

II. *On the Diameter and Magnitude of the Georgium Sidus; with a Description of the dark and lucid Disk and Periphery Micrometers.* By William Herschel, Esq. F. R. S.

Read November 7, 1782.

IT is not only of the greatest consequence to the astronomer, but also gives the highest pleasure to every intelligent person, to have a just idea of the dimensions of the solar system, and the heavenly bodies that belong to it. As far then as they fall within the reach of our instruments, they ought carefully to be examined and measured by all the various methods we can invent. Almost every sort of micrometer is liable to some inconveniences and deceptions: it will, however, often happen, that we may correct the errors of one instrument by the opposite defects of another. The measures of the diameter of the Georgium Sidus, which were delivered in my first paper, differ considerably from each other. However, if we set aside the three first, on a supposition (as I have hinted before) that every minute object, which is much smaller than what we are frequently used to see, will at first sight appear less than it really is; and take a mean of the remaining observations, we shall have

have $4'' 36\frac{1}{2}'''$ for the diameter of the planet. On comparing the measures then with this mean, we find but two of them that differ somewhat more than half a second from it; the rest are almost all within a quarter of a second of that measure. This agreement, in the dimensions of any other planet, would appear very considerable; but not being satisfied, when I thought it possible to obtain much more accurate measures, I employed the lamp-micrometer in preference to the former. The first time I used it upon this occasion I perceived, that if, instead of two lucid points, we could have an intire lucid disk to resemble the Planet, the measures would certainly be still more compleat. The difficulty of dilating and contracting a figure that should always remain a circle, appeared to me very considerable, though nature, with her usual simplicity, holds out to us a pattern in the Iris of the eye, which, simple as it appears, is not one of the least admirable of her inimitable works. However, I recollected, that it was not absolutely requisite to have every insensible degree of magnitude; since, by changing the distance, I could without much inconvenience make every little intermediate gradation between a set of circles of a proper size, that might be prepared for the purpose. Intending to put this design into practice, I contrived the following apparatus.

A large lanthorn, of the construction of those small ones that are used with my lamp-micrometer*, must have a place for three flames in the middle, which is necessary, in order that we may have the quantity of light required, by lighting one, two, or all of them. The grooves, instead of brass sliding doors, must be wide enough to admit a paste-board, and three or four thickneses of paper. I prepared a set of circles, cut

* Phil. Transf. vol. LXXII. p. 166.

out in paste-board, increasing by tenths of an inch from two inches to five in diameter, and these were made to fit into the grooves of the lamp. A good number of pieces, some of white, others of light blue paper, of the same size with the paste-boards, were also cut out, and several of them oiled, to render them more transparent. The oiled papers should be well rubbed, that they may not stain the dry papers when placed together. This apparatus being ready, we are to place behind the paste-board circle, next to the light, one, two, or more, either blue or white, dry or oiled, papers; and by means of one or more flames, to obtain an appearance perfectly resembling the disk we would compare it with. It will be found, that more or less altitude of the object, and higher or lower powers of the instrument, require a different assortment of papers and lights, which must by no means be neglected: for if any fallacy can be suspected in the use of this apparatus, it is in the degree of light we must look for it. In a few experiments I tried with these lucid disks, where I placed several of them together, and illuminated them at once, it was found, that but very little more light will make a circle appear of the same size with another, which is one, or even two-tenths of an inch less in diameter. A well known and striking instance of this kind of deception is the moon, just before or after the conjunction, where we may see how much the luminous part of the disk projects above the rest.

The method of using the artificial disks is the same which has been described with the lamp-micrometer, of which this apparatus may be called a branch. We are only to observe, that the Planet we would measure should be caused to go either just under, or just over, the illuminated circle. It may indeed
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also be suffered to pass across it; but in this case, the lights will be so blended together, that we cannot easily form a proper judgement of their magnitudes. By a good screw to the motions of my telescope I have been able, at any time, to keep the Planet opposite the lucid disk for five minutes together, and to view them both with the most perfect and undisturbed attention. The apparatus I employed being now sufficiently explained, several alterations that were occasionally introduced will be mentioned in the observations and experiments on the Georgium Sidus, as they follow, in the order of time in which they were made.

Observations on the Light, Diameter, and Magnitude, of the Georgium Sidus.

Oct. 22, 1781. The Georgium Sidus was perfectly defined with a power of 227; had a fine, bright, steady light; of the colour of Jupiter, or approaching to the light of the Moon.

Nov. 28, 1781. I measured the diameter of the Georgium Sidus by the lamp-micrometer, and took one measure, which I was assured was too large; and one, which I was certain was too little; then taking the mean of both, I compared it with the diameter of the star, and found it to agree very well.

Hence $\frac{\text{Image} = 2.4 \text{ inches}}{\text{Distance} = 431 \text{ inches}} = \text{tang. } .0055684$; and $\frac{\text{Angle} = 19' 8''}{\text{Power} = 227.6}$
= the diameter $5''.06$. But the evening was foggy, and the star having much aberration, I was induced to try the above method of extreme and mean diameters, suggested by
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the method of altitudes, where two equally distant extremes give us a true mean.

Nov. 19, 1781. The diameter measured $32\frac{1}{4}$ parts of my micrometer, the wires being outward tangents to the disk. On shutting them gradually by the same light, they closed at 24; therefore the difference is $8\frac{1}{4}$ parts, which, according to my scale, gives $5'' 2'''$ for the diameter. This was taken with 227, and the measure seemed large enough. Not perfectly pleased with my light, which was rather too strong, I repeated the measure, and had $33\frac{1}{4}$ parts; then shutting the wires gradually, by *this* light they closed at 25: the difference, which is $8\frac{1}{2}$ parts, gives $5'' 11'''$.

Aug. 29, 1782. 15 h. I saw the Georgium Sidus full as well defined with 460, as Jupiter would have been at that altitude with the same power.

Sept. 9, 1782. Circumstances being favourable, I took a measure of the diameter of the Georgium Sidus with the power of 460, and silk-thread micrometer. After a proper allowance for the zero, I found $4'' 11'''$.

Oct. 2, 1782. I had prepared an apparatus of lucid disks, and measured the diameter of the Georgium Sidus with it. Having only white oiled papers, I placed two of them together, and used only a single lamp; but could not exactly imitate the light of the Planet. When I first saw the Sidus and luminous circle together, I was struck with the different colours of their lights; which brought to my recollection γ Andromedæ, ϵ Bootis, α Herculis, β Cygni, and other coloured stars. The Planet unexpectedly appeared blueish, while the lucid disk had a strong tincture of red; but neither of the colours were so vivid and sparkling as those of the just mentioned stars.

The distance of the luminous circle from the eye (which I always measure with deal rods) was 588,25 inches. The circle measured 2,35 inches. Hence we have the angle $13' 44''$; which, divided by the power 227, gives $3'',63$ for the diameter of the Planet. I suspected some little fallacy from the want of a perfect resemblance in the light and colour of the artificial disk to the real appearance of the Planet.

Oct. 4, 1782. I measured the diameter of the Georgium Sidus again, by an improvement in my apparatus, for I now used pale blue papers, both oiled and plain, instead of white; by which means I obtained a resemblance of colours; and by an assortment of one oiled and two dry papers with two lamps burning, I effected the same degree of light which the Planet had, and both figures were equally well defined. By first changing the disk, and, when I had one which came nearest, changing my distance, I came at a perfect equality between the Planet and disk. The measure was several times repeated with great precaution. The result was $\frac{2,8}{692,6} = ,0040283$; and $\frac{13' 53'',85}{227} = 3'',67$. If any thing be wanting to the perfection of this measure, it is perhaps that the Sidus should be in the meridian, in order to have all the advantages of light and distinctness.

Oct. 10, 1782. The measures of the Planet by the lucid disk micrometer appearing to me very small, I resolved to ascertain the power of my telescope again most scrupulously, by an actual experiment, without any deduction from other principles. On a most convenient and level plain I viewed two slips of white paper, and measured their images upon a wall. The distances were measured by deal rods, every repetition whereof

was certainly true to half a tenth of an inch; nor did the direction of the measure ever deviate, so much as two inches, from a straight line.

Distance of the object from the eye in inches	7255,5
Distance of the eye from the vertex of the speculum	80,2
Distance of the vertex of the speculum from the object	7335,7
Distance of the eye from the wall	2292,35
Diameter of the largest paper	,99125
Diameter of the smallest	,5075
Image of the largest paper on the wall	73,
Image of the smallest on the same	37,8
Angle subtended by the large paper at the vertex of the speculum	27'',87
Angle subtended by its image on the wall, at the eye	1° 49' 26'',4.
Power of the telescope deduced from the large paper	235,6
Angle subtended by the small paper at the vertex of the speculum	14'',27.
Angle subtended by its image on the wall, at the eye,	56' 40'',9,
Power of the telescope deduced from the small paper	238,3
Mean of both experiments, as being equally good	237,
Focal length of the speculum upon those objects	86,1625
Upon Capella	85,2
And 237 diminished in the ratio of 85,2 to 86,1625 gives 234,3 for the power of the instrument upon the fixed stars.	

It appears then, from these experiments, that the power of the telescope has not been over-rated; and that, therefore, the measures of the Georgium Sidus cannot be found too small on that account.

There is one cause of inaccuracy or deception in very small measures, long suspected, but never yet sufficiently investigated. That there is a *dispersion* of the rays of light in their passage through the atmosphere, we may admit from various experiments; if then the quantity of this dispersion be, in general, regulated by certain dispositions of the air, and other causes, it will follow, that a *concentration* may also take place: for should the rays of light, at any time, be less dispersed than usual, they might with as much reason be said to be concentrated, as the mercury of a thermometer is said to be contracted by cold, when it falls below the zero.

Oct. 12, 1782. The night was so fine, that I saw the Georgium Sidus very plainly with my naked eye. I took a measure of its diameter by the lucid disk, and found, that I was obliged to come nearer, as the Planet rose higher, and gained more distinct light. At the altitude of 52° it was as follows:

$$\frac{3,415}{731,3} = ,0046698; \text{ and } \frac{16'3'',2}{227} = 4'',24.$$

Oct. 13, 1782. 16 h. I viewed the Georgium Sidus with several powers. With 227 it was beautiful. Still better with 278. With 460, after looking some time, very distinct. I perceived no flattening of the polar regions, to denote a diurnal motion; though, I believe, if it had had as much as Jupiter, I should have seen it. With 625 pretty well defined.

Oct. 19, 1782. The inconvenience arising from the quantity of light contained in the lucid disk, suggested to me the

idea of taking only an illuminated periphery, instead of the area of a circle. By this means I hoped to see the circle well defined, and yet have but little light to interfere with the appearance of the Planet. The breadth of my lucid periphery was one-twentieth of an inch. The result of this measure proved $\frac{3,3}{765,45} = ,0041486$; and $\frac{14' 15'',69}{227} = 3''77$.

Oct. 26, 1782. In my last experiment I found the lucid periphery much broader than I could have wished; therefore, I prepared one of no more than one-fortieth part of an inch in breadth, the outer circle measuring very exactly 4,00, and the inner circle 3,95. With this slender ring of light illuminated with only one single lamp, I measured the Georgium Sidus, by removing the telescope to various distances; and found at last the following result: $\frac{4,}{1033,05} = ,0038720$; and $\frac{13' 18'',6}{227} = 3'',51$.

Nov. 4, 1782. I was now fully convinced that light, be it in the form of a lucid circle, or illuminated periphery, would always occasion the measures to be less than they should be, on account of its vivid impression upon the eye, whereby the magnitude of the object, to which the Planet was compared, would be increased. It occurred to me then, that if a lucid circle encroached upon the surrounding darker parts, a lucid square border, round a dark circle, would in its turn advance upon the artificial disk. In my last measures, where the Planet had been compared to a lucid ring, I had plainly observed that the Sidus, which was but just equal to the illuminated periphery, was considerably larger than the black area contained within the ring. This seemed to point out a method to discover the quantity of the deception arising from the illumination; and consequently, to furnish us with a correction applicable to such mea-

tures; which would be *plus*, when taken with a lucid disk or ring; and *minus*, when obtained from a dark ring or circle. Having suspended a row of paste-board circles against an illuminated sheet of oiled paper, I caused the Georgium Sidus to pass by them several times, and selected from their number that to which the Planet bore the greatest resemblance in magnitude. I produced a perfect equality by some small alteration of my distance, and the result was as follows:

$$\frac{3,165}{633,95} = ,0049925; \text{ hence } \frac{17' 9'',8}{227} = 4'',53.$$

I was desirous of seeing what would be the effect of lessening the light of the illuminated frame, against which the dark disks were suspended, and also waited a short time that the Planet might rise up higher. The measure being then repeated at a different distance, and with a different black disk, I obtained the following particulars:

$$\frac{3,59}{803,05} = ,0044704; \text{ and } \frac{15' 22'',1}{227} = 4'',06.$$

I intend to pursue these experiments still farther, especially in the time of the Planet's opposition, and am therefore unwilling as yet to draw a final conclusion from the several measures. In a subject of such delicacy we cannot have too many facts to regulate our judgement. Thus much, however, we may in general surmise, that the diameter of the Georgium Sidus cannot well be much less, nor perhaps much larger, than about four seconds. From this, if we will anticipate more exact calculations hereafter to be made, we may gather that the real diameter of that planet must be between four and five times that of the earth: for by the calculations of M. DE LA LANDE, contained in a letter he has favoured me with, the distance of the Georgium Sidus is stated at 18,913, that of the earth

earth being 1. And if we take the latter to be seen, at the sun, under an angle of $17''$, it would subtend no more than $,''898$, when removed to the orbit of the Georgium Sidus. Hence we obtain $\frac{4}{,898} = 4,454$; which number expresses how much the real diameter of the Georgium Sidus exceeds that of the earth.

