No. 338 were used as the basis of the calculation.

$$\begin{aligned} T &= 1894 \text{ Oct. } 12.18817 \text{ Gr. M. T.} \\ \omega &= 296^\circ\, 34'\, 35''.2 \\ \Omega &= 48\;\; 44\;\; 37.1 \\ i &= 2\;\; 57\;\; 53.9 \\ \log q &= 0.1436451 \\ e &= 0.571895 \\ \text{Period} &= 2141.6 \text{ days} \end{aligned} \qquad \left.\begin{matrix} \\ \\ \\ \end{matrix}\right\} 1894.0$$

With these was calculated an ephemeris of 1 day intervals from 1894 Nov. 10.5 to 1895 Jan. 30.5 Berlin M. T.

Ephemeris for Berlin Mean Midnight.

1894	α	δ	log $\varDelta$	Ab. T.
Nov. 19	$22^h 14^m 9^s.94$	$-13^\circ 34' 16''.04$	0.0075	$8^m 27^s.3$
20	17 10.23	13 13 56.29	0108	31.2
21	20 9.90	12 53 32.38	0142	35.2
22	23 8.96	12 33 4.67	0176	39.3
23	26 7.40	12 12 33.54	0210	43.4
24	29 5.23	11 51 59.35	0244	47.5
25	32 2.44	11 31 22.48	0279	51.7
26	32 59.00	11 10 43.29	0314	8 55.9
27	22 37 54.93	−10 50 2.15	0.0349	9 0.2
Nov. 28	$22^h 40^m 50^s.22$	$-10^\circ 29' 19''.42$	0.0384	$9^m 4^s.6$
29	43 44.85	10 8 35.48	0419	9.1
30	46 38.82	9 47 50.70	0454	13.6
Dec. 1	49 32.13	9 27 5.42	0490	18.2
2	52 24.77	9 6 20.00	0525	22.8
3	55 16.73	8 45 34.78	0561	27.4
4	22 58 8.01	8 24 50.10	0597	32.2
5	23 0 58.61	8 4 6.28	0634	37.0
6	23 3 48.52	−7 43 23.68	0.0670	9 31.8

1894–95		α	δ	log Δ	Ab. T.
Dec.	6	23h 3m 48s.52	−7° 43′ 23″.68	0.0670	9m 31s.8
	7	6 37.75	7 22 42.60	0706	46.7
	8	9 26.29	7 2 3.35	0741	51.7
	9	12 14.14	6 41 26.22	0779	9 56.6
	10	15 1.30	6 20 51.53	0815	10 1.7
	11	17 47.77	6 0 19.52	0853	6.8
	12	20 33.55	5 39 50.48	0889	11.9
	13	23 18.64	5 19 24.65	0926	17.1
	14	26 3.05	4 59 2.27	0963	22.4
	15	28 46.80	4 38 43.53	1000	27.8
	16	31 29.88	4 18 28.63	1037	33.2
	17	34 12.31	3 58 17.75	1075	38.7
	18	36 54.08	3 38 11.10	1112	44.2
	19	39 35.21	3 18 8.81	1149	49.7
	20	42 15.73	2 58 11.05	1186	10 55.3
	21	44 55.62	2 38 17.99	1224	11 1.0
	22	47 34.89	2 18 29.79	1261	6.7
	23	50 13.57	1 58 46.60	1299	12.5
	24	52 51.65	1 39 8.57	1336	18.3
	25	55 29.14	1 19 35.85	1374	24.2
	26	23 58 6.05	1 0 8.57	1411	30.2
	27	0 0 42.37	0 40 46.89	1449	36.2
	28	3 18.15	0 21 30.98	1486	42.2
	29	5 53.35	−0 2 20.94	1524	48.3
	30	8 28.01	+0 16 43.07	1561	11 54.4
	31	11 2.11	0 35 40.93	1598	12 0.5
Jan.	1	13 35.66	0 54 32.51	1635	6.7
	2	0 16 8.68	+1 13 17.70	0.1673	12 13.0

1895		α	δ	log Δ	Ab. T.
Jan.	3	0h 18m 41s.19	+1° 31′ 56″.38	0.1710	12m 19s.3
	4	21 13.13	1 50 28.43	1747	25.6
	5	23 44.58	2 8 53.73	1784	32.0
	6	26 15.49	2 27 12.17	1822	38.5
	7	28 45.89	2 45 23.67	1858	45.0
	8	31 15.81	3 3 28.12	1895	51.5
	9	33 45.21	3 21 25.46	1931	12 58.1
	10	36 14.13	3 39 15.61	1969	13 4.7
	11	38 42.56	3 56 58.51	2005	11.3
	12	41 10.52	4 14 34.08	2042	18.0
	13	43 38.01	4 32 2.32	2078	24.7
	14	46 5.04	4 49 23.19	2115	31.5
	15	48 31.63	5 6 36.64	2151	38.3
	16	50 57.78	5 23 42.66	2188	45.2
	17	53 23.51	5 40 41.23	2224	52.1
	18	55 48.81	5 57 32.33	2260	13 59.0
	19	0 58 13.71	6 14 15.97	2296	14 6.0
	20	1 0 38.22	6 30 52.09	2332	13.1
	21	3 2.33	6 47 20.65	2367	20.2
	22	5 26.06	7 3 41.63	2403	27.2
	23	7 40.42	7 19 55.03	2438	34.3
	24	10 12.41	7 36 0.81	2474	41.4
	25	12 35.04	7 51 58.94	2509	48.6
	26	14 57.32	8 7 49.39	2544	14 55.8
	27	17 19.24	8 23 32.14	2579	15 3.1
	28	19 40.82	8 39 7.16	2614	10.4
	29	22 2.06	8 54 34.44	2649	17.7
	30	1 24 22.96	+9 9 53.96	0.2683	15 25.0

3. Observations and Comparison Stars.

The observations were collected from the usual sources and it is believed that all have been included. The published data of observation were checked wherever possible by independent computation and the parallax factors and reductions to apparent place were recomputed with the constants of the Berlin Jahrbuch.

The comparison stars used in the observations are 47 in number. Their positions have been investigated with considerable care, perhaps with more than is strictly necessary in view of the large probable errors of the observations. It seemed safer however to reduce the errors in the star places as much as possible in order to make them negligible as compared with the errors of observation, especially as the case under consideration is one in which the available material is so scanty as to render difficult the attainment of that degree of accuracy which is to be desired.

I am indebted to Professor Leuschner for much of the star catalogue data obtained by him from the libraries of various observatories while abroad in 1895–96, and to Professor Schaeberle as acting director of the Lick Observatory for his courtesy in allowing me to use the catalogues at Mt. Hamilton.

Practically all of the existing catalogues were searched. The catalogue positions were reduced to the beginning of the years 1894 and 1895 by Kreutz's tables (A. N. v. 134) which are based upon Struve's constants. Systematic corrections derived from the introductions to various catalogues, from vol. VII of the Bonner Beobachtungen and from Auwers' papers in A. N. Nos. 3195-96, 3413-14, and 3463, were applied to reduce to the system of the Astronomische Gesellschaft. When systematic corrections could not be found or when they seemed uncertain the simple catalogue position was used. In a few cases however where the total number of observations is large the positions lacking systematic corrections were given zero weight especially if the observations forming the position were old or few in number.

The weighting of the catalogues for the formation of the final positions is in accordance with the system published by Davis in his Declinations and Proper Motions of Fifty-six Stars. This system was derived by a consideration of the probable errors of the catalogues concerned, and its homogeneity has been tested by Dr. Davis in the introduction to his paper Although established primarily for declinations it has been used for right ascensions as well. A few catalogues have been used in the present paper which do not appear in the Davis system. Wherever possible these were weighted in accordance with the methods used in forming that system.

After the reduction of the catalogue positions to the beginning of the year of observation and the application of systematic corrections and weights, the simple mean by weights was drawn for each comparison star unless there was some indication of proper motion, in which case the final position of the star and its proper motion were obtained by a least square solution. The following list includes the computed weights of the comparison stars, although in the further computations they were all given equal weight.

Final Comparison Star Positions.

No.	Epoch	Mag.	α	Wt.	P. M.	δ	Wt.	P. M.
1	1894.0	8.2	$0^h\ 0^m\ 42^s.17$	4.4	—	$-0^\circ\ 28'\ 7''.3$	4.4	—
2	»	9.0	0 2 12.77	1.2	—	− 0 24 40.6	1.2	—
3	»	9.2	0 2 23.65	1.9	—	− 0 27 32.1	1.9	—
4	»	7.2	0 9 10.48	6.6	$-0^s.0026$	+ 0 42 27.7	6.6	—
5	»	8.5	0 14 35.86	1.1	—	+ 0 34 39.5	1.1	—
6	»	7.0	0 54 23.05	14.5	−0.0003	+ 5 55 0.2	13.2	—
7	1895.0	7.2	0 58 20.13	4.4	−0.0013	+ 6 12 4.0	4.4	—
8	»	8.2	1 13 59.15	3.6	−0.0026	+ 7 50 34.5	3.6	—
9	»	8.3	1 17 22.44	2.7	−0.0045	+ 8 11 20.0	2.7	—
10	»	7.9	1 17 36.34	2.7	—	+ 8 38 22.8	2.7	—
11	»	9.5	1 18 5.16	1.0	—	+ 8 31 45.5	1.0	—
12	»	9.2	1 20 1.93	1.1	—	+ 8 45 22.3	1.1	—
13	»	9.0	1 20 57.93	5.5	+0.0081	+ 8 59 3.9	5.5	—
14	1894.0	8.9	22 21 49.41	1.8	—	−12 48 41.2	1.8	—
15	»	8.5	22 22 30.24	3.6	—	−12 25 53.2	3.6	—
16	»	8.8	22 24 8.06	1.6	—	−12 15 24.5	1.6	—
17	»	9.1	22 25 34.34	2.6	—	−11 39 29.6	2.4	—
18	»	8.0	22 36 25.29	4.1	—	−10 40 47.0	4.2	—
19	»	7.0	22 37 26.63	13.6	−0.0017	−10 39 29.0	12.4	$+0''.005$
20	»	7.3	22 39 46.64	11.2	—	−10 12 5.0	10.4	—
21	»	8.0	22 40 45.68	3.6	—	−10 15 14.9	3.6	−0.094
22	»	9.2	22 43 22.47	1.2	—	− 9 29 29.2	1.2	—
23	»	8.2	22 45 39.08	1.7	−0.0028	− 9 53 11.3	1.7	−0.062
24	»	9.3	22 47 50.54	1.1	—	− 9 39 24.6	1.1	—
25	»	8.5	22 53 27.96	7.2	−0.0037	− 8 46 52.2	7.2	—
26	»	9.1	22 53 47.53	3.1	—	− 9 7 46.5	3.1	—
27	»	7.0	22 54 47.78	11.1	—	− 9 26 53.9	10.8	−0.028
28	»	6.8	23 26 2.99	20.6	+0.0106	− 4 39 59.9	19.3	−0.179
29	»	9.4	23 26 13.55	1.0	—	− 5 0 2.7	1.0	—
30	»	7.2	23 28 1.08	5.1	—	− 4 59 10.4	5.1	—
31	»	9.8	23 28 31.41	1.0	—	− 4 35 16.0	1.0	—
32	»	9.5	23 28 52.18	1.0	—	− 4 34 11.7	1.0	—
33	»	7.8	23 29 47.28	6.5	—	− 4 26 27.4	6.8	—
34	»	8.5	23 33 22.58	1.2	—	− 3 32 47.2	1.2	—
35	»	9.4	23 33 59.52	1.0	—	− 4 3 49.7	1.0	—
36	»	8.5	23 38 9.26	3.8	—	− 3 54 1.4	3.5	—
37	»	8.8	23 38 59.87	1.0	—	− 3 2 42.4	1.0	—
38	»	7.0	23 39 6.05	7.5	—	− 3 45 47.2	7.2	—
39	»	8.9	23 39 56.92	1.2	—	− 3 12 23.4	1.2	—
40	»	5.4	23 42 29.56	51.6	+0.0047	− 3 21 3.5	45.4	+0.001
41	»	9.2	23 47 31.03	1.0	—	− 2 19 5.7	1.0	—
42	»	7.5	23 49 12.69	5.4	−0.0031	− 2 32 8.8	5.4	—
43	»	8.4	23 53 6.14	1.4	—	− 2 16 28.8	1.4	—
44	»	7.2	23 54 8.01	2.1	—	− 2 26 27.9	2.1	—
45	»	8.0	23 57 31.19	5.6	—	− 1 29 0.5	5.3	—
46	»	9.0	23 58 49.15	2.2	—	− 0 35 52.1	2.2	—
47	»	7.0	23 59 37.69	20.1	—	− 1 5 30.1	17.4	−0.053

Some of the positions of the comet were referred by steps to the comparison stars of the above list. In such cases the intermediate stars are designated by *a*, *b*, *c*, etc. and their positions referred to the proper comparison stars as determined by the various observers are:

a — 17	$+5^{m}37^{s}.27$	$+\ 3'\ 43''.5$
b — 21	+4 56.71	+ 8 11.0
c — 28	+2 28.69	+ 4 29.0 1)
d — 28	+2 49.73	+ 5 48.0 2)
d — 28	+2 48.89	+ 5 46.8 3)
e — 35	+0 29.14	+ 7 40.9
f — 36	−3 40.80	— 2 8.1
g — 34	+3 49.71	+ 0 1.7
h — 37	+3 25.92	+ 9 3 3
i — 42	4 5.69	— 7 12.0
j — 42	−3 29.18	— 0 38 5
k — 44	−6 10.43	+ 2 47.6
l — 43	−4 50.68	+ 1 30 6
m — 47	$-4^{m}10^{s}.68$	$-10'\ 37''.0$
n — 1	+0 12.29	−10 36.4
o — 1	+0 22.72	— 7 13.3
p — 3	−0 10.93	+ 2 52.7
q — 5	−3 15.10	— 1 36.2
r — 4	+2 28.40	— 1 46.0
s — 7	+0 18.12	+ 5 8.2
t — 8	−1 4.36	+ 2 20.5
u — 9	−2 3.04	+ 1 17.9
v — 10	+0 21.19	−13 26.7
w — 11	−0 8.13	— 6 50.8
x — 13	+1 40.81	— 2 41.3

1) Difference in δ discordant. 2) Measured by Brown. 3) Measured by Howe.

It was not until the calculation had been finished and the results were being collected for printing that the discordance in the two values for the right ascension of *d* — 28 was noticed. Doubtless a reference to the original measures would have revealed an error in one or the other and would have made it possible to somewhat improve the third normal place.

4. Comparison of Observations with Ephemeris.

No	Date of obs.	Obs.	Cp.	*	$\Delta\alpha$	Par.	O — C	$\Delta\delta$	Par.	O — C
	1894									
1	Nov. 21.66319	B	20.7	14	$-1^{m}13^{s}.44$	$+0^{s}.09$	$-0^{s}.08$	$-\ 1'\ 45''.5$	$+6''.5$	$+\ 4''.0$
2	22 44399	J	10.5	15	+0 24.70	+0.37	−0.64	— 8 47.3	+6.3	— 8.6
3	22.70271	B	12.4	15	+1 12.20	+0.20	+0.47	— 3 23.6	+6.3	— 3.1
4	23.26008	J	5.5	16	+1 13.01	−0 03	−0.60	— 2 26.7	+7 0	— 2.8
5	23.68819	B	10.4	16	+2 29 94	+0.16	+0.25	+ 6 18.0	+6.3	— 6.6
6	25.27933	Bi	4 4	*a*	+0 8.39	−0.01	−0.40	— 0 29.7	+7.2	— 0.2
7	25.28594	„	4.4	*a*	+0 9.25	+0.01	−0.69	— 0 20.2	+7.2	+ 1.1
8	25.30237		4.4	*a*	+0 12.21	+0.04	−0.61	— 0 0.9	+7.2	+ 0.1
9	28 53181	S	4.4	19	+3 25.84	+0.08	−0.29	+10 27.2	+6.1	— 2.5
10	28.53181	»	4.4	18	+4 26 98	+0.08	−0.49	+11 45 9	+6.1	— 1.9
11	28.72265	B	12.4	21	+0 40.49	+0.25	+0.25	— 9 44.5	+5.7	+ 2.6
12	29.36272	J	6.6	20	+3 30.52	+0 22	−0.56	+ 0 18.4	+6.3	— 0.4
13	29 66878	H	10.10	*b*	−1 31.55	+0.23	−0.19	+ 1 37.7	+5.9	— 0.9
14	30.31758	J	6.5	23	+0 24.50	+0.13	−0.43	+ 1 15.3	+6.3	+ 2.2
15	30.66117	B	12.4	24	−2 46.64	+0.10	+0.20	— 5 28 5	+5.8	— 3.1
16	Dec. 1.32973	J	4 9	22	+5 36 83	+0.15	−0.26	— 5 26.3	+6.2	+ 2 2
17	1.34110	K	—	27	−5 46.74	+0.15	−0.41	— 3 48.4	+6.6	+ 2.3
18	2 27433	P	4 4	26	−2 5 07	+0.08	−0.33	— 3 35.4	+6.6	+ 0.4
19	2.32149	J	6.6	26	−1 57.34	+0.13	−0.68	— 2 35.1	+6.2	+ 1.5
20	2.36307	K	20.8	26	−1 49 55	+0.21	+0.02	— 1 43.7	+6.4	+ 1.3
21	3.36833	J	6.6	25	+1 22.39	+0.24	−0.56	— 1 45 8	+6.0	— 2.4
22	14.51562	Br	6.6	29	−0 11.03	+0.06	−0.09	+ 1 2 7	+6.3	+ 6.2
23	14.53396	»	4 4	29	−0 8.15	+0.12	−0.16	+ 1 25 6	+4 9	+ 5.3
24	14 55057	W	6.6	30	−1 52.75	+0 04	+0.02	+ 0 52.5	+5.3	+ 5.2
25	15.51355	Br	− 4	31, *c*	—	—	—	— 3 31 2	+4.8	+ 2.0
26	15 52347	»	4 −	31, *c*	+0 16 18	+0 08	+0.16	—	—	—
27	15.53182	»	− 4	31, *c*	—	—	—	— 3 8 3	+4 8	+ 2.6
28	15.54189		−.3	32, *d*	—	—	—	— 3 59 2	+4 8	+ 3 7
29	15.55090	Br & Hu	1 −	32, *d*	0 0 00	+0.14	+0.55	—	—	—
30	15 62069	H	10.10	32, *d*	+0 11 44	+0.12	+0.01	— 2 23.4	+4 9	+ 3.1
31	16.30764	J	4 4	33	+1 7.97	+0.12	−0.21	+ 3 49 1	+5.1	+ 6.3
32	17.51495	Br	4 −	35	+0 12.29	+0.07	+0.14	—	—	—
33	17.52808	„	−.5	35	—	—	—	+ 5 46.2	+4 7	+ 2.6
34	17.54065		4 −	35	+0 16.67	+0.12	+0 40	—	—	—
35	17.55356	A	1.−	35	+0 18.67	+0.15	+0.34	—	—	—
36	17.55948		−.2	35	—	—	—	+ 6 25.4	+4.6	+ 3.8

No.	Date of obs.	Obs.	Cp.	*	$\Delta\alpha$	Par.	O − C	$\Delta\delta$	Par.	O − C
	1894									
37	Dec. 17.62222	H	1.1	*e*, *f*	0$^{\rm m}$ 0$^{\rm s}$.00	+0$^{\rm s}$.13	−0$^{\rm s}$.44	0′ 0″.0	+4″.7	+ 3″.3
38	17 65716	»	10.10	*e*, *f*	+0 5 33	+0.20	−0.70	+ 0 39.2	+4.7	+ 0.2
39	18.33499	J	6.6	38	−2 41.62	+0.17	+0.18	+ 3 58.8	+5.0	+ 4 4
40	18.64086	H	10.10	*g*	+0 1.70	+0.17	+0.34	− 2 56.6	+4.6	+ 1.9
41	18.66399	W	8.4	34	+3 55.60	+0.24	+0.84	− 2 28.8	+5.0	+ 0.3
42	19 35855	J	4.5	40	−3 20 29	+0.21	+0.02	− 0 12.3	+4.9	+ 5.9
43	19.58735	St	16.−	39	−0 10.80	+0.21	+0.06	—	—	—
44	19.60218	»	−.5	39	—	—	—	− 4 6.7	+4.4	− 1.4
45	19.65045	H	14.10	40	−2 33.41	+0.19	−0.06	+ 5 34.6	+4.5	+ 2.1
46	20.60650	»	20 10	*h*	+0 3.23	+0.10	−0.68	− 2 45.1	+4.5	+ 2.3
47	21.59743	»	10.10	*i*	+0 0.70	+0.08	−0.39	+ 2 39.5	+4 5	+ 3.5
48	21.68884	W	10.6	*j*	−0 20.05	+0 27	+0.99	− 3 21.9	+4.7	+ 4.2
49	22.26650	P	5 5	*k*	−1 3 01	+0.08	−0.10	+ 0 18.3	+5.1	+ 8 4
50	22.52831	Br	4.−	41	+0 5 03	+0.10	−0.23	—	—	—
51	22.54074	»	−.5	41	—	—	—	+ 1 1.9	+4.3	+ 0.5
52	22.54914	»	4.−	41	+0 8.47	+0.14	−0.06	—	—	—
53	22 60561	H	15.10	*l*	−0 26.50	+0.09	+0.37	− 1 41.7	+4.4	+ 7.7
54	24.71044	W	6.3	45	−4 9 44	+0.29	+0 22	− 5 56.4	+4 6	[+28 1]
55	25.26631	P	5.5	45	−2 42.29	+0.08	−0.39	+ 4 29.1	+4 9	+ 2.0
56	25.60427	H	−.5	*m*	—	—	—	− 1 47 3	+4 2	+ 2.7
57	25.61772	»	2.−	*m*	+0 17 74	+0.13	+0.23	—	—	—
58	26.34684	J	4 5	47	−1 58.70	+0.19	+0.13	+ 2 0.4	+4.4	+ 0.9
59	27.30877	C	10.10	46	+1 19.45	+0.16	−0.77	− 9 8.0	+4.3	− 7.9
60	27.53061	Br & A	−.4	*n*	—	—	—	− 1 50.4	+4.0	+ 0.7
61	27.54977	Br	9.−	*n*	−0 8.02	+0.15	−0.52	—	—	—
62	27 58628	W	9.5	*o*	−0 11.01	+0.12	[+1.18]	− 4 8.2	+4.5	+ 1.9
63	28.35724	J	4.4	1	+2 10.88	+0.20	+0.29	+ 3 33.2	+4.3	+ 5.2
64	28.61323	W	8.6	2, *p*	+1 20.21	+0.17	+0.38	+ 4 43.4	+4.4	[−12.3]
65	31.59973	H	−.5	*q*	—	—	—	+ 4 8.7	+3 8	+ 1.6
66	31.61426	»	4.−	*q*	−0 4.22	+0.12	0.00	—	—	—
67	31.64491	W	8.3	*r*	−0 17.80	+0.21	−0.08	− 2 49.4	+2 4	+10.6
	1895									
68	Jan. 18.35415	J	7.8	6	+1 4.32	+0.19	−0.13	+ 0 5.0	+3.3	+ 5.5
69	19.67310	H	1.1	*s*	0 0.00	+0.21	−0.33	0 0.0	+3.0	+ 8.7
70	25.68511	B	3 6	*t*	+0 6.53	+0.18	+0.07	+ 1 55.9	+2.6	+ 1.1
71	26.67587		6.6	*u*	+0 2.36	+0.17	−0.41	− 2 11.8	+2.5	− 3.0
72	27.66756	»	5.6	*v*, *w*	−0 15.35	+0.16	−0.93	+ 1 9.7	+2.5	+ 1.5
73	28.67994		4.−	12	+0 4.81	+0.17	+0.61	—	—	—
74	28 68999		−.7	12	—	—	—	− 3 23.4	+2.5	+ 0.9
75	29 68100	»	4.6	*x*	−0 11 63	+0.17	−0.34	+ 0 50.8	+2.4	− 2.0

A = Anderson, Washington; 26 in. Equ.
B = Barnard, Mt. Hamilton; 12 in. Equ. for observations 1, 3, 5, 11, 15; 36 in. for 70 to 75.
Bi = Bigourdan, Paris; Equ. de la tour de l'Ouest.
Br = Brown, Washington; 26 in. Equ.
C = Cerulli, Teramo; 15.5 in. Equ.
H = Howe, University Park, Col.; 20 in. Equ.
Hu = Hubbard, Washington; 26 in. Equ.
J = Javelle, Nice; 0.76 m Equ.
K = Kobold, Strassburg; 18 in. Equ.
P = Palisa, Vienna; 27 in. Equ. der k. k. Sternwarte.
S = Searle, Washington; 9 in. Equ.
St = Stone, Charlottesville, Va.; 26 in. Equ.
W = Wilson, Northfield, Minn.; 16 in. Equ.

The dates are in Berlin mean time and have been corrected for aberration.

It will be noted that several positions of the comet are referred to two comparison stars. With the following exceptions both stars are in such cases given unit weight:

in observations 25 and 27, give *c* weight 0 in δ
in observations 28, 29, and 30, give 32 weight $^1/_2$ in α

The bracketed residuals have been excluded from the computation.

5. Formation of Normal Places.

The horizontal lines in the list of observations show the grouping for the normal places. As a first approximation all the observations were given unit weight and the simple means were taken. The resulting normal place residuals in the sense observation — ephemeris were found to be

	Mean Date	$\Delta\alpha$	Mean Date	$\Delta\delta$
I	Nov. 23.70	$-0^{s}.29$	Nov. 23.70	$-2''.0$
II	30.68	-0.29	30.68	$+0.1$
III	Dec. 16.21	0.00	Dec. 16.04	$+3.7$
IV	20.62	$+0.10$	20.49	$+3.3$
V	27.70	-0.05	27.92	$+2.0$
VI	Jan. 19.01	-0.23	Jan. 19.01	$+7.1$
VII	27.68	-0.20	27.68	-0.3

With these residuals as ordinates and the times as abscissae two curves were plotted which were assumed to represent the deviation of the ephemeris in α and δ from the observed positions. Then in order to gain some idea of the relative reliability of the different series of observations each observation residual was corrected by the ordinate of the curve corresponding to the instant of observation, thus forming a new series of residuals which were assumed to represent very approximately the actual errors of the individual observations, the errors of the star places being in general so small as to be negligible as compared with the errors of observation. The observations were then grouped in series according to the observer and the weight computed for each series by means of the formula

$$p = \frac{\varepsilon_0^2\,(u-1)}{[vv]}$$

where u = number of observations in each series, ε_0 = mean error of an observation of weight unity.

For this calculation assume

$$\varepsilon_0 = \pm 0^{s}.26 \text{ for } \alpha \quad\text{and}\quad \pm 2''.7 \text{ for } \delta.$$

The following table shows the results of this calculation and also the weights which were finally adopted.

Observer	u	Comput. Wt.	Adopted Wt.
Barnard, 12 in. Equatorial	5.5	— , —	0.5 , 0.5
Barnard, 36 in. Equatorial	5.5	— , 0.5	1.0 , 1.0 [1]
Bigourdan	3.3	— , —	0.8 , 0.8
Brown, Hubb. and And.	10.9	0.6 , 2.0	0.6 , 1.0 [2]
Cerulli	1.1	— , —	0.2 , 0.2
Howe	12.12	0.8 , 0.8	0.8 , 0.8 [3]
Javelle	13.13	1.0 , 1.0	1.0 , 1.0
Kobold	2.2	— , —	1.0 , 1.0
Palisa	3.3	— , —	1.0 , 1.0
Searle	2.2	— , —	0.5 , 0.5
Stone	1.1	— , —	0.5 , 0.5
Wilson	6.5	0.2 , 0.3	0.2 , 0.3

[1] Excepting observations 72 and 73, which give 0.5 , 1.0

[2] » » 29, » » 0.3 , —
» » 60, » » — , 0.5
» » 61, » » 0.3 , —

[3] » » 38 and 46, » » 0.5 , 0.8
» » 69, » » 0.5 , 0.5

In this connection the residuals in right ascension of the five observations Nos. 1, 3, 5, 11, and 15 made by Barnard with the 12 in. equatorial at Mt. Hamilton require special attention. It will be noted that in the first normal place these are the only observations giving rise to positive residuals in α. The same is true of the second normal place with the exception of observation No. 20 which gives a small positive residual. After applying to the residuals of the Barnard observations the ordinates of the normal place curve in the manner above explained the numbers representing the approximate errors of observation were

$$+0^{s}.22 \quad +0^{s}.77 \quad +0^{s}.55 \quad +0^{s}.53 \quad +0^{s}.48$$

The prevalence of positive errors of roughly the same order of magnitude would indicate the presence of some systematic difference in these observations as compared with those of the other observers; but the other observations entering into these two normal places were made by several different observers, and that a systematic error should exist in all these observations is out of the question. Upon request Professor Barnard kindly communicated the original data for his observations and they were rereduced, but without the discovery of any error in the published values. As to the possibility of his having made settings upon a different point from the other observers Prof. Barnard writes:

> »The comet was a faint object, and it is perhaps possible to have observed a different point from what others observed. My recollection is that the comet had a faint tail and a faint nucleus, consequently, unless it was well seen — because of its elongated character — one might not observe the precise center of the head, but from the fact that it was very small he could not be far out in his settings.«

Although no source could be found for the systematic difference the residuals were arbitrarily corrected by 0ˢ51 which is the mean of the five quantities given above, and the resulting residuals were given the weight 0.5.

With the application of these corrections and the new system of weights, the residuals were again combined to form normal place residuals with the following results:

	Mean Date	$\Delta\alpha$	Red.	Mean Date	$\Delta\delta$	Red.
I	Nov. 23.70	−0ˢ516	−0ˢ004	Nov. 23.70	−2″26	−0″08
II	30.68	−0.374	−0.004	30.68	+0.37	−0.06
III	Dec. 16.21	−0.036	+0 005	Dec. 16.04	+3.68	+0.02
IV	20.62	+0.022	−0.001	20.49	+3.73	+0.01
V	27.70	−0.001	+0.001	27.92	+2.11	+0.05
VI	Jan. 19.01	−0.197	−0.003	Jan. 19 01	+6.54	0.00
VII	27.68	−0.210	+0.001	27.68	−0 48	+0.01

The columns headed Red. give the values for reducing the $\varDelta\alpha$ and $\varDelta\delta$ from the mean date of observation to the nearest Berlin mean midnight. The final residuals for the normal places are therefore:

Observation — ephemeris.

	Date	$\Delta\alpha$	p_α	No. Pos.	$\Delta\delta$	p_δ	No. Pos.
I	Nov. 23 5	−0ˢ520	5.9	8	−2″34	5.9	8
II	30 5	−0.378	10 8	13	+0.31	10.8	13
III	Dec. 16.5	−0.031	7.2	12	+3.70	10.7	12
IV	20.5	+0.021	8.8	13	+3.74	9.1	12
V	27.5	0.000	5.5	10	+2.16	5.7	9
VI	Jan. 19.5	−0.200	1.5	2	+6.54	0.0	2
VII	27.5	−0.209	4.0	5	−0.47	5.0	5

The weights for the normal places are the sums of the weights of the individual observations in the normal place groups.

6. Computation of Perturbations.

The effect of Jupiter, Saturn, Mars, and the Earth upon the positions of the comet during the period of visibility were computed by the method of variation of constants. The masses used were:

$$\text{Jupiter} = \frac{1}{1047.568} \qquad \text{Saturn} = \frac{1}{3501.6}$$

$$\text{Earth} = \frac{1}{355499} \qquad \text{Mars} = \frac{1}{2680337}$$

The calculation was based upon Chandler's elements A. J. No. 338, referred to 1900.0. They are:

Epoch Dec. 1.0 1894. Equinox 1900.0.

$$\begin{aligned} M &= 8^\circ\,22'\ 1''2 \\ \pi &= 345\ \ 24\ \ 13.8 \\ \Omega &= 48\ \ 48\ \ 52.9 \\ i &= 2\ \ 57\ \ 55\ 5 \\ \varphi &= 34\ \ 52\ \ 56.9 \\ \mu &= 605''1520 \end{aligned}$$

Dec. 10.0 1894 was choosen as the epoch of osculation, and the perturbations were computed for 20 day intervals beginning with 1894 Nov. 11. The resulting perturbations in the elements were:

Date	$\varDelta i$	$\varDelta\Omega$	$\varDelta\varphi$	$\varDelta\pi$	$\varDelta L$	$\varDelta\mu$
1894 Nov. 11	+0″024	−0″257	− 0″776	− 4″788	−3″416	+0″0107
Dec. 1	+0 013	−0.116	− 0.525	− 1.804	−1.100	+0.0062
21	−0.021	+0.127	+ 0.809	+ 2.082	+0.987	−0.0091
1895 Jan. 10	−0.086	+0.335	+ 3.291	+ 7.264	+2.371	−0.0361
30	−0.196	+0.302	+ 6.933	+14.078	+2.512	−0.0753
Febr. 19	−0.371	−0.262	+11.708	+22.765	+0.814	−0.1268

From these the values for the dates of the normal places were found by interpolation — the calculated values being checked by a graphical interpolation from the curves ormed by plotting the perturbations in the elements. The quantities desired, however, are the effects of the perturbations in α and δ and these were derived from the perurbations in the elements by means of the differential ormulae given in the following section for determining the definitive corrections to the elements. These formulae are he ones given by Schonfeld in A. N. No. 2692-93 and since they involve the three elements $\varkappa$, λ and ν in place of the usual three i, Ω and ω, the perturbations in the latter elements must be transformed into perturbations in $\varkappa$, λ and ν by means of

$$\begin{aligned} d\varkappa &= d\omega + \cos i\, d\Omega \\ d\lambda &= \sin\omega\, di - \cos\omega \sin i\, d\Omega \\ d\nu &= \cos\omega\, di + \sin\omega \sin i\, d\Omega \end{aligned}$$

This transformation together with the above mentioned interpolation gives the following perturbations in the elements for the dates of the normal places.

Date	$\Delta\varkappa$	ΔM_0	$\Delta\mu$	$\Delta\varphi$	$\Delta\lambda$	Δr
1894 Nov. 23.5	− 3″002	+ 1″035	+0″0090	−0″741	−0″013	+0″017
30.5	− 1.888	+ 0.731	+0.0064	−0.544	−0.009	+0.011
Dec. 16.5	+ 1.115	− 0.558	−0.0049	+0.415	+0.008	−0.008
20.5	+ 1.970	− 1.028	−0.0086	+0.761	+0.015	−0.014
27.5	+ 3.600	− 2.057	−0.0165	+1.484	+0.029	−0.026
1895 Jan. 19.5	+10.267	− 7.624	−0.0531	+4.874	+0.109	−0.076
27.5	+13.128	−10.546	−0.0706	+6.415	+0.152	−0.095

These quantities were then substituted into the differential formulae whose coefficients are given below and the corresponding perturbations in α and δ were found to be:

Observation — Undisturbed Position.

	Date	$\Delta\alpha\cos\delta$	$\Delta\delta$
I	1894 Nov. 23.5	− 0″347	−0″147
II	30.5	− 0.017	−0.008
III	Dec. 16.5	− 0.266	−0.128
IV	20.5	− 0.583	−0.281
V	27.5	− 1.439	−0.701
VI	1895 Jan. 19.5	− 7.009	−3.340
VII	27.5	−10.000	−4.668

Applying these perturbations with the reversed sign to the normal place residuals, after the right ascensions of the latter have been multiplied by the cosines of the declinations we derive the residuals Undisturbed Position minus Ephemeris. These are the absolute terms of the equations of condition used in determining the definitive osculating elements.

Undisturbed Position — Ephemeris.

	Date	$\Delta\alpha\cos\delta$	$\Delta\delta$
I	1894 Nov. 23.5	−7″28	−2″19
II	30.5	−5.57	+0.32
III	Dec. 16.5	−0.20	+3.83
IV	20.5	+0.90	+4.02
V	27.5	+1.44	+2.86
VI	1895 Jan. 19.5	+4.03	+9.88
VII	27.5	+6.90	+4.20

The residual in δ for the normal place of Jan. 19.5 appears to be discordant when compared with those of the other normal places. That this is actually the case becomes more certain when it is noted that all of the normal places except this one depend upon from 5 to 13 observations while this is based upon only 2, Nos. 68 and 69, and the latter of these depends upon an assumed coincidence between comet and comparison star. It was suspected that it would be impossible to pass through the normals an orbit which would give a good representation for the declination of this date, and a preliminary solution proved this to be the case. Although the errors of the positions forming this norma are not larger than those occurring in a number of other observations they are of the same sign, thus preventing compensation. A consideration of all the data led me to believe that the retention of these observations as a separate normal place would add nothing to the accuracy of the results. Nor did it seem advisable to combine them with the normals of Dec. 27.5 or Jan. 27.5 on account of the magnitude of the intervening intervals. The declinations were therefore excluded from the calculation while the righ ascensions, not presenting any special discordance, were retained and given a small weight.

7. Differential Formulae and Least Square Solution for Definitive Elements.

Transforming the ephemeris positions of the come for the dates of the normals to the equinox of 1900.0, which has been choosen for the calculation, they become:

	Date	α	δ	$\log\Delta$
I	1894 Nov. 23.5	336° 35′ 53″78	−12° 10′ 55″96	0.021015
II	30.5	341 43 40.94	− 9 46 11.10	0.045424
III	Dec. 16.5	352 56 19.98	− 4 16 47.57	0.103769
IV	20.5	355 37 46.84	− 2 56 30.25	0.118683
V	27.5	0 14 25.27	− 0 39 7.03	0.144884
VI	1895 Jan. 19.5	14 37 14.90	+ 6 15 48.73	0.220572
VII	27.5	19 23 38.89	+ 8 25 1.24	0.257886

These coordinates together with Chandler's elements referred to the equinox of 1900.0 form the basis for the calculation of the differential formulae, which, as has already been stated, was carried out according to the method of Schönfeld. The computation of these coefficients was checked by assigning arbitrary variations to the elements and determining the resulting changes in α and δ both by the differential formulae and by the ordinary ephemeris formulae.

The equations of condition thus derived are:

$$\begin{array}{llllllllll}
 & & & & & & & & & \log\sqrt{p} \\
1) & 9.9794\,d\varkappa & +0.6565\,dM_0 & +2.3668_n\,d\mu & +9.0488\,d\varphi & +9.6572_n\,d\lambda & +9.4308_n\,dr & = & 0.8619_n & 0.3854 \\
2) & 9.9645 & +0.6348 & +2.2762_n & +9.6080 & +9.6362_n & +9.4873_n & = & 0.7459_n & 0.5167 \\
3) & 9.9342 & +0.5791 & +2.0119_n & +9.9723 & +9.5599_n & +9.5660_n & = & 9.2967_n & 0.4286 \\
4) & 9.9275 & +0.5642 & +1.9257_n & +0.0184 & +9.5354_n & +9.5773_n & = & 9.9538 & 0.4722 \\
5) & 9.9159 & +0.5374 & +1.7397_n & +0.0788 & +9.4874_n & +9.5907_n & = & 0.1581 & 0.3702
\end{array}$$

$$
\begin{array}{rlllllllll}
 & & & & & & & & & \log \sqrt{p} \\
6) & 9.8882\,dx & +\,0.4481\,dM_0 & +\,1.3176\,d\mu & +\,0.1897\,d\varphi & +\,9.2873_n\,d\lambda & +\,9.5927_n\,dr & = & 0.6050 & 0.0880 \\
7) & 9.8808 & +\,0.4168 & +\,1.6076 & +\,0.2102 & +\,9.2012_n & +\,9.5816_n & = & 0.8387 & 0.3010 \\
8) & 9.6025 & +\,0.2756 & +\,1.9662_n & +\,8.9129 & +\,0.0463 & +\,9.8199 & = & 0.3404_n & 0.3854 \\
9) & 9.6141 & +\,0.2782 & +\,1.8881_n & +\,9.3537 & +\,0.0029 & +\,9.8540 & = & 9.5051 & 0.5167 \\
10) & 9.6219 & +\,0.2566 & +\,1.6157_n & +\,9.7051 & +\,9.8937 & +\,9.8998 & = & 0.5832 & 0.5147 \\
11) & 9.6205 & +\,0.2462 & +\,1.5140_n & +\,9.7506 & +\,9.8643 & +\,9.9062 & = & 0.6042 & 0.4795 \\
12) & 9.6155 & +\,0.2244 & +\,1.2715_n & +\,9.8100 & +\,9.8108 & +\,9.9141 & = & 0.4564 & 0.3779 \\
13) & 9.5623 & +\,0.0837 & +\,1.4011 & +\,9.9030 & +\,9.5390 & +\,9.9194 & = & 0.6232 & 0.3495
\end{array}
$$

The coefficients are logarithmic and the last column contains the logarithm of the square root of the weights of the equations of condition. Applying these weights and introducing new unknowns defined by the relations

$$
\left.
\begin{array}{llll}
x = [0.4900]\,dx & & t = [0.5200]\,d\varphi \\
y = [1.1600]\,dM_0 & & u = [0.5200]\,d\lambda \\
z = [2.8000]\,d\mu & & w = [0.4200]\,dr
\end{array}
\right| \quad (A)
$$

and further choosing 1.2700 as the logarithm of the unit of error, there resulted the following weighted homogeneous equations of condition (logarithmic coefficients):

$$
\begin{array}{rllllllll}
1) & 9.8748\,x & +\,9.8819\,y & +\,9.9522_n\,z & +\,8.9142\,t & +\,9.5226_n\,u & +\,9.3962_n\,w & = & 9.9773_n \\
2) & 9.9912 & +\,9.9915 & +\,9.9929_n & +\,9.6047 & +\,9.6329_n & +\,9.5840_n & = & 9.9926_n \\
3) & 9.8728 & +\,9.8477 & +\,9.6405_n & +\,9.8809 & +\,9.4685_n & +\,9.5746_n & = & 8.4553_n \\
4) & 9.9097 & +\,9.8764 & +\,9.5979_n & +\,9.9706 & +\,9.4876_n & +\,9.6295_n & = & 9.1560 \\
5) & 9.7961 & +\,9.7476 & +\,9.3099_n & +\,9.9290 & +\,9.3376_n & +\,9.5409_n & = & 9.2583 \\
6) & 9.4862 & +\,9.3761 & +\,8.6056 & +\,9.7577 & +\,8.8553_n & +\,9.2607_n & = & 9.4230 \\
7) & 9.6918 & +\,9.5578 & +\,9.1086 & +\,9.9912 & +\,8.9822_n & +\,9.4626_n & = & 9.8697 \\
8) & 9.4979 & +\,9.5010 & +\,9.5516_n & +\,8.7783 & +\,9.9117 & +\,9.7853 & = & 9.4558_n \\
9) & 9.6408 & +\,9.6349 & +\,9.6048_n & +\,9.3504 & +\,9.9996 & +\,9.9507 & = & 8.7518 \\
10) & 9.6466 & +\,9.6113 & +\,9.3304_n & +\,9.6998 & +\,9.8884 & +\,9.9945 & = & 9.8279 \\
11) & 9.6100 & +\,9.5657 & +\,9.1944_n & +\,9.7101 & +\,9.8238 & +\,9.9657 & = & 9.8137 \\
12) & 9.5034 & +\,9.4423 & +\,8.8494_n & +\,9.6679 & +\,9.6687 & +\,9.8720 & = & 9.5643 \\
13) & 9.4218 & +\,9.2732 & +\,8.9506 & +\,9.7325 & +\,9.3685 & +\,9.8489 & = & 9.7027
\end{array}
$$

The usual least square method gave as normal equations (numerical coefficients):

$$
\begin{array}{rllllllll}
1) & +\,4.2893\,x & +\,4.0257\,y & -\,2.7810\,z & +\,3.8095\,t & +\,0.1734\,u & +\,0.2153\,w & +\,0.2722 & = 0 \\
2) & +\,4.0257 & +\,3.8040 & -\,2.7452 & +\,3.4000 & +\,0.1372 & +\,0.1669 & +\,0.5226 & = 0 \\
3) & -\,2.7810 & -\,2.7452 & +\,2.5497 & -\,1.4801 & +\,0.0256 & +\,0.0375 & -\,1.6937 & = 0 \\
4) & +\,3.8095 & +\,3.4000 & -\,1.4801 & +\,4.7055 & +\,0.3146 & +\,0.3909 & -\,1.7799 & = 0 \\
5) & +\,0.1734 & +\,0.1372 & +\,0.0256 & +\,0.3146 & +\,3.5163 & +\,3.8867 & -\,1.6398 & = 0 \\
6) & +\,0.2153 & +\,0.1669 & +\,0.0375 & +\,0.3909 & +\,3.8867 & +\,4.8210 & -\,2.0085 & = 0
\end{array}
$$

The similarity of the coefficients of the first and second and of the fifth and sixth equations indicated that one or nore of the unknowns would be affected with considerable uncertainty, and a preliminary solution showed x and y to be indeterminate. Rewriting the normals so that these unknowns appeared last in the solution the following elimination equations were found (logarithmic coefficients):

$$
\begin{array}{rllllllll}
1) & 0.40649\,z & +\,0.17030_n\,t & +\,8.40909\,u & +\,8.57461\,w & +\,0.44420_n\,x & +\,0.43858_n\,y & +\,0.22884_n & = 0 \\
2) & & 0.58504 & +\,9.51786 & +\,9.61563 & +\,0.34145 & +\,0.25682 & +\,0.44140_n & = 0 \\
3) & & & 0.54255 & +\,0.58557 & +\,8.12710 & +\,8.00432 & +\,0.14179_n & = 0 \\
4) & & & & 9.71950 & +\,7.77815 & +\,7.38917 & +\,9.19493_n & = 0
\end{array}
$$

By successive substitution w, u, t and z were expressed as functions of x and y through (log. coefficients):

$$
\left.
\begin{array}{lll}
w = 8.05865_n\,x & +\,7.66967_n\,y & +\,9.47543 \\
u = 7.94448 & +\,7.35411 & +\,8.82905 \\
t = 9.75604_n & +\,9.67150_n & +\,9.83286 \\
z = 9.88069 & +\,9.90540 & +\,0.02295
\end{array}
\right| \quad (B)
$$

and substituting these into the original homogeneous weighted equations of condition the following series was found for he determination of x and y (logarithmic coefficients):

1) $8.3414\,x + 7.5119\,y + 8.5587_n = 0$
2) $7.5563 + 7.1139 + 8.8817 = 0$
3) $8.2455_n + 7.4771_n + 8.6702_n = 0$
4) $8.2900_n + 7.5563_n + 8.8621_n = 0$
5) $8.0755_n + 7.3802_n + 7.7993 = 0$
6) $8.0792 + 7.3222 + 9.0328 = 0$
7) $8.5198 + 7.7559 + 8.5011_n = 0$
8) $8.0043 + 7.1139 + 9.2750 = 0$
9) $7.3424 + 6.6990 + 7.7672 = 0$
10) $7.9777_n + 7.1614_n + 9.3228 = 0$
11) $7.9395_n + 7.1761_n + 9.1638 = 0$
12) $7.6812_n + 6.9777_n + 9.1126 = 0$
13) $8.2553 + 7.4914 + 9.2653 = 0$

Check $[nn\cdot 4] = 0.1829$ $[n'n'] = 0.1829$

New unknowns defined by

$$x' = [8.5200]\,x \qquad y' = [7.7600]\,y \qquad \text{(C)}$$

were introduced to secure homogeneity and the resulting series was solved by least squares. The normal equations for x' and y' were (numerical coefficients):

$$+2.9052\,x' + 2.8490\,y' + 0.2745 = 0$$
$$+2.8490 + 2.8292 + 0.2601 = 0$$

Here again the similarity in coefficients denoted uncertainty in the solution, but as y' appeared to be the more uncertain of the two, x' was expressed in terms of y' giving (logarithmic coefficients):

$$x' = 9.99152_n\,y' + 8.97544_n \qquad \text{(D)}$$

This value for x' substituted into the equations of condition for x' and y' gave the following series for the determination of y' (numerical coefficients):

1) $-0.0851\,y' - 0.0988 = 0$
2) $+0.1193 + 0.0659 = 0$
3) $-0.0001 - 0.0034 = 0$
4) $-0.0482 - 0.0172 = 0$
5) $-0.0647 + 0.0970 = 0$
6) $+0.0095 + 0.0736 = 0$
7) $+0.0104 - 0.1261 = 0$
8) $-0.0732 + 0.1595 = 0$
9) $+0.0217 - 0.0004 = 0$
10) $+0.0293 - 0.1832 = 0$
11) $-0.0031 - 0.1210 = 0$
12) $-0.0230 + 0.1433 = 0$
13) $+0.0056 + 0.1328 = 0$

Check $[nn\cdot 5] = 0.1570$ $[n''n''] = 0.1569$

A new unknown y'' was introduced such that

$$10\,y'' = y'$$

and the series solved for y'' giving

$$\log y'' = 8.40572$$

whence $\log y' = 9.40572$

The residuals for the normal places were found by substituting y' into the above equations of condition. When squared and added

$$[vv] = 0.1547$$

while from the elimination, as a check,

$$[nn\cdot 6] = 0.1546$$

Then by successive substitution of y' into (D), of x' and y' into (C), and finally of x and y into (B) the most probable values of the unknowns were found to be

$\log x = 1.0167_n$ $\log t = 1.1509_n$
$\log y = 1.6457$ $\log u = 8.8806$
$\log z = 1.4584$ $\log w = 9.3244$

Restoring the original unknowns by (A) and reintroducing the second of arc as the unit of measurement the following corrections to the elements chosen for the calculation were obtained.

$\log d\varkappa = 1.7967_n$ $\log d\varphi = 1.9009_n$
$\log dM_0 = 1.7557$ $\log d\lambda = 9.6306$
$\log d\mu = 9.9284$ $\log d\nu = 0.1744$

The corrections to i, ω and ☊ were derived from $d\varkappa$, $d\lambda$ and $d\nu$ by

$$di = \cos\omega\, d\nu + \sin\omega\, d\lambda$$
$$\sin i\, d☊ = \sin\omega\, d\nu - \cos\omega\, d\lambda$$
$$d(☊ + \omega) = d\varkappa + \mathrm{tg}\,{}^1\!/_2\, i \sin i\, d☊$$
$$d(☊ - \omega) = -d\varkappa + \mathrm{ctg}\,{}^1\!/_2\, i \sin i\, d☊$$

As thus determined the final corrections to Chandler'
elements are

$dM_0 = +57''0$ $d☊ = -29''5$
$d\mu = +0''8479$ $d\pi = -62''7$
$d\varphi = -79''6$ $d\omega = -33''2$
$di = +0''3$ $dL = -5''7$

whence the definitive osculating elements:

Epoch 1894 Dec. 1.0. Osculation 1894 Dec. 10.0.

$M_0 = 8°\,22'\,58''2 \pm 4''2$
$\pi = 345\;\,23\;\,11.1 \pm 4.4$ } 1900.0
☊ $= 48\;\,48\;\,23.4 \pm 27.7$ } 1900.0
$i = 2\;\,57\;\,55.8 \pm 1.4$ } 1900.0
$\varphi = 34\;\,51\;\,37.3 \pm 7.1$
$\mu = 605''9999 \pm 0''0665$

The appended quantities are the mean errors an
are based upon the standard value for a single observatio
of unit weight

$$\varepsilon_0 = \pm 2''8$$

computed from the residuals of the equations of condition

To test the accuracy of the least square solution th
definitive corrections were substituted into the origina
equations of condition; the resulting residuals were squared
multiplied by the proper weight, and added with the resul

$$[vv] = 54''0$$

The value of $[nn\cdot 6]$ from the least square solutio
was 0.1546. Expressed in seconds of arc

$$[nn\cdot 6] = 53''6$$

The agreement is satisfactory in view of the fact that only four places of decimals have been used in the solution. The reduction in the sum of the squares of the weighted residuals is from

1349″3 to 54″0

Finally the definitive elements were used to compute the undisturbed positions of the comet for the dates of the normal places. To these the perturbations were applied and the results compared with the observed positions. The outstanding differences, in the sense obs. — comput., resulting from a six place calculation are tabulated below, together with the residuals obtained by direct substitution of the definitive corrections to the elements into the equations of condition.

Date	$\Delta\alpha \cos\delta$		$\Delta\delta$	
	Def. Elem.	Diff. Form.	Def. Elem.	Diff. Form.
1894 Nov. 23.5	+0ˢ09	+0ˢ07	−0″9	−1″1
30.5	−0.04	−0.03	0.0	0.0
Dec. 16.5	+0.01	0.00	+1.2	+1.0
20.5	0.00	+0.01	+0.8	+0.8
27.5	−0.05	−0.04	−1.2	−1.1
1895 Jan. 19.5	−0.03	−0.08	—	—
27.5	+0.07	+0.07	−1.3	−1.1

In order to determine the effect of small variations in dμ upon the sum of the squares of the weighted residuals the values of the increments to the other elements were substituted into the weighted observation equations and the numerical terms were summed. The resulting equations of condition for dμ were found to be:

1) $2.7522_n \, d\mu + 1.4085 = 0$
2) $2.7929_n + 1.4527 = 0$
3) $2.4405_n + 1.0990 = 0$
4) $2.3979_n + 1.0549 = 0$
5) $2.1099_n + 0.7741 = 0$
6) $1.4056 + 0.0341_n = 0$
7) $1.9086 + 0.5811_n = 0$
8) $2.3516_n + 1.0159 = 0$
9) $2.4048_n + 1.0634 = 0$
10) $2.1304_n + 0.7761 = 0$
11) $1.9944_n + 0.6405 = 0$
12) $1.6494_n + 0.3368 = 0$
13) $1.7506 + 0.3860_n = 0$

in which the coefficients are logarithmic, and the logarithm of the unit of measurement is 1.2700.

The definitive value for log dμ was found by the least square solution to be 9.9284. The variations

+0.0100 +0.0020 −0.0020 −0.0100

were successively applied to this logarithm and the resulting values were substituted in the above series of equations. The residuals found by each substitution were squared and added. The following table exhibits the relation between the sums and the variations assumed for dμ.

log dμ	Δdμ	$[pvv]$
9.9384	+0″0199	455″
9.9304	+0.0041	71
9.9284	0.0000	54
9.9264	−0.0037	68
9.9184	−0.0192	427

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