XVIII. *Observations on the Planet Venus.* By William Herschel, *LL. D. F. R. S.*

Read June 13, 1793.

THE planet Venus is an object that has long engaged my particular attention. A series of observations upon it, which I began in April, 1777, has been continued down to the present time.

My first view, when I engaged in the pursuit, was to ascertain the diurnal rotation of this planet; which, from the contradictory accounts of CASSINI and BIANCHINI, the former of which states it at 23 hours, while the latter makes it 24 days, appeared to me to remain unknown, as to its real duration: for the observations of these gentlemen, how widely different soever with regard to time, can leave no doubt but that this planet actually has a motion on its axis.

The next object was the atmosphere of Venus; of the existence of which also, after a few months observations, I could not entertain the least doubt.

The investigation of the real diameter, was the third object I had in view.

To which may be added, in the last place, an attention to the construction of the planet, with regard to permanent appearances; such as might be occasioned by, or ascribed to, seas, continents, or mountains.

The result of my observations would have been communicated long ago, if I had not still flattered myself with the hopes of some better success, concerning the diurnal motion of Venus; which, on account of the density of the atmosphere of this planet, has still eluded my constant attention, as far as concerns its period and direction. Even at this present time, I should hesitate to give the following extract from my journals, if it did not seem incumbent upon me to examine by what accident I came to overlook mountains in this planet, which are said to be "*of such enormous height, as to exceed four, five, and even six times the perpendicular elevation of Cimboraco, the highest of our mountains!*"*

The same paper, which contains the lines I have quoted, gives us likewise many extraordinary relations, equally wonderful; such as hints of the various and singular properties of the atmosphere of Saturn.† A ragged margin in Venus, resembling the uneven border of the moon, as it appears to a power magnifying from 1 to 4.‡ One cusp of Venus appearing pointed, and the other blunt, owing to the shadow of some mountain.§ Flat spherical forms conspicuous on Saturn.|| All which being things of which I have never taken any notice, it will not be amiss to shew, by what follows, that neither want of attention, nor a deficiency of instruments, could occasion my not perceiving *these mountains of more than 23 miles in height*;** *this jagged border of Venus*; *and these flat spherical forms on Saturn.*

* See Phil. Trans. for 1792, Part II. page 337. † Ibidem, p. 309. ‡ p. 310. § p. 312. || p. 336. ** The height of Chimbo-raço, according to Mr. CONDAMINE, is 3200 French toises; and the English mile, by Mr. DE LA LANDE, measures 830. If the mountains in Venus exceed Chimbo-raço six times in perpendicular elevation, they must be more than 23 miles in height.

Indeed with regard to Saturn, I cannot hesitate a single moment to say, that, had any such things as flat spherical forms existed, they could not possibly have escaped my notice, in the numberless observations with 7, 10, 20, and 40-feet reflectors, which I have so often directed to that planet. However, if the gentleman who has seen the mountains in Venus, has made observations on flat spherical forms on Saturn, it is to be regretted that he has not attended to the revolution of this planet on its axis, which could not remain an hour unknown to him when he saw these forms.

Last night,* for instance, I saw two small dark spots on Jupiter; I shall not call them flat spherical forms, because their flatness, as well as their sphericity, must be hypothetical; moreover, these two terms seem to me to contradict each other. These were evidently removed, in less than an hour, in such a manner as to point out, very nearly, the direction and quantity of the rotation of this planet.

Before I remark on the rest of the extraordinary relations above-mentioned, I will give a short extract of my observations on Venus, with such deductions as it seems to me that we are authorised to make from them.

Observations.

April 17, 1777. The disk of Venus was exceedingly well defined, distinct, and bright, but no spot was visible by which I could judge of her diurnal motion. The same telescope shews the spots on Mars extremely well. 7-feet reflector.

April 26, 1777. The disk well defined, and bright, but no spot. 10-feet reflector.

* May 31, 1793.

February 21, 1780. No spot on the disk of Venus; diameter 15″,9, mean of three measures.

May 2, 1780. No spot; power 449; diameter 17″,2.

May 28, 1780. No spot; power 268 and 449; diameter 22″,8.

May 29, 1780. I viewed Venus with a 20-feet Newtonian reflector; power 447. The edge of the disk was so sharp and well defined, that there can be no wish to see it better. There was no spot of any kind.

I could see no projections of any mountains, though the phase of Venus is now such as would be most favourable for shewing them.

June 19, 1780. There is, on Venus, a bluish, darkish spot, *a d c;* and another, which is rather bright, *c e d;* they meet in an angle at *c*, the place of which is about one-third of the diameter of Venus from the cusp *a*. See Tab. XXII. fig. 1.

June 21, 23, 24, 25, 26, 28, 29, 30, and July 3, 1780. Continued observations were made upon these, and other faint spots, and drawings of them annexed. The instrument I used was a 20-feet Newtonian reflector, furnished with no less than five different object specula, some of which were in the highest perfection of figure and polish; the power generally 300 and 450. But the result of them would not give me the time of the rotation of Venus. For the spots assumed often the appearances of optical deceptions, such as might arise from prismatic affections; and I was always very unwilling to lay any stress upon the motion of spots, that either were extremely faint and changeable, or whose situation could not be precisely ascertained.

However, that Venus has a motion on an axis cannot be

doubted from these observations; and that she has an atmosphere is as evident, from the changes I took notice of, which surely cannot be upon the solid body of the planet.

Sept. 18, 1780. No spot on Venus; diameter 38″,4.

Oct. 10, 1780. With a very perfect 7-feet speculum; power 227, 460, and 932. No spot visible; diameter 41″,3.

Oct. 11, 1780. No spot; diameter 27″,8.

Oct. 20, 21, 23, 1780. No spot visible.

April 17, 1783. 10-feet reflector; power 324. I see some darkish spots on Venus. 7-feet reflector; power 227. The same appearances; but in neither of the instruments are they determined enough to serve for the purpose of finding the rotation.

May 21, 1783. 10-feet reflector; a new speculum; power 250.

7^h 30′. No spot visible.

8^h 30′. There seems to be an ill defined spot.

9^h 15′. No motion can be perceived that may be depended upon, though the figure seems rather advancing towards the centre.

May 30, 31, and June 1, 6, 1783. Spots were observed with 10 and 20-feet reflectors, and also motion perceived in them. Continued observations were recorded; and a great many figures delineated.

Dec. 3, 1783. With 460, and 932. No spot. No kind of protuberance, or indenture in the line which terminates the illumination, that might denote a mountain.

Feb. 13, 1785. No spot. A new 10-feet Newtonian reflector.

April 8, 1788. No spot on Venus; but she is still at too great a distance for such observations.

Nov. 30, 1789. No satellite visible. If she has one, it must be less in appearance than a star of the 8th or 9th magnitude; power 300.

Dec. 2, 1789. No spot; power 157, 300, and 460.

May 23, 1791. 40-feet reflector. The light of Venus is so brilliant that it becomes very uneasy for the eye to bear it long. There is no spot on the disk.

I had prepared my apparatus for a regular succession of observations with this instrument, having turned it towards the west, and put on the round-motion to keep the planet in view; but found that the great advantage of this telescope, which is its superior light, was, on this occasion, not only unnecessary, but rather an inconvenience.

Nov. 24, 1791. Correction of the clock, — 46″,7.

I took measures of the diameter of Venus with the 20-feet reflector; power 157.

12^h 18′	1st measure	45″,486
	2d ———	46 ,142
	3d ———	45 ,514
	4th ———	45 ,814
	5th ———	46 ,033
	6th ———	46 ,252
Mean of the six measures		45″,874

I took five more, with a power of 300, the morning being very fine and clear.

12^h $36'$	1st measure	$44''$,885
	2d ———	45 ,705
	3d ———	45 ,104
	4th ———	45 ,322
	5th ———	45 ,842

Mean of the five measures $45''$,372

Mean of the two sets $45''$,623

These measures were taken with a speculum that has been lately re-polished, and therefore required new tables for casting them up. Such tables were made by the following transits.

Nov. 25, 1791. Transits of equatorial stars, taken to determine the value of the micrometer, which is divided into revolutions of sixty parts each.

First set, 23″,0 23,0 23,0 23,0 23,2 23,1 23,1 23,0 23,1 23,1 = 23″,06 = 21 revolutions; correction + 7,2 parts, for zero and concave wires.

Second set, 16″,8 16,6 16,4 16,5 16,7 16,6 16,5 16,8 16,4 16,5 = 16,58 = 15 revolutions 1,3 parts. Correction + 7,2.

By the first set, 1 part = o″,272964

Second set – – 273748

Mean of the two sets o″,273356

In the first set, the micrometer was opened to 21 revolutions; and ten equatorial stars were observed to pass from one wire to the other. The opening was afterwards changed, and ten other stars were again observed to pass over the wires; after which the micrometer was read off, and found to be 15 revolutions and 1,3 parts.

Feb. 4, 1793. Correction of the clock, — 1′ 28″,0.

2^h 55′. 7-feet reflector; power 172. The air is very clear, and I see Venus very well defined; but cannot perceive any inequality on the edge of the planet that might denote a mountain; though the situation is favourable, being a little more enlightened than what we may call her last quarter. With 215, I had a very distinct view for a long time; but cannot perceive any inequality on the line which divides light from darkness.

With 287, I perceive no mountains: with 430, very distinct, I perceive no mountains. The terminating line is not so sharply defined as the circumference; but no inequality is visible.

With the same power, I see on Saturn, the equatorial belt, the shadow of the ring on Saturn, the shadow of Saturn on the ring, the division of the ring, &c.

I do not find any spot on Venus; so that there is no possibility to assign its diurnal motion.

March 3, 1793. Correction of the clock, — 2′ 0″,6.

6^h 30′. 7-feet reflector; I observed Venus with many powers, but could perceive no spot by which its diurnal motion might be ascertained.

April 3, 1793. Correction of the clock, — 2′ 43″,9.

9^h 9′. 7-feet reflector; power 215. The evening remarkably fine. There is no spot upon the disk of Venus, by which its rotation might be ascertained. The horns are equally sharp. There is nothing that has the appearance of a mountain, like what we see in the moon. With 287, very well defined, appearances are the same. With 430, not the least appearance of any mountains.

April 4, 1793. Correction of the clock, — 2′ 45″,3.

9ʰ 8′. There is no spot upon the disk of Venus. The horns are perfectly alike.

Not the least appearance like the mountains of the moon. With 287, and 430, very distinct.

April 5, 1793. Correction of the clock, — 2′ 46″,7.

8ʰ 25′. 7-feet reflector; power 215, 287, and 430. There are no spots upon Venus, by which its diurnal motion could be ascertained. The horns are exactly alike; and no inequality, like the mountains of the moon, is visible.

April 6, 1793. Correction of the clock, — 2′ 48″,1.

9ʰ 29′. With the 7-feet reflector; power 430. There is no kind of spot visible in any part of the disk. The two horns are exactly alike; and no appearance of mountains can be perceived.

April 7, 1793. Correction of the clock, — 2′ 49″,6.

9ʰ 8′. With the 7-feet reflector; power 215, 287, 430, and 860. I can see no spot upon the disk. Both horns are perfectly alike. Nothing resembling the mountains upon the moon can be perceived. I see it beautifully well, and sharply defined.

April 8, 1793. Correction of the clock, — 2′ 51″,0.

9ʰ 2′. With the 10-feet reflector; power 300, and 400. There is no spot upon Venus. The shape of the two horns is perfectly alike, and no appearance of mountains can be perceived. The illumination of the horns is also perfectly alike.

April 9, 1793. Correction of the clock, — 2′ 52″,1.

8ʰ 45′. With the 10-feet reflector; power 300. No spot upon Venus. Both horns perfectly alike. No appearance of mountains.

The light of Venus is brighter all around the limb, than on

that part which divides the enlightened, from the unenlightened part of the disk. With 400, appearances are the same.

9^h 16′. The bright part, on the limb of Venus, is like a bright bead, of nearly an equal breadth all around.

April 16, 1793. Correction of the clock, — 2′ 59″,5.

10^h 3′. 7-feet reflector, with different powers. No spot upon the disk. No mountains visible. Both horns alike.

A luminous margin, as usual, all around the limb.

April 20, 1793. Correction of the clock, — 3′ 3″,8.

10^h 0′. 7-feet reflector; power 172, 215, 287, 430, and 860. No spot upon the disk. Both horns exactly alike. Not the least appearance of any mountains.

With 287, there is a narrow luminous border all around the limb, and the light afterwards diminishes pretty suddenly, and suffers no considerable diminution as we go towards the line which terminates the enlightened part of the disk. It is however less bright near the terminating line than farther from it. With powers lower than 287, the narrow luminous border cannot be so well distinguished.

April 22, 1793. Correction of the clock, — 3′ 5″,9.

9^h 30′. 7-feet reflector; power 430. Very distinct. No spot. No appearance of mountains. Both horns perfectly alike.

With 860, 1290, and 1720, not the least appearance of mountains. Even the last power is considerably distinct.

10^h 20′. With 430, the luminous margin, compared to the light adjoining to it, may be expressed by, *suddenly much brighter all around the limb.*

April 28, 1793. Correction of the clock, — 3′ 12″,3.

12^h 0′. 7-feet reflector; power 215. No spot. Both horns perfectly alike. No appearance of mountains.

April 29, 1793. Correction of the clock, — 3′ 13″,4.

10^h 30′. 7-feet reflector; power 215. No spot. Both horns perfectly alike. Not the least appearance of any mountains.

With 287 and 430. Both horns equally sharp: no mountains visible.

May 1, 1793. Correction of the clock, — 3′ 15″,5.

10^h 45′. With the 10-feet reflector; power 300. No spot. Both horns perfectly alike, and very sharp. Not the least appearance of any mountains.

With 600, very distinct. Both horns extremely sharp, and alike. No mountains.

With 400, the same appearances.

May 5, 1793. Correction of the clock, — 3′ 19″,8.

11^h 27′. 7-feet reflector; power 215, 287, and 430. Both horns perfectly alike. No spot. Not the least appearance of any mountains.

May 12, 1793. Correction of the clock, — 3′ 27″,3.

11^h 10′. 7-feet reflector; power 215. Beautifully distinct. No spot visible; indeed the crescent is so slender, that we cannot expect to see any spots upon the disk.

Not the least appearance of any mountains, or inequality on the border.

The slender part of the crescent appears often knotty, but this is evidently a deception arising from undulations in the air; for, with proper attention, the knots may be perceived to change place. Little scratches in the great, or small speculum, may also occasion seeming irregularities; but, with proper attention, all such deceptions may be easily detected. Both horns perfectly alike.

With 287, 430, and 860, all that has been mentioned before is perfectly verified, and confirmed.

11^h $43'$. I tried also the lower powers of 172, and 115; but they are inferior, in effect, to 215, 287, and 430; and not adequate to the delicacy and power required in such observations.

I have often taken notice, and again this evening, that the illuminated part of Venus is more than a semi-circle. Whether the excess of the sun's diameter alone will account for this, or how far we are to take the twilight of the atmosphere of Venus into consideration, I have hitherto deferred investigating, as my disk-micrometer wants a moveable parallel, in order to be adjustable, by observation, to the quantity of the horns which is enlightened beyond an hemisphere.

May 13, 1793. Correction of the clock, — $3'$ $28''{,}4$.

11^h $45'$. 7-feet reflector; power 115, 172, 215, 287, and 430. Both horns perfectly alike. No appearance of mountains.

The points of the horns appear more blunt than they were last night, and are not drawn out to so slender a point; but this is evidently a deception, owing to the indifference of the night; for great sharpness, and distinct vision, are wanting in every other object I am looking at.

May 18. 1793. Correction of the clock, — $3'$ $33''{,}7$.

12^h $28'$. 7-feet reflector; power 287. Both horns perfectly alike. No appearance of mountains. No spot. But, at the present altitude of Venus, it is impossible to make any observations that require delicacy, and demand very distinct vision with high powers.

May 19, 1793. Correction of the clock, — 3′ 34″,7.

11^h 45′. 7-feet reflector; power 287. Both horns perfectly alike, in shape and illumination. Not the least appearance of any mountains. The horns are exceedingly slender.

12^h 0′. I do not see any diminution of light on the edge of the horns, but what may be accounted for from their slenderness; being brought to very fine points, that lose themselves by their minuteness.

I saw it in great perfection, with a newly polished, plain speculum, which excels my former one in sharpness.

May 20, 1793. Correction of the clock, — 3′ 35″,8.

12^h 20′. No spot or unevenness in the light of Venus upon either cusp, or in any other part, that could in the least make me suspect a mountain.

I measured the diameter of Venus, and projection of the cusps beyond an hemisphere, by my disk-micrometer. This was not done by an illumination, as described in the apparatus, (Phil. Trans. Vol. LXXIII. p. 4.) when I used it for a nocturnal planet; for, day-light being sufficiently strong, there was no occasion to light the lamps. On the measuring disk were drawn concentric circles; and also a diameter, having several lines parallel to it, in one of the semicircles. If there had been time, I should have prepared a straight edge, *b e*, moveable parallel to the diameter *a d*. See Tab. XXII. fig. 2.

First measure, with the double eye-glass; power about 90. Diameter of Venus 2390. Projection 500. But the power is too low to be accurate.

Second measure; power 215. Diameter of Venus 4800. Projection 620. Here the projection is probably as much too small as the former was too large; but the planet is too low for re-

peating the measures. A mean of both may, perhaps, not be far from the truth; which gives, diameter 3595; projection 560.

Here 1797,5 being radius, and 560 sine, we find the angle *a c b*, or *d c e*, equal to 18° 9′ 8″,2.

A few very evident results may be drawn from the foregoing observations.

With regard to the rotation of Venus on an axis, it appears that we may be assured of this planet's having a diurnal motion, and though the real time of it is still subject to considerable doubts, it can hardly be so slow as 24 days. Its direction, or rather the position of the axis of Venus, is involved in still greater uncertainty.

The atmosphere of Venus is probably very considerable; which appears not only from the changes that have been observed in the faint spots on its surface, but may also be inferred from the illumination of the cusps, when this planet is near its inferior conjunction; where the enlightened ends of the horns reach far beyond a semicircle. I must here take notice, that the author we have before quoted on this subject, has the merit of being the first who has pointed out this inference, but he has overlooked the penumbra arising from the diameter of the sun; * which has certainly a considerable share in

* He mentions it upon another occasion, and says in a note, p. 313, that "*this whole penumbra, which, according to the greatest apparent diameter of Venus, extends from 59 to 60″*, (for what reason he fixes upon these quantities does not appear) "*measures, in the direction perpendicular to the line of the cusps, only* 0″,36." But if, according to him, the apparent diameter of the sun be 44′, (which is less than it ought to be) the penumbra must certainly extend likewise upon the surface of Venus

the effect of the extended illumination, and in his angle of 15° 19′ will amount to more than two degrees and a third. His measures are also defective; as probably the mirror of his 7-feet reflector, which was a very excellent one, was by that time considerably tarnished, and had lost much of the light necessary to shew the extent of the cusps in their full brilliancy.

I do not give the calculations I have made of the extent of the twilight of Venus, because my measures were not so satisfactory to myself as I wish them to be; nor so near the conjunction as we may hereafter obtain them; neither were they sufficiently repeated. My computations, however, when compared to those given in the paper on the atmosphere of Venus, shew sufficiently that it is of much greater extent, or refractive power, than has been computed in that paper. Those calculations indeed are so full of inaccuracies, that it would be necessary to go over them again, in order to compare them strictly with my own, for which at present there is no leisure.

I ought also to take notice here, that the same author, it seems, has taken measures of the horns of Venus by an instrument, which, in his publications, he calls a *projection table*, and describes as his own *; of which, however, those who do not know its construction may have a very perfect idea, when they read the descriptions of my lamp, disk, and periphery

over 44′ of a great circle; and, in the situation which he mentions, that is, perpendicular to the line of the cusps at the time of the greatest elongation, and when the apparent diameter of Venus is 60″, (as he makes it) it must measure 0″,384.

* See *Beiträge zu den neuesten astronomischen Entdeckungen*, p. 210. And *Selenotopographische Fragmente*, p. 63.

micrometers, joined to what I have mentioned above, of using the disk-micrometer without lamps when day-light is sufficiently strong; or even with an illumination in front, where the object is bright enough to allow of it, such as the moon, &c.

I remember drawing the picture of a cottage by it, in the year 1776, which was at three or four miles distance; and going afterwards to compare the parts of it with the building, found them very justly delineated.

I have also many times had the honour of shewing my friends the accuracy of the method of applying one eye to the telescope, and the other to the projected picture of the object in view; by desiring them to make two points, with a pin, upon a card fixed up at a convenient place, where it might be viewed in my telescope; and this being done, I took the distance of these points from the picture I saw projected, in a pair of proportional compasses, one side of which was to the other as the distance of the object, divided by the distance of the image, to the magnifying power of the telescope; and giving the compasses to my friends, they generally found that the proportional ends of them exactly fitted the points they had made on the card. All which experiments are only so many different ways of using the lamp-micrometer.

As to the mountains in Venus, I may venture to say that no eye, which is not considerably better than mine, or assisted by much better instruments, will ever get a sight of them; though, from the analogy that obtains between the only two planetary globes we can compare, (the moon and the earth) there is little doubt but that this planet also has

inequalities on its surface, which may be, for what we can say to the contrary, very considerable.

The real diameter of Venus, I should think, may be inferred with great confidence, from the measures I took with the 20-feet reflector, in the morning of the 24th of November, 1791; which, when reduced to the mean distance of the earth, give 18″,79 for the apparent diameter of this planet.

This result is rather remarkable, as it seems to prove that Venus is a little larger than the earth, instead of being a little less, as has been supposed; yet, upon the nicest scrutiny, I cannot find fault with the measures. The planet was put between the two wires of the micrometer, which were outward tangents; and they were, after each measure, shut, so as to meet with the same edge, and in the same place where the planet was measured. In this situation the proper deduction, for not being central measures, was pointed out by the index plate. The transits of the 25th were corrected for a small concavity of the wires, which being pretty thick and stubborn, were not strained sufficiently to make them quite straight, the amount of which was also ascertained by an examination of the division where the wires closed at the ends, and where they closed in the centre. The zero was, with equal precaution, referred to a point at an equal distance from the contact of the wires on each side; for they are at liberty to pass over each other, without occasioning any derangement. The *shake*, or *play*, of the screw is less than 3-tenths of a division.

The two planets, however, are so nearly of an equal size, that it would be necessary to repeat our measures of the diameter of Venus, in the most favourable circumstances, and

with micrometers adjusted to the utmost degree of precision, in order to decide with perfect confidence that she is, as appears most likely, larger than the earth.

The remarkable phænomenon of the bright margin of Venus, I find, has not been noticed by the author we have referred to: on the contrary, it is said, page 310, "*this light appears strongest at the outward limb a b c, from whence it decreases gradually, and in a regular progression, towards the interior edge, or terminator.*" But the luminous border, as I have described it, in the observations of the 9th, 16th, 20th, and 22d of April, does not in the least agree with the above representation.

With regard to the cause of this appearance, I believe that I may venture to ascribe it to the atmosphere of Venus, which, like our own, is probably replete with matter that reflects and refracts light copiously in all directions. Therefore on the border, where we have an oblique view of it, there will of consequence be an increase of this luminous appearance. I suppose the bright belts, and polar regions of Jupiter, for instance, which have a greater light than the faint streaks, or yellow belts, on that planet, to be the parts where its atmosphere is most filled with clouds, while the latter are probably those regions which are free from them, and admit the sun to shine on the planet; by which means we have the reflection of the real surface, which I take to be generally less luminous.

If this conjecture be well founded, we see the reason why spots on Venus are so seldom to be perceived. For, this planet having a dense atmosphere, its real surface will com-

Fig. 1.

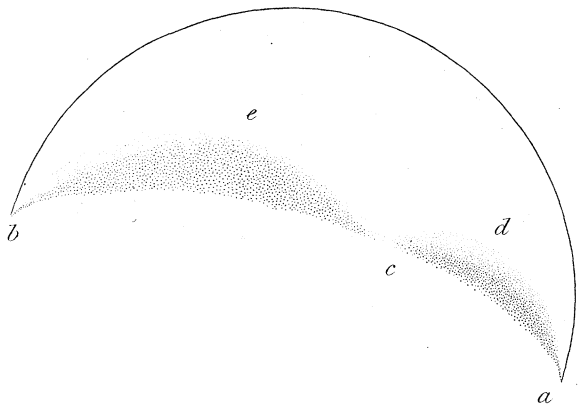
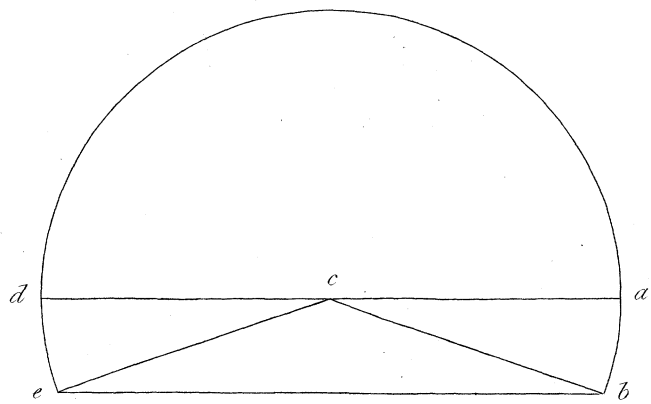


Fig. 2.



monly be enveloped by it, so as not to present us with any variety of appearances. This also points out the reason why the spots, when any such there are, appear generally of a darker colour than the rest of the body.