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XV. *Observations of the changeable Brightness of the Satellites of Jupiter, and of the Variation in their apparent Magnitudes; with a Determination of the Time of their rotatory Motions on their Axes. To which is added, a Measure of the Diameter of the Second Satellite, and an Estimate of the comparative Size of all the Four.* By William Herschel, LL.D. F. R. S.

Read June 1, 1797.

IT may be easily supposed when I made observations on the brightness of the 5th satellite of Saturn, by way of determining its rotation upon its axis, and found that these observations proved successful, that I should also turn my thoughts to the rest of the satellites, not only of Saturn, but likewise of Jupiter, and of the Georgian planet. Accordingly I have from time to time, when other pursuits would permit, attended to every circumstance that could forward the discovery of the rotation of the secondary planets; especially as there did not seem to lie much difficulty in the way. For since I have determined, by observation, that the 5th satellite of Saturn is in its rotation subject to the same law that our moon obeys, it seems to be natural to conclude that all the secondary planets, or satellites, may probably stand in the same predicament with the two I have mentioned; consequently a few observations that coincide with this proposed theory, will go a good way towards a confirmation of it.

I had another point in view when I made the observations

which are contained in this paper. It was an attempt to avail myself of the abundant light and high powers of my various telescopes, to examine the nature and construction of the bodies of the satellites themselves, and of their real magnitudes. Here phænomena occurred that will perhaps be thought to be remarkable, and even inconsistent or contradictory. So far from attempting to lessen the force of such animadversions, I shall be the first to point out difficulties, in order that future observations may be made to resolve them.

Perhaps it would have been better to delay the communication of these observations, till I had continued them long enough to be able to account for things which at present must be left doubtful. But as in final conclusions to be drawn from astronomical observations, we ought to take care not to be precipitate; so on the other hand I am perhaps too scrupulous in satisfying myself, and should probably require the observations of several years before I could venture to be decisive. It will also be seen by the dates of the first observations, that a further delay in the communication cannot be adviseable; since much information may possibly be gained by throwing open, to other observers, the road it will be eligible to take for a satisfactory investigation of the subject; especially as we have reason to congratulate ourselves on the spirit of observation, and increase of large instruments, that seem to have taken place in various parts of Europe.

I shall now transcribe the observations from my journals. They are as follows.

## OBSERVATIONS.

*A remarkable Conjunction of two Satellites of Jupiter.*

May 14, 1790.  $11^{\text{h}} 30' 10''$ ; correct sidereal time. The 2d and 3d satellites of Jupiter are so closely in conjunction, that with a 7-foot reflector, charged with a magnifying power of 350, I cannot see a division between them.

$11^{\text{h}} 34' 10''$ . The shadow of the 1st satellite is still upon the disc of the planet.

*Intenseness of Light and Colour of the Satellites.*

July 19, 1794.  $17^{\text{h}} 12' 47''$ . 7-foot reflector. The 1st satellite of Jupiter is of a very intense bright, white, shining light. It is brighter than the 2d or 4th. I speak only of the light, and not of the size.

The colour of the 4th satellite is inclining to red. In brightness it is very nearly, but not quite equal to the 2d. I make no allowance for its being farther from the bright disc of Jupiter than the 2d.

10-foot reflector, power 170. The 3d satellite is just gone upon the body; before it went on, it appeared to me to be smaller than usual.

The 2d satellite is of a dull, ash-colour; not in the extreme, but rather inclining to that tint.

July 21, 1794.  $16^{\text{h}} 56' 45''$ . 10-foot reflector; power 170. The 3d satellite of Jupiter is round, large, and well defined. It is very bright, and its light is very white.

The 4th satellite is also round, large, and well defined. I estimate its magnitude in proportion to that of the 3d satellite to be as 4 to 5. Its light is not white, but inclined to orange.

*Brightness and Diameter distinguished.*

July 26, 1794.  $17^{\text{h}} 14' 41''$ . 10-foot reflector; power 170. The 4th satellite is very dim. It is of a pale, dusky, reddish colour.

The 2d satellite is of a bright, white colour.

The 3d satellite is very bright, and white.

The 1st satellite is very brilliant, and white.

$17^{\text{h}} 22' 41''$ . *The Magnitudes with 240.*

The 3d satellite is the largest.

The 2d satellite is the smallest.

*With 300.*

The 4th satellite is a very little larger than the 2d, though less bright.

The 1st satellite is larger than either the 4th or 2d.

With 400, the order of the magnitudes is 3 1 4 2.

With the same power, the order of the light is 3 1 2 4.

Now and then it appeared to me doubtful whether the 4th satellite was larger than the 2d; and as their light is of an unequal intensity, it is difficult without much attention, to be decisive about the magnitudes.

*Diameter of the second Satellite by entering on the Disc of the Planet.*

July 28, 1794.  $17^{\text{h}} 25' 40''$ . 10-foot reflector; power 170. The 2d satellite is nearly in contact with the following limb of Jupiter.

17<sup>h</sup> 29' 40". It seems to be very near the contact. With 300, very near the contact.

17<sup>h</sup> 30' 40". It seems to be in contact. It is brighter than that part of Jupiter where it enters.

17<sup>h</sup> 31' 40". It is more than half entered.

17<sup>h</sup> 33' 40". It seems to be nearly quite entered. Its superior brightness makes it seem protuberant.

17<sup>h</sup> 34' 40". It is certainly quite entered.

17<sup>h</sup> 35' 25". I see a little of the disc of Jupiter on the outside of the satellite, equal to about  $\frac{1}{4}$  of its diameter.

17<sup>h</sup> 39' 40". The 3d satellite is very bright, and of its usual colour.

The 4th satellite is faint, and also of its usual colour.

The 1st satellite is very bright, and the light of it is of its usual intensesness.

#### *The Magnitudes with 300.*

The diameter of the 4th seems to be to that of the 3d, as 2 to 3; or perhaps more exactly, as 3 to 5.

The diameter of the 4th satellite exceeds that of the 1st a very little.

#### *With 400.*

With this power the diameter of the 4th satellite certainly exceeds that of the 1st.

The diameter of the 4th, is to that of the 3d, as 3 to 5.

July 30, 1794. 19<sup>h</sup> 1' 37". 10-foot reflector; power 300. The 4th satellite of Jupiter is a little larger than the 1st. It is of its usual colour.

The 2d is less than the 1st.

The 3d is larger than the 4th.

July 31, 1794. 17<sup>h</sup> 18' 38". 10-foot reflector; power 170.  
The four satellites of Jupiter are very favourably placed for my purpose.

The 1st is less bright than the 2d; it is a very little larger than the 2d: the difference in the size is but barely visible.

The light of the 2d is very intense and white.

The light of the 3d is very intense and bright.

The light of the 4th is dull; and seems to be inferior to the usual proportion it bears to the other satellites.

18<sup>h</sup> 38' 38". *With* 300.

The 4th satellite is larger than the 1st.

The 2d satellite is a little larger than the 1st, or at least equal to it.

The 3d is undoubtedly the largest. The order of the magnitudes therefore is, 3 4 2 1.

My Brother, ALEXANDER HERSCHEL, looked at the satellites, and estimated the order of their magnitudes exactly the same; though he was not present when I made the foregoing estimations.

August 1, 1794. 17<sup>h</sup> 38' 37". 10-foot reflector; power 170.  
The light of all the four satellites is very brilliant, the evening being very fine.

*With* 300.

The northmost and farthest of the two satellites which are in conjunction, is the smallest: I suppose it to be the 2d.

The southmost and nearest of the two satellites in conjunction, is the next in size: I suppose it to be the 1st.

The 4th satellite is a little larger than the largest of the two satellites which are in conjunction; but the difference is only visible with a great deal of attention.

The 3d satellite is much larger than the 4th.

August 9, 1794.  $17^{\text{h}} 56' 32''$ . 10-foot reflector; power 170. The light of the 1st satellite is very intense and white.

The light of the 2d satellite is also pretty intense and white.

The light of the 3d satellite is neither so intense nor so white as that of the 1st.

The light of the 4th is dull and of a ruddy tinge.

With 300, and 400, the second is the least, and the 3d is the largest. I am in doubt whether the 4th or the 1st is largest; with 600, I suppose the 1st to be larger than the 4th.

September 30, 1795.  $20^{\text{h}} 15' 17''$ . 7-foot reflector; power 210. Order of the magnitudes of the satellites of Jupiter 3 - 2 . 1 , 4. Power 110. 3 - 2 , 1 . 4. With 460, 3 - 2 , 1 , 4.\*

October 2, 1795.  $20^{\text{h}} 18' 22''$ . 7-foot reflector; power 287. Jupiter's satellites 3 - - 2 - 1 , 4. The 2d and 3d satellites are not yet in conjunction.

$20^{\text{h}} 43' 22''$ . The conjunction between the 3d and 2d satellites is past. The distance between them is now one diameter of the 3d.

August 18, 1796.  $18^{\text{h}} 47' 21''$ . 7-foot reflector; power 287. The 4th satellite is less bright than the 1st; notwithstanding

\* Here, in order to denote the different magnitudes of the satellites, I used the notation which has been explained in my *First Catalogue of the comparative Brightness of the Stars*. See Phil. Trans. for the year 1796, Part I. page 189.



the latter is so near the planet as to have its light overpowered by Jupiter, while the 4th is at a great distance. I mean light or brightness, not magnitude.

The 1st is very bright.

September 15, 1796.  $19^{\text{h}} 25' 25''$ . 10-foot reflector; power 300. The 2d satellite of Jupiter is a little less than the 1st.

The 3d is much larger than any of the rest.

Power 600. The difference in the magnitude of the 1st and 2d satellites, with this power, is pretty considerable.

September 21, 1796.  $19^{\text{h}} 24' 5''$ . 10-foot reflector; power 600. The shadow of the 1st satellite is upon one of the dark belts of Jupiter.

In order to use very high powers with this telescope, I tried it upon the double star  $\zeta$  Aquarii with 1200. The air is very tremulous, but I see now and then the two stars of this double star very well defined.

With the same power, the satellites of Jupiter are very large, but not so well defined as the above star.

*The Brightness of the Satellites compared to the Belts and Disc of the Planet.*

The 1st satellite, which is lately come off the southern belt, is nearly of the same brightness with that belt; power 600. With 400, it is nearly as bright as the brighter part of the planet, or rather a mean between the belt and the planet.

The 2d satellite is considerably bright; its colour is whiter than that of the 1st; it is however not so white as the colour of the bright part of Jupiter.

The colour of the 4th satellite is as dingy as that of the belt; very much less bright and less white than that of the 2d.

The brightness of the 3d satellite is not intense; its colour, however, is white, though not so white as the bright part of the planet.

September 24, 1796. 20<sup>h</sup> 55' 24". 10-foot reflector; power 600. The 1st satellite of Jupiter is very bright, and of a white colour; it is also very large.

The 2d satellite is faint and bluish; its light is not much brighter than that of the belt.

The 3d satellite is pretty bright; its light is whitish. It seems to be comparatively less than it ought to be; or rather, its apparent smallness is owing to the uncommon largeness of the 1st.

The 1st satellite, with 200, compared to the 3d, is proportionally larger than I have seen it before.

September 30, 1796. 20<sup>h</sup> 8' 4". 10-foot reflector; power 600. The satellites of Jupiter are well defined, and the night is beautiful.

The 3d satellite, in proportion to the 1st, is much larger than it was September 24. I ascribe the change to an apparent diminution of the 1st.

20<sup>h</sup> 30' 4". The 1st satellite is evidently less in proportion to the 3d, than it was September 24.

The 2d satellite is considerably bright; its light is whitish; much brighter than the belt, but not so bright as the bright part of the disc. Its magnitude is less than that of the 4th; but its light is considerably superior.

The 3d satellite is remarkably well defined. Its light is considerably brighter than that of the belts.

The magnitude of the 1st satellite exceeds that of the 2d. It is nearly equal to that of the 4th.

22<sup>h</sup> 58' 4". Appearances as before.

October 15, 1796. 21<sup>h</sup> 23' 42". 10-foot reflector; power 600. The 2d satellite is uncommonly bright; its apparent magnitude is also larger than usual.

The 4th satellite is very faint; it is not brighter than the belt, but is of a bluish, ruddy colour.

The apparent magnitude of the 2d satellite, after long looking, is very nearly equal to that of the 1st; but at first sight it seems to be larger, owing to its superior brightness.

The apparent diameter of the 2d satellite is certainly larger than that of the 4th.

23<sup>h</sup> 55' 42". The light of the 1st satellite, compared to that of the 2d, is considerably increased since the last observation. It is now nearly as bright as the 2d.

October 16, 1796. 0<sup>h</sup> 23' 49". 10-foot reflector; power 600. The 1st, 2d, and 3d satellites of Jupiter seem all considerably bright.

The 3d is much larger than the 1st, and the 1st a little larger than the 2d.

The intensity of the light seems to be pretty equal in all the three; that of the 2d, however, is perhaps a little stronger than that of the 1st; for, notwithstanding its apparent less diameter, it seems to make as strong an impression as the 1st.

October 25, 1796. 21<sup>h</sup> 44' 48". 10-foot reflector; power 600. The 1st satellite of Jupiter, compared to the 3d, is small.

The 3d satellite is bright and large.

The 2d is brighter than the 1st. Compared to its usual brightness and magnitude, it is very bright and small.

The 1st satellite, compared to its usual brightness and magnitude, is faint and small.

The air is so tremulous that the power of 600 is too high, and the necessary uniformity required in these observations will not permit a lower to be used. Perhaps one of 400 might be more generally employed; and it may be proper to use it constantly.

November 3, 1796.  $23^{\text{h}} 55' 47''$ . 10-foot reflector; power 600. The 4th satellite of Jupiter is large and bright.

The 3d satellite is large and bright.

The 1st satellite is pretty small, and not very bright.

The 2d satellite is small, and considerably bright.

The brightness and magnitude of each satellite refer to its own usual brightness and magnitude.

Before we can proceed to draw any conclusions from these observations, we ought to take notice of many causes of deception, and of various difficulties that attend the investigation of the brightness of the satellites.

The difference in the state of the atmosphere between two nights of observation, cannot influence much our estimation of the brightness of a satellite, provided we adopt the method of comparative estimations. If we endeavour by much practice to fix in our mind a general ideal standard of the brightness of each satellite, we shall find the state of the atmosphere in different nights very much disposed to deceive us; but if we learn to acquire a readiness of judging of the comparative brightness of each satellite with respect to the other three, we may arrive at much more precision, since the different disposition of the air will nearly affect all the satellites alike. But here, as we get rid of one cause of deception, we fall under the penalty of another. The situation of those very satellites to which we are

to refer the light of the satellite under estimation, being changeable, permits us no longer to trust to their standard, without a full scrutiny of the causes that may have produced an alteration in them.

In the foregoing observations it will also be seen, that I attempted to compare the intenseness of the light of the satellites with the different brightness of the disc of Jupiter; but these endeavours will always fail, on account of the little assurance we can have that the parts of the disc, setting aside its quick rotation, will remain for any time of the same lustre.

A very material difficulty arises from the magnifying power we use in our estimations. If it be a low one, such as for instance 180 (for a lower should not even be attempted), then we run the risk of being disappointed in bright nights by the sparkling of the brilliant light of the satellites. Besides, we cannot then see the bodies of them, and judge of their comparative magnitude, with the same power that we view their light. If we choose a high magnifier, we shall be often disappointed in the state of the atmosphere, which will of course occasion an interruption in the series of our observation, of which the regular continuance is of the greatest consequence. If we change our power according to the state of the atmosphere, we introduce a far worse cause of confusion; for it will be next to impossible to acquire, for each magnifying power, an ideal standard of comparative brightness to which we can trust with confidence.

If the magnitudes are not attended to, and carefully contradistinguished from the intenseness of light, we shall run into considerable error, by saying that a satellite is large, when we mean to express that it is bright. It is so common to call stars that are less bright than others, small, that we must be careful

to avoid such ambiguities, when the condition of the satellites is under investigation. Nor is it possible to throw the size and light into one general idea, and take the first *coup d'oeil* in looking at them, to decide about the general impression this compound may make. When our attention is forcibly drawn by a considerable power to the apparent size of the satellite we are looking at, its brightness can no longer be taken in that general way, but must be abstracted from size.

Let us now see what use may be drawn from the observations I have given.

It appears in the first place very obviously, that considerable changes take place in the brightness of the satellites. This is no more than might be expected. A variegated globe, whether terraqueous like the earth, or containing regions of soil of an unequal tint, like that side of the moon which is under our inspection, cannot, in its rotation, present us with always the same quantity of light reflected from its surface.

In the next place, the same observations point out what we could hardly expect to have met with; namely, a considerable change in the apparent magnitude of the satellites. Each of them having been at different times the standard to which another was referred, we cannot refuse to admit a change so well established, singular as it may appear.

The first of these inferences proves that the satellites have a rotatory motion upon their axes, of the same duration with their periodical revolutions about the primary planet.

The second either shews that the bodies of the satellites are not spherical, but of such forms as they have assumed by their quick periodical and slow contemporary, rotatory motions, and which forms in future may become a subject for mathematical

investigation ; or it may denote, in case geometrical researches should not countenance a sufficient deviation from the spherical form, that some part of the discs of these satellites reflects hardly any light, and therefore in certain situations of the satellite makes it appear of a smaller magnitude than in others.

Here then we see evidently that a considerable field for speculation, as well as observation, is opened to our view ; and almost every attempt to enter upon the work must seem premature, for want of more extended observations. However, from those that have been given, such as they are, I will shew how far we may be authorized to say, that the satellites revolve on their axes in the same time that they perform a periodical revolution about the planet.

I shall take the usual method of throwing the observations of each satellite into a graduated circle. The zero of the degrees into which I suppose it divided, is in all observations assumed to be in the place of the geocentric opposition.

In order to bring these observations to the circle, the places of the satellites have been calculated from my own tables of the mean motion in degrees, and according to epochs continually assumed from the geocentric conjunctions pointed out in the configurations of the Nautical Almanac ; and the nearest of these conjunctions have been always used. This method is fully sufficient for the purpose, as greater precision in the calculation is not required.

The observations extend from July 19, 1794, to November 3, 1796 ; and therefore include a period which takes in 470 rotations of the 1st satellite ; 234 of the 2d ; 116 of the 3d ; and 50 of the 4th : that is, provided we admit that these rotations

are performed in the same time the satellites revolve in their orbits.

In the following table are the calculated places of the satellites; the correct sidereal times, given with the observations, having been turned into mean time.

*Table of the Positions of the four Satellites of Jupiter at the Time of the Observations.*

Time of Observ.	I	II	III	IV	Time of Observ.	I	II	III	IV
1794. July 19 <sup>d</sup> 9 <sup>h</sup> 21'	127 <sup>o</sup>	346 <sup>o</sup>	179 <sup>o</sup>	46 <sup>o</sup>	1796. Aug. 18 <sup>d</sup> 8 <sup>h</sup> 21'	115 <sup>o</sup>	o	o	191 <sup>o</sup>
July 21. 8. 57			278	89	Sept. 15. 7. 44	36	328	198	
July 26. 8. 56	124	333	169	205	Sept. 21. 7. 19	172	214	138	210
July 28. 8. 59	171	176	270	248	Sept. 24. 8. 38	74	163	305	275
July 30. 10. 27	231	25	13	292	Sept. 30. 7. 27	206	46	244	36
July 31. 8. 40	59	118	60	312	Oct. 15. 7. 44	28	130		5
Aug. 1. 8. 56	265	221	111	334	Oct. 15. 10. 15	49			
Aug. 9. 8. 42	83	310	152	138	Oct. 16. 10. 39	256	243	334	
1795. Sept. 30. 7. 37	294	62	219	100	Oct. 25. 7. 25	261	72	59	
Oct. 2. 7. 32	341	264	319	143	Nov. 3. 9. o	306	270	151	58

It will be necessary now to explain in what manner, with the assistance of this table, the observations of the brightness and magnitudes of the satellites have been reduced to the expressions they bear in the four circles of the figures contained in Tab. VIII. and IX. By way of uniformity I judged it would be best to reduce the estimations of magnitude to those of brightness; as it may be justly supposed that when a satellite is at any given time larger in proportion to another than it was at another time, it will also be brighter than it was at that other time, due regard being had to the light of the satellite to which its magni-



tude has been compared. To manage the space allotted to the figure advantageously, I have used the abbreviations formerly employed in my catalogue of Nebulæ, *v* B, *c* B, B, *p* B, *p* F, F, *c* F, *v* F, for all the gradations of light that are necessary to express the brightness of the satellites at the time of observation. It will be easily remembered that B and F mean bright and faint; and *p*, *c*, *v*, stand for pretty, considerably, and very.

Now, when the observation mentions the brightness of the satellite, I place it in the figure as it is given. In that of the first, for instance, July 19, 1794, we find the satellite called very bright; I therefore put down in fig. 1. (Tab. VIII.) at 127 degrees, *v* B. But where the brightness is not expressed, I have recourse to the comparative magnitude, if that can be had. By fig. 3. (Tab. IX.) it appears that the 2d satellite is less subject to a change of brightness than either the 1st or 4th: it becomes, for that reason, a pretty good standard for the light of these other satellites. Therefore, in the observation of October 2, 1795, for instance, where the 1st satellite is described as undoubtedly less than the 2d, I put down very faint, or *v* F, at 341 degrees of the circle in fig. 1.; for in the observation of July 19, before mentioned, when the satellite was called very bright, it was at the same time described as undoubtedly larger than the 2d. In this case, as regard must be had to the relative state of the satellite we refer to, the four figures I have given will assist us in determining the condition of the light of the satellite we wish to admit as a standard.

In reducing the 2d satellite to the circle, I have generally used a reference to the magnitude of the 1st, where marks of

brightness were wanting; and sometimes also to the magnitude of the 4th, and even of the 3d.

The 3d satellite can hardly be ever compared to any but the 2d in magnitude; and this only in its degree of excess.

The magnitude of the 4th satellite has been generally compared with that of the 1st; and also sometimes with that of the 2d.

To make an application of the contents of the figures, will now require little more than a bare inspection of them.

The 1st satellite appears evidently to have a rotation upon its axis that agrees with its revolution in its orbit. It cannot be supposed that, in the course of 470 revolutions, all the bright observations could have ranged themselves in one half of the orbit, while the faint ones were withdrawn to the other. The satellite appears in the middle of the duration of its brightness, when it is nearly half way between its greatest eastern elongation, in the nearest part of its orbit; or when advancing towards its conjunction. I have pointed out this circumstance by a division with dotted lines, and the words bright and faint, inserted within the circle, fig. 1. This satellite, therefore, revolves on its axis in  $1^d 18^h 26',6$ .

The 2d satellite, though much less subject to change, on account, as we may suppose, of having only a small region on its body which reflects less light than the rest; has, nevertheless, its rotation directed by the same law with the 1st. It will hardly be necessary to take notice of a single deviation which occurs at 163 degrees, fig. 2.; as from the proximity of the satellite to the conjunction, a mistake in the estimation may easily take place. I generally made it a rule not to make

allowance for the influence of the superior light of the planet; but it seems that we can hardly abstract sufficiently on such occasions. Two similar cases occur, in fig. 3. at 179; and fig. 4. at 5 degrees.

It is indeed not impossible but that occasional changes, on the bodies of the satellites themselves, may occasion some temporary irregularity of their apparent brightness: it will, however, not be necessary to make such an hypothesis, till we have better authority for it. The brightest side of this satellite is turned towards us when it is between the greatest eastern elongation and the conjunction. It revolves, consequently, on its axis in  $3^{\text{d}} 18^{\text{h}} 17',9$ .

The 3<sup>d</sup> satellite suffers but little diminution of its brightness, and is in full lustre at the time of both its elongations. It is however not impossible but that, after having recovered its light, on the return from the opposition, it may suffer a second defalcation of it in the nearest quadrant about half way towards the conjunction. The two independent observations at 151 and 152 degrees, fig. 3. seem to give some support to this surmise. It revolves on its axis in  $7^{\text{d}} 3^{\text{h}} 59',6$ .

The 4<sup>th</sup> satellite presents us with a few bright views when it is going to its opposition, and on its return towards the greatest eastern elongation; but otherwise it is generally overcast. Its colour also is considerably different from that of the other three; and it revolves on its axis in  $16^{\text{d}} 18^{\text{h}} 5',1$ .

It will not be amiss to gather into one view, all the observations that relate to the colour of the satellites.

The 1<sup>st</sup> is white; but sometimes more intensely so than at others.

The 2<sup>d</sup> is white, bluish, and ash-coloured.

The 3d is always white; but the colour is of different intensity, in different situations.

The 4th is dusky, dingy, inclining to orange, reddish and ruddy at different times; and these tints may induce us to surmise that this satellite has a considerable atmosphere.

I shall conclude this paper with a result of the observation of the diameter of the second satellite, taken by its entrance upon the disc of the planet, July 28, 1794, and marked in fig. 2. at 176 degrees.

The duration by the observation is fixed at 4 minutes; in which time it passes over an arch in its orbit of  $16' 52'',9$ . Now as its distance from the planet is to its distance from the earth, so is  $16' 52'',9$  to the diameter of the satellite; or the mean distance of the 2d satellite may be rated, with M. DE LA LANDE, at  $2' 57''$ , or  $177''$ . Then putting this equal to radius, we shall have the following analogy. Radius is to  $177''$ , as the tangent of  $16' 52'',9$  is to the angle, in seconds, which the diameter of the second satellite subtends when seen from the earth. And by calculation, this comes out  $0'',87$ ; that is less than nine-tenths of a second.

I have not been scrupulously accurate in this calculation, as the real distance of Jupiter at the time of observation should have been computed, whereas I have contented myself with the mean distance. Nor am I very confident that the angle of the greatest elongation, admitted to be  $2' 57''$ , is quite accurate; but I judged it unnecessary to be more particular, because the time of my observation in the beginning of the transit upon the disc, I find was only taken down in whole minutes of the clock. The end, however, is more accurately determined, by the observation which was made  $45''$  after the immersion; when a

part of the disc, equal to about  $\frac{1}{4}$  of the diameter of the satellite, is said to be visible. It seems that observations of this kind, made with very good telescopes, charged with high powers, are capable of great precision. For the remark that a margin of Jupiter, equal to about  $\frac{1}{4}$  of the diameter of the satellite, became visible in  $45''$  of time, adds great support to the accuracy of the observation of the foregoing  $4$  minutes: and, at all events, it is evidently proved, from the whole of the entrance upon the disc, that the diameter of this satellite is less, by one half at least, than what from the result of the measures of former observers it has been supposed to be.

A method has also been used, of deducing the diameter of the satellites from the time they employ to immerge into the shadow of the planet; but this must be very fallacious, and ought not to be used.

I should not pass unnoticed the apparent magnitude of the satellites. The expressions that have been given of them may be collected into the following narrow compass.

1, 4, 2    4; 1    3 -, 4; 1 - 2    4, 2, 1    3 -- 4; 1; 2  
 1, 4, 2    3 - 2, 1, 4    3 -- 2 - 1, 4    1 ? 2    4 . 1 - 2  
 1 ; 2 - 4    3 -- 1, 2    2 - 1

From which we may conclude, that the 3d satellite is considerably larger than any of the rest; that the 1st is a little larger than the 2d, and nearly of the size of the 4th; and that the 2d is a little smaller than the 1st and 4th, or the smallest of them all.

WM. HERSCHEL.

Slough, near Windsor,  
 April 30, 1797.