

Dr. HERSCHEL's Observations

situation in the Saturnian system intitles them, very probably, to the first and second place. This I have done to the end that in future we may not be liable to mistake, in referring to former observations or tables, where the five known satellites have been named according to the order they have hitherto been supposed to hold in the range of distance from the planet.

It may appear remarkable, that these satellites should have remained so long unknown to us, when, for a century and an half past, the planet to which they belong has been the object of almost every astronomer's curiosity, on account of the singular phenomena of its ring. But it will be seen presently, from the situation and size of the satellites, that we could hardly expect to discover them till a telescope of the dimensions and aperture of my forty-feet reflector should be constructed; and I need not observe how much we Members of this Society must feel ourselves obliged to our Royal Patron, for his encouragement of the sciences, when we perceive that the discovery of these satellites is intirely owing to the liberal support whereby our most benevolent King has enabled his humble astronomer to complete the arduous undertaking of constructing this instrument.

The planet Saturn is, perhaps, one of the most engaging objects that astronomy offers to our view. As such it drew my attention so early as the year 1774; when, on the 17th of March, with a $5\frac{1}{2}$ -feet reflector, I saw its ring reduced to a very minute line, as represented in fig. 1. (Tab. I.) On the 3d of April, in the same year, I found the planet as it were stripped of its noble ornament, and dressed in the plain simplicity of Mars. See fig. 2. I pass over the following year, in which, with a 7-feet reflector, I saw the ring gradually open, till it came to the appearance expressed in fig. 3. (Tab. II.) the

on the Planet Saturn.

3

original of which was delineated from nature, on the 20th of June, 1788, by means of a very good 10-foot reflector.

It should be noticed, that the black disk, or belt, upon the ring of Saturn is not in the middle of its breadth; nor is the ring subdivided by many such lines, as has been represented in divers treatises of astronomy; but that there is one single, dark, considerably broad line, belt, or zone, upon the ring, which I have always permanently found in the place where my figure represents it. I give this, however, only as a view of the northern plane of the ring, as the situation of the planet has hitherto not afforded me any other. The southern one, which is lately come to be exposed to the sun, will shortly be opened sufficiently to enable me to give also the situation of its belts, if it should have any.

From my observations it appears, that the zone on the northern plane of the ring is not, like the belts of Jupiter or those of Saturn, subject to variations of colour and figure; but is most probably owing to some permanent construction of the surface of the ring itself. That however, for instance, this black belt cannot be the shadow of a chain of mountains, may be gathered from its being visible all round on the ring; for at the ends of the ansæ there could be no shades visible, on account of the direction of the sun's illumination, which would be in the line of the chain; and the same argument will hold good against supposed caverns or concavities. It is moreover pretty evident, that this dark zone is contained between two concentric circles, as all the phænomena answer to the projection of such a zone. Thus, in fig. 4. which was taken the 11th of May, 1780, we may see, that the zone is continued all round the ring, with a gradual decrease of breadth towards the middle,

answering to the appearance of a narrow circular plane, projected into an ellipsis.

As to the surmise, which might occur to us, of a division of the ring, or rather of two rings, one about the other, with a distance of open space between them, it does not appear eligible to venture on so artificial a construction, by way of explaining a phænomenon that does not absolutely demand it. If one ring, of a breadth so considerable as that of Saturn, is justly to be esteemed the most wonderful arch that, by the laws of gravity, can be held together, how improbable must it appear to suppose it subdivided into narrow slips of rings, which by this separation will be deprived of a sufficient depth, and thus lose the only dimension which can keep them from falling upon the planet? It is however true, that as yet we do not know of the rotation of the ring, which may be of such a proper velocity as greatly to assist its strength; and that, in the subdivisions, of course the different velocities for each division may be equally supposed to keep them up. If the southern plane should prove to be very differently marked, it will at once remove every surmise of such a division; but if it should offer us the same appearance of a dark zone, in the same situation, and of an equal breadth with the one I have observed on the northern side, I would still remark, that, since a most effectual way to verify the duplicity of the ring is within our reach, it will be the best way to suspend our judgement till that can be put to the trial. The method I allude to is an occultation of some considerable star by Saturn, when, if the ring be divided, it will be seen between the openings, as well as between the ring and Saturn.

With regard to the nature of the ring, we may certainly affirm, that it is no less solid and substantial than the planet itself.

on the Planet Saturn.

5

itself. The same reasons which prove to us the solidity of the one will be full as valid when applied to the other. Thus we see, in fig. 3. and 4. the shadow of the body of Saturn upon the ring, which, in fig. 3. is eclipsed towards the north, on the following side, and in fig. 4. about the middle, according to the opposite situation of the sun. In the same manner we see the shadow of the ring cast on the planet, where in fig. 1. and 2. we find it on the equatorial part; and May 28, 1780, I saw it towards the south. If we deduce the quantity of matter, contained in the body, from the power whereby the satellites are kept in their orbits, and the time of their revolution, it must be remembered, that the ring is included in the result. It is also in a very particular manner evident, that the ring exerts a considerable force upon these revolving bodies, since we find them strongly affected with many irregularities in their motions, which we cannot properly ascribe to any other cause than the quantity of matter contained in the ring; at least we ought to allow it a proper share in the effect, as we do not deny but that the considerable equatorial elevation of Saturn, which I shall establish hereafter, must also join in it.

The light of the ring of Saturn is generally brighter than that of the planet: for instance, April 19, 1777, I saw the southern part of the ring, which passed before the body, very plainly brighter than the disk of Saturn, on which it was projected; and on the 27th of the same month, I found, that with a power of 410, my seven-feet reflector had hardly light enough for Saturn, when the ring was notwithstanding sufficiently bright. Again, the 11th of March, 1780, I tried the powers of 222, 332, and 449, successively, and found the light of Saturn less intense than that of the ring; the colour of the body with the high powers turning to a kind of yellow,

while that of the ring still remained white. The same result happened on June 25, 1781, with the power 460.

I come now to one of the most remarkable properties in the construction of the ring, which is its extreme thinness. The situation of Saturn, for some months past, has been particularly favourable for an investigation of this circumstance; and my experiments have been so complete, that there can remain no doubt on this head.

When we were nearly in the plane of the ring, I have repeatedly seen the first, the second, and the third satellites, nay even the sixth and seventh, pass before and behind the ring in such a manner that they served as excellent micrometers to estimate its thickness by. It may be proper to mention a few instances, especially as they will serve to solve some phenomena that have been remarked by other astronomers, without having been accounted for in any manner that could be admitted, consistently with other known facts. July 18, 1789, at 19 h. 41' 9'', sidereal time, the first satellite seemed to hang upon the following arm, declining a little towards the north, and I saw it gradually advance upon it towards the body of Saturn; but the ring was not so thick as the lucid point. July 23, at 19 h. 41' 8'', the second satellite was a very little preceding the ring; but the ring appeared to be less than half the thickness of the satellite. July 27, at 20 h. 15' 12'', the second satellite was about the middle, upon the following arm of the ring, and towards the south; and the sixth satellite on the farther end, towards the north; but the arm was thinner than either of them. August 29, at 22 h. 12' 25'', the third satellite was upon the ring, near the end of the preceding arm; and my remark at the time when I saw it was, that the arm seemed not to be the fourth, at least not the third, part of the diameter of the satellite, which, in the situation

situation it was, I took to be less than one single second in diameter. At the same time I also saw the seventh satellite, at a little distance following the third, in the shape of a bead upon a thread, projecting on both sides of the same arm: hence we are sure, that the arm also appeared thinner than the seventh satellite, which is considerably smaller than the sixth, which again is a little less than the first satellite. August 31, at 20 h. 48' 26'', the preceding arm was loaded about the middle by the third satellite. October 15, at 0 h. 43' 44'', I saw the sixth satellite, without obstruction, about the middle of the preceding arm, though the ring was but barely visible with my forty-foot reflector, even while the planet was in the meridian; however, we were then a little inclined to the plane of the ring, and the third satellite, when it came near its conjunction with the first, was so situated that it must have partly covered the first a few minutes after the time I lost it behind my house. In all these observations the ring did not in the least interfere with my view of the satellites. October 16, I followed the sixth and seventh satellites up to the very disk of the planet; and the ring, which was extremely faint, opposed no manner of obstruction to my seeing them gradually approach the disk, where the seventh vanished at 21 h. 46' 44'', and the sixth at 22 h. 36' 44''.

I might bring many other instances, if the above were not quite sufficient for the purpose. There is, however, some considerable suspicion, that, by a refraction through some very rare atmosphere on the two planes of the ring, the satellites might be lifted up and depressed, so as to become visible on both sides of the ring, even though the ring should be equal in thickness to the diameter of the smallest satellite, which may amount to a thousand miles. As for the argument of its
incredible

incredible thinness, which some astronomers have brought from the short time of its being invisible, when the earth passes through its plane, we cannot set much value upon them; for they must have supposed the edge of the ring, as they have also represented it in their figures, to be square; but there is the greatest reason to suppose it either spherical or spheroidal, in which case evidently the ring cannot disappear for any long time. Nay, I may venture to say, that the ring cannot possibly disappear on account of its thinness; since, either from the edge or the sides, even if it were square on the corners, it must always expose to our sight some part which is illuminated by the rays of the sun: and that this is plainly the case, we may conclude from its being visible in my telescopes during the time when others of less light had lost it, and when evidently we were turned towards the unenlightened side, so that we must either see the rounding part of the enlightened edge, or else the reflection of the light of Saturn upon the side of the darkened ring, as we see the reflected light of the earth on the dark part of the new moon. I will, however, not decide which of the two may be the case; especially as there are other very strong reasons to induce us to think, that the edge of the ring is of such a nature as not to reflect much light.

I cannot leave this subject without mentioning both my own former surmises, and those of several other astronomers, of a supposed roughness in the surface of the ring, or inequality in the planes and inclinations of its flat sides. They arose from seeing luminous parts on its extent, which were supposed to be projecting points, like the moon's mountains; or from seeing one arm brighter or longer than another; or even from seeing one arm when the other was invisible. I was, in the beginning of this season, inclined to the same opinion, till one of these supposed

on the Planet Saturn.

9

posed luminous points was kind enough to venture off the edge of the ring, and appeared in the shape of a satellite. Now, as I had collected every inequality of this sort, it was easy enough for me afterwards to calculate all such surmises by the known periodical time of the first, second, third, sixth, and seventh satellites; and I have always found that such appearances were owing to some of these satellites which were either before or behind the ring. The 20th of October, for instance, at 22 h. 35' 46'', I saw four of Saturn's satellites all in one row, and at almost an equal distance from each other, on the following side; and yet the first satellite, which was the farthest of them all, was only about half-way towards its greatest elongation from the body of Saturn, as may be seen in fig. 5. (Tab. III.). How easily, with an inferior telescope, this might have been taken for one of the arms of Saturn, I leave those to guess who know what a degree of accuracy it must require to distinguish objects that are so minute, and at the same time so faint, on account of their nearness to the disk of the planet. Upon the whole, therefore, I cannot say, that I had any one instance that could induce me to believe the ring was not of an uniform thickness; that is, equally thick at equal distances from the center, and of an equal diameter throughout the whole of its construction. The idea of protuberant points upon the ring of Saturn, indeed, is of itself sufficient to render the opinion of their existence inadmissible, when we consider the enormous size such points ought to be of, for us to see them at the distance we are from the planet.

From these supposed luminous points I am, by imperceptible steps, brought to the discovery of two satellites of Saturn, which had escaped unnoticed, on account of their little distance from the planet, and faintness; which latter is partly to be

ascribed to their smallness, and partly to being so near the light of the ring and disk of Saturn. Strong suspicions of the existence of a sixth satellite I have long entertained; and, if I had been more at leisure two years ago, when the discovery of the two Georgian satellites took me as it were off the scent, I should certainly have been able to announce its existence as early as the 19th of August, 1787, when, at 22 h. 18' 56'', I saw, and marked it down as being probably, a sixth satellite, which was then about 12 degrees past its greatest preceding elongation. But, as I observed before, not having time to give my thoughts to the subject, I reserved a full investigation of the number of satellites, and the nature of the ring of Saturn for a future opportunity. Besides, not having any tables of the satellites, I could not confidently say, whether the fifth satellite was not one of the five which I perceived in motion that night, though afterwards I found, that the real fifth had also been in view, and was marked down as a star, by the letter *b*, in a figure I delineated of Saturn and its satellites that evening.

In the year 1788 very little could be done towards a discovery, as my twenty-foot speculum was so much tarnished by *zenith sweeps*, in which it had been more than usually exposed to falling dews, that I could hardly see the Georgian satellites. In hopes of great success with my forty-foot speculum, I deferred the attack upon Saturn till that should be finished; and having taken an early opportunity of directing it to Saturn, the very first moment I saw the planet, which was the 28th of last August, I was presented with a view of six of its satellites, in such a situation, and so bright, as rendered it impossible to mistake them, or not to see them. The retrograde motion of Saturn amounted to nearly $4\frac{1}{2}$ minutes *per* day, which

on the Planet Saturn.

11

which made it very easy to ascertain whether the stars I took to be fatellites really were so; and, in about two hours and an half, I had the pleasure of finding, that the planet had visibly carried them all away from their places. I continued my observations constantly, whenever the weather would permit; and the great light of the forty-foot speculum was now of so much use, that I also, on the 17th of September, detected the seventh fatellite, when it was at its greatest preceding elongation.

As soon as I had observations enough to make tables of the motion of these new fatellites, I calculated their place backwards, and soon found that many suspicions of these fatellites, in the shape of protuberant points on the arms, were confirmed, and served to correct the tables, so as to render them more perfect. Fig. 6. represents the seven fatellites of Saturn, as they were situated October 18, at 21 h. 22' 45". The small star *s* served to shew the motion of the planet in a striking manner; as, in about $3\frac{3}{4}$ hours after the above-mentioned time, the whole Saturnian system was completely moved away, so as to leave the star *s* as much following the second and first fatellites, which then were in conjunction, as it now was before the second.

By comparing together many observations of the sixth fatellite, I find, that it completes a sidereal revolution about Saturn in one day, 8 hours, 53' 9". And if we suppose, with M. DE LA LANDE *, that the fourth is at the mean distance of 3' from the center of Saturn, and performs one revolution in 15 d. 22 h. 34' 38", we find the distance of the sixth, by KEPLER'S law, to be 35'',058. Its light is considerably strong, but not equal to that of the first fatellite; for, on the 20th of

* Afr. § 2996, 2997.

October, at 19 h. 56' 46'', when these two satellites were placed as in fig. 7. the first, notwithstanding it was nearer the planet than the sixth, was still visibly brighter than the latter. It would, however, be worth while to try whether a good achromatic telescope, of a large aperture, might not possibly shew it at the time of its greatest distance from the planet, and when no other satellite is near; that is, provided it will shew the other five satellites with great ease, as otherwise there will be no reason to expect it should shew the sixth.

In the period of this satellite I have employed the observation of the 19th of August, 1787, as, from other calculations, it seems the revolution is determined near enough to reach back so far.

The most distant observations of the seventh satellite, being compared together, shew, that it makes one sidereal revolution in 22 hours, 40 minutes, and 46 seconds: and, by the same *data* which served to ascertain the dimension of the orbit of the sixth, we have the distance of the seventh, from the center of Saturn, no more than 27'' 366. It is incomparably smaller than the sixth; and, even in my forty-foot reflector, appears no bigger than a very small lucid point. I see it, however, also very well in the twenty-foot reflector; to which the exquisite figure of the speculum not a little contributes. It must nevertheless be remembered, that a satellite once discovered is much easier to be seen than it was before we were acquainted with its place.

The revolution of this satellite is not nearly so well ascertained as that of the former. The difficulty of having a number of observations is uncommonly great; for, on account of the smallness of its orbit, the satellite lies generally before and behind the planet and its ring, or at least so near them that,
except

on the Planet Saturn.

13

except in very fine weather, it cannot easily be seen well enough to take its place with accuracy. On the other hand, the greatest elongations allow so much latitude for mistaking its true situation, that it will require a considerable time to divide the errors that must arise from imperfect estimations.

The orbits of these two satellites, as appears from many observations of them, are exactly in the plane of the ring, or at least deviate so little from it, that the difference cannot be perceived. It is true, there is a possibility that the line of their nodes may be in, or near, the present greatest elongation, in which case the orbits may have some small inclination; but as I have repeatedly seen them run along the very minute arms of the ring, even then the deviation cannot amount to more than perhaps one or two degrees; if, on the contrary, the nodes should be situated near the conjunction, this quantity would be so considerable that it could not have escaped my observation.

From the ring and satellites of Saturn we now turn our thoughts to the planet, its belts, and its figure.

April 9, 1775. I observed a northern belt on Saturn, which was a little inclined to the line of the ring.

May 1, 1776. There was another belt, inclined about 15 degrees to the same line, but it was more to the south, and on the following side came up to the place in which the ring crosses the body.

July 13, — The belt was again depressed towards the north, almost touching the line where the ring passed behind the body.

April 8, 1777. There were two fine belts, both a little inclined to the ring.

June

- June 20, 1778. There were two belts parallel to the ring; but the northern one had some faint, cloudy appearance, towards the preceding, or western side.
- May 11, 1779. Two equatorial belts.
- 13, — A bright belt over a dark one.
 - 22, — One dark, and one very faint white belt.
 - 23, — A dark belt, and a pretty bright white one.
- Jan. 21, 1780. Two belts; the most north clouded.
- 22, — Faint belts.
- May 17, — A dark, equatorial belt.
- 23, — A strong, equatorial belt.
- June 19, at 10 h. 15', With a new, excellent seven-foot speculum, I see two belts, and a cloudy appearance, which is not come up to the middle; but, as it is a large figure, some part of it is already past the center (this is, provided Saturn turns upon its axis the same way as Jupiter does). See fig. 8. where the ring is omitted.
- June 20, 1780. 10 h. 10', The same figure is on the disk, but seems to be more central than it was yesterday.
- 21, 9 h. 25', The same two belts; a strong, dark spot, near the margin of the disk; see fig. 9.; ring not expressed.
 - 10 h. 1', The spot not so remarkable as it was at 9 h. 25'.
 - 26, Small twenty-foot telescope; an equatorial belt, and another less marked.
 - 29, Two dark equatorial belts.
- April 19, Two belts.
- August 23, Two belts, a little declining from the equatorial position.

on the Planet Saturn.

15

August 26, A broad belt much inclined; with 200, 250, 300, 400, faint appearances of a second and of a third belt.

— 27, The belts less inclined.

Sept. 2, A darkish belt, but very little inclined; and a fine white belt, close to the ring.

— 5, The belt a little inclined.

— 6, The belt not inclined.

— 8, The bright belt close to the ring, and two dark equatorial belts.

It will not be necessary to continue the account of these belts up to the present time; but I have constantly observed them, and found them generally in equatorial situations, though now and then they were otherwise.

We may draw two conclusions from what has been reported. The first, which relates to the changes in the appearance of the belts, is, that Saturn has probably a very considerable atmosphere, in which these changes take place; just as the alterations in the belts of Jupiter have been shewn, with great probability, to be in his atmosphere. This has also been confirmed by other observations: thus, in occultations of Saturn's satellites, I have found them to hang to the disk a long while before they would vanish. And though we ought to make some allowance for the encroachment of light, whereby a satellite is seen to reach up to the disk sooner than it actually does, yet, without a considerable refraction, it could hardly be kept so long in view after the apparent contact. The time of hanging upon the disk, in the seventh satellite, has actually amounted to 20 minutes. Now, as its quick motion during that interval carries it through an arch of near six degrees, we find, that this would denote a refraction of about two seconds, provided

provided the encroaching of light had no share in the effect. By an observation of the sixth satellite, the refraction of Saturn's atmosphere amounts to nearly the same quantity; for this satellite remained about 14 or 15 minutes longer in view than it should have done; and as it moves about $2\frac{3}{4}$ degrees in that time, and its orbit is larger than that of the seventh, the difference is inconsiderable. It is not my present intention to enter into a consideration of the amount of these refractions, otherwise we might perhaps find data enough to subject them to some calculation. But what has been said will suffice to shew, that very probably Saturn has an atmosphere of a considerable density.

The next inference we may draw from the appearance of the belts on Saturn is, that this planet turns upon an axis which is perpendicular to the ring. The arrangement of the belts, during the course of fourteen years that I have observed them, has always followed the direction of the ring, which is what I have called being equatorial. Thus, as the ring opened, the belts began to advance towards the south; and to shew an incurvature answering to the projection of an equatorial line, or to a parallel of the same. When the ring closed up, they returned towards the north; and are now, while the ring passes over the center, exactly ranging with the shadow of it on the body; generally one on each side, with a white belt close to it. When I say, that the belts have always been equatorial, I pass over trifling exceptions, which certainly were owing to local causes. The step from equatorial belts to a rotation on an axis is so easy, and, in the case of Jupiter, so well ascertained, that I shall not hesitate to take the same consequence for granted here. But, if there could remain a doubt, the observations of

on the Planet Saturn.

17

June 19, 20, and 21, 1780, where the same spot was seen in three different situations, would remove it completely.

There is another argument, of equal validity with the former, which now I shall bring on. It is founded upon the following observations, and will shew that Saturn, like Jupiter, Mars, and the Earth, is flattened at the Poles; and therefore ought to be supposed to turn on its axis.

July 22, 1776. I thought Saturn was not exactly round.

May 31, 1781. It appears as if the body of Saturn was at least as much flattened as that of Jupiter; but as the ring interferes, this may be better ascertained eight years hence.

August 18, 1787. The body of Saturn is of unequal diameters, the equatorial one being the longest.

Sept. 14, 1789, 23 h. 36' 32". Having reserved the examination of the two diameters of Saturn to the present as the most favourable time, I measured them with my twenty-feet reflector, and a good parallel-wire micrometer.

Equatorial diameter, 1ft measure,	21,94
2d . . .	23,11
3d . . .	21,73
4th . . .	22,85
Mean	<u>22,81</u>

Polar diameter, 1ft measure,	20,57
2d . . .	20,10
3d . . .	21,16
Mean	<u>20,61</u>

By this it appears that Saturn is considerably flattened at the poles. And as the greatest measures were taken in the line of the ring and of the belts, we are assured that the axis of the planet is perpendicular to the plane of the ring; and that the equatorial diameter is to the polar one nearly as 11 to 10.

We may also infer the real diameter of Saturn from these measures, which are perhaps more to be depended upon than any that have hitherto been given. But as in my journal I have measures that were repeatedly taken these ten years past, not only of the diameter of Saturn, but of the ring, and its opening, whereby its inclination may be known; as well as of the distance of the fourth, and fifth, and other satellites, which will be of great use in ascertaining the quantity of matter contained in the planet, I reserve a full investigation of these things for another opportunity; since, from the date of this Paper, it will be sufficiently evident, that there can be no time for me to enter properly into the subject.

One beautiful observation of the transit of the shadow of the fourth satellite over the disk of Saturn, I must add, to conclude this Paper.

Last night, November 2, 1789, at 23 h. 13' sidereal time, being always in quest of any appearance that may afford the means of ascertaining the rotation of Saturn on an axis, I discovered a black spot on the following margin of the disk of that planet.

At 23 h. 21', I perceived a protuberance on the south preceding edge of the disk, which I supposed to be the fourth satellite going to emerge.

on the Planet Saturn.

19

At 23', I found that the black spot had advanced a little towards the preceding side.

At 30', with a power of 300, I found it still advancing, and saw that the spot was a little to the north of the equatorial belt, but so that a small part of it was upon the belt.

At 35', the black spot was a little more than one-eighth of the diameter of Saturn advanced from the following edge towards the center.

At 39', the fatellite was detached.

At 49', the spot was advanced so as to be about one-third of its way towards the center; and the fourth fatellite near half its own apparent diameter clear of the edge.

In this situation of the planet I took an eye-draught of it, (see fig. 10.) as it appeared with the black spot on the belt; the lately emerged fourth fatellite; two parallel dark belts, the intermediate space between them and the equatorial one being a little brighter than the rest of the disk; the sixth, third, and second fatellites on the preceding side; the ring projecting like two very slender lines on each side of the disk, and containing the first fatellite upon the following arm, with the fifth at a considerable distance following.

At 0 h. 5', the black spot was got a little more than half way towards the center. It was much darker than the belt, and more upon it than before.

At 1 h. 2', by advancing gradually towards the south, it was now almost intirely drawn upon the equatorial belt.

At 1 h. 13', the black spot approached towards a central situation.

At 1 h. 21' 51'', it was perfectly central, and at the same time upon the middle of the equatorial belt.

D 2

I followed

Dr. HERSCHEL's Observations, &c.

I followed the shadow of the fatellite with great attention up to the center, in order to secure a valuable epocha, which may serve to improve our tables of the mean motion of this fatellite.

WILLIAM HERSCHEL.

Slough, near Windfor,
November 3, 1789.



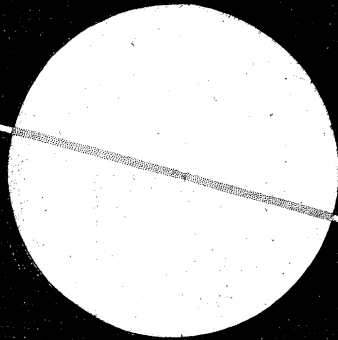


Fig. 1.

March 27. 1774.

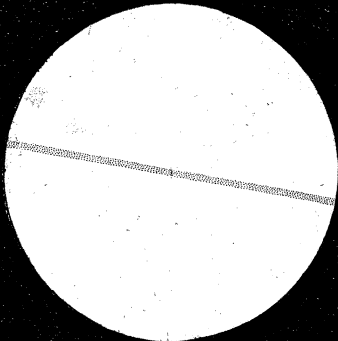


Fig. 2.

April 3. 1774.

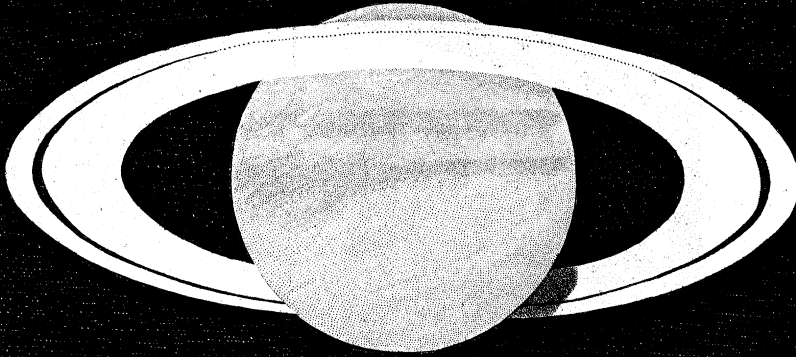


Fig. 3.

June 20th 1778

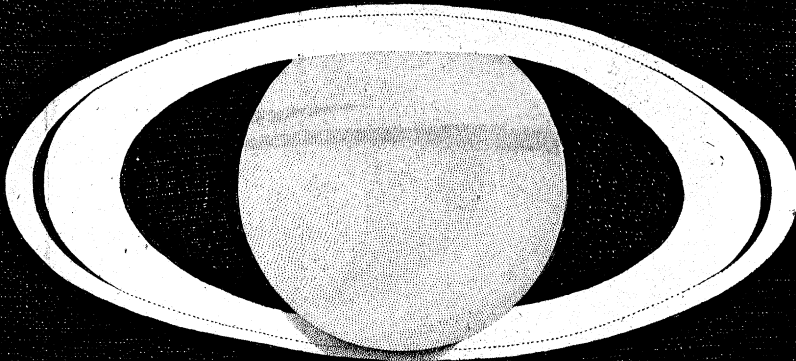


Fig. 4.

May 11th 1780.

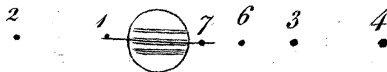
Fig. 5.



4

5

Fig. 6.



5

Fig. 7.



Fig. 8.

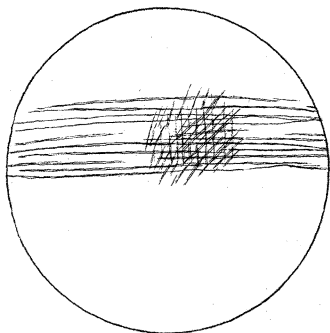


Fig. 9.

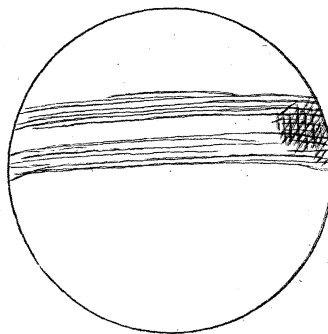
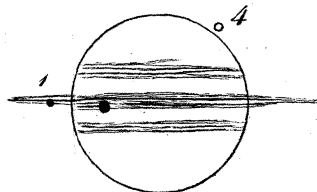


Fig. 10.



5