

**XLVII.** *Observations of the Transit of Venus over the Sun, and the Eclipse of the Sun, on June 3, 1769; made at the Royal Observatory. By the Rev. Nevil Maskelyne, B. D. F. R. S. and Astronomer Royal.*

Read June 15, 1769. **T**HE weather, which had been cloudy or rainy here, with a south wind, for the greatest part of the day, began to clear up at 4 o'clock in the afternoon, the wind having returned to the west, the same quarter in which it had been the afternoon before, which was remarkably fine and serene, though it changed early in the morning preceding the transit. Towards the approach of Venus's ingress on the Sun, the sky was become again very serene, and so continued all the evening, which afforded as favourable an observation of the transit here as could well be expected, considering that the Sun was only  $7^{\circ} 3'$  high at the external, and  $4^{\circ} 33'$  at the internal contact. I observed the external contact of Venus at  $7^{\text{h}} 10' 58''$  apparent time, with an uncertainty seemingly not exceeding  $5''$ ; and the internal contact, by which I mean the completion of the thread of light between the circumferences of the Sun and Venus, at  $7^{\text{h}} 29' 23''$  apparent time, with a seeming uncertainty of only  $3''$ ; for so long was the thread of light in forming, or the Sun's light in flowing round and filling up that part of his circumference which was obscured by

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Venus's exterior limb. Nevertheless, I would not hence infer, that observations made by astronomers in distant places should agree together within such narrow limits; for I know they will not even in the same place, and that a difference in the skill or judgment of the observers, in the telescopes, and perhaps in some other little circumstances, not easily distinguished, may produce much greater disagreements, especially if the Sun be low, as it was here; in like manner as in observing the eclipses of Jupiter's satellites, the immersion or emersion shall often seem instantaneous, or nearly so, equally to two observers in distant places, and yet the absolute times of the observations may differ a minute of time or more from each other, owing to the difference of telescopes, weather, or other circumstances. Indeed, in the present case, the limit of differences is certainly much narrower; but what it is I shall not at present venture to suggest, as that may better be done when all the observations that shall have been made of the transit are collected together. The telescope which I used was an excellent reflecting one of two feet focus, made by the late ingenious Mr. Short, and is the same with which the last transit was observed here by Mr. Charles Green. I applied the magnifying power of 140 times, and used smoked glasses to defend the sight, which are much preferable to black or red glasses, as shewing the objects more distinct, and being much more pleasant to the eye.

I shall now endeavour to describe, as accurately as I can, some other phenomena which I noted during the immersion of Venus, and to mention some others, which by some ingenious persons were expected to have

have been seen, but which I could not discover.

It had been thought by some, that Venus's circumference might probably be seen, in part at least, before she entered at all upon the Sun, by means of the illumination of her atmosphere by the Sun; I therefore looked out diligently for such an appearance, but could see no such thing.

I was also attentive to see if any penumbra or dusky shade preceded Venus's first impression on the Sun at the external contact, such a phenomenon having been observed by the Rev. Mr. Hirst, F. R. S. at the former transit of Venus, in 1761, which he observed with much care and diligence at Madras, in the East-Indies; but I could not discern the least appearance of that kind. I would not, however, be therefore thought to call in question either Mr. Hirst's discernment or fidelity; as I am sensible that the tremors of the limbs of the Sun and Venus, occasioned by the vapours at the altitude of  $7^{\circ}$ , might easily obscure a faint object.

When Venus was a little more than half immersed into the Sun's disc, I saw her whole circumference completed, by means of a vivid, but narrow and ill-defined border of light, which illuminated that part of her circumference which was off the Sun, and would otherwise have been invisible. This I might, probably, have seen sooner, if I had attended to it. I continued to see it till within a few minutes of the internal contact, and grew apprehensive that it would prevent the appearance of the thread of light, when it came to be formed; but it disappeared about two or three minutes before, as well

well as I can remember: after which the regularity of Venus's circular figure was disturbed towards the place where the internal contact should happen, by the addition of a protuberance, dark like Venus, and projecting outwards, which occupied a space upon the Sun's circumference, which bore a considerable proportion to the diameter of Venus. Fifty-two seconds before the thread of light was formed, Venus's regular circumference, supposed to be continued as it would have been without the protuberance, seemed to be in contact with the Sun's circumference supposed also completed. Accordingly, from this time, Venus's regular circumference, supposed defined in the manner just described, appeared wholly within the Sun's circumference; and it seemed, therefore, wonderful that the thread of light should be so long before it appeared, the protuberance appearing in its stead.

At length, when a considerable part of the Sun's circumference, equal to  $\frac{1}{3}$ <sup>d</sup> or  $\frac{1}{4}$ <sup>th</sup> of the diameter of Venus, remained still obscured by the protuberance, a fine stream of light flowed gently round it from each side, and completed the same in the space of three seconds of time, from 7<sup>h</sup> 29' 20'' to 7<sup>h</sup> 29' 23'' apparent time; and Venus appeared wholly within the Sun's lucid circumference; but the protuberance, tho' diminished, was not taken away till about 20'' more, when, after being gradually reduced, it disappeared, and Venus's circular figure was restored.

An ingenious gentleman of my acquaintance having desired me to examine if there was any protuberance of the Sun's circumference about the point of the internal contact, as he supposed such an ap-

pearance ought to arise from the refraction of the Sun's rays through Venus's atmosphere, if she had one; I carefully looked out for such a circumstance, but could see no such thing; neither could I see any ring of light round Venus, a little after she was got wholly within the Sun: but, I confess, I did not re-examine this latter point afterwards, when she was further advanced upon the Sun, at which time other persons at the observatory saw such an appearance.

How far the ring of light, which I saw round that part of Venus's circumference which was off the Sun, during the immersion, may deserve to be considered as an indication of an atmosphere about Venus, I shall not at present inquire; but I think it very probable, that the protuberance, which disturbed Venus's circular figure at the internal contact, was owing to the enlargement of the diameter of the Sun, and the contraction of that of Venus, produced by the irregular refraction of the rays of light through our atmosphere, and the consequent undulation of the limbs of the two planets; the altitude of Venus being only  $4^{\circ} 48'$ , though the Sun's limb was more distinct and steady than usual at that altitude. This conjecture seems corroborated by two circumstances: one is, that Venus's limb, from its first appearance to the total immersion, as well as afterwards, was very ill defined, and undulated very much; the other is, that her horizontal diameter, which I measured soon after the internal contact with an excellent achromatic object-glass micrometer, fitted to the two-feet reflecting telescope, was only  $55\frac{3}{4}''$ , by a mean of eight trials, or about  $3''$  less than it should have been, from the observations made, with the like instrument, at the transit

transit of Venus in 1761, by Mr. Short, Mr. Canton, Mr. Haydon, and Mr. Mason, when the Sun was at a considerable altitude; and most likely the Sun's diameter was enlarged in proportion, though it might have been difficult to have ascertained it by actual measure, had time allowed me to make the experiment with the same micrometer before the Sun entered into a black cloud near the horizon.

Six other persons also observed the contacts of Venus here, and noted some other phænomena. Their names are, the Rev. Malachy Hitchins, a gentleman well acquainted with astronomy and astronomical calculations, who has made and examined many belonging to the Nautical Almanac, and has been so obliging as to come here and assist me in making astronomical observations, during the absence of my assistant, Mr. William Bayley, who is gone to the North Cape, by appointment of the Royal Society, to observe the transit of Venus there. The others are, the Rev. William Hirst, who observed the former transit of Venus, in 1761, at Madras; John Horsley, Esq; a gentleman whom I had the pleasure of first commencing an acquaintance with during my voyage from St. Helena to England, in the Warwick East-India ship, and who then, and in several voyages since to the East-Indies and home again, observed and calculated the longitude from distances of the Moon from the Sun and fixed stars with the greatest accuracy; Mr. Samuel Dunn, who has had a good deal of practice in making astronomical observations, and who carefully observed the former transit of Venus, in 1761, at Chelsea; Mr. Peter Dollond, whose great skill in constructing achromatic and reflecting telescopes;

lescopes; and Mr. Edward Nairne, whose skill likewise in the same way, and in making all kinds of mathematical and philosophical instruments are sufficiently known to the public.

Mr. Horsley and Mr. Dunn observed with me in the great room; Mr. Hitchins and Mr. Hirst in the eastern summer-house; and Mr. Dollond and Mr. Nairne in the western summer-house; by three clocks placed in the respective rooms, which were compared with the clock in the transit room, before the external contact, and again after the internal contact was past; whence the times of the observations, as noted by the clocks, were reduced to the time of the transit clock, and thence to apparent time.

Their observations, together with my own, are given in the following table, as reduced to apparent time.

	External contact.			Regular circumferences in contact.			1 thread of light completed, or the internal contact.			Telescope made use of.	Magnifying power.
	h	'	"	h	'	"	h	'	"		
N. Maskelyne	7	10	58	7	28	31	7	29	23	2 feet reflector.	140
M. Hitchins	7	10	54	7	28	47	7	28	57	6 f. reflector.	90
W. Hirst	7	11	11	—	—	—	7	29	18	2 f. reflector.	55
J. Horsley	7	10	44	7	28	15	7	29	28	10 f. achromatic.	50
S. Dunn	7	10	37	7	29	28	7	29	48	3½ f. achromatic.	140
P. Dollond	7	11	19	—	—	—	7	29	20	3½ f. achromatic.	150
E. Nairne	7	11	30	—	—	—	7	29	20	2 f. reflector.	120

Mr. Dollond and Mr. Nairne used telescopes of their own construction; but they did not wait till the

thread of light was formed at the internal contact, but noted the time, when they judged it was just ready to be formed. The  $3\frac{1}{2}$  feet achromatic telescopes were those made with 3 object-glasses.

The differences between the different observations seem pretty considerable, and greater than I expected, considering that all the telescopes may be reckoned pretty nearly equal, excepting the 6 feet reflector, which is much superior to them all; and to its greater excellence and distinctness I principally attribute the difference of 26'' by which Mr. Hitchins saw the internal contact before me; as I can depend upon his observations. Possibly the greatness of the differences might arise from the low altitude of the Sun and Venus; and then the like differences would not be so much to be feared in places where the observation may be made at higher altitudes; otherwise the sun's parallax will not be deducible from the transit of Venus with that accuracy which has been expected.

The other appearances about Venus, noted by the six observers, which they have communicated to me, are as follows:

Mr. Hitchins remarks, that, at the first contact, though there was a tremulous motion in the Sun's limb, yet that part of it which the planet entered was very well defined, and the first impression of Venus appeared to be instantaneous, and as a black, sharp point. At the internal coincidence of circumferences, the fluctuation of the Sun's limb was increased, and the limb of Venus being affected in like manner, there was an uncertainty of about 10'' in estimating the said coincidence; but at the breaking in of the thread of light between the limbs, there was  
not



not a greater uncertainty than a second and half of time. At the internal coincidence of circumferences, the limb of Venus next to that of the Sun being protuberant, her vertical diameter appeared to be longer than the horizontal one; but when the Sun approached the horizon, and was scarce above a degree high, Venus's horizontal diameter appeared to be sensibly longer than the vertical, which was, probably, owing to refraction. After the internal contact, there appeared a luminous Ring round the body of Venus, about the thickness of half her semi-diameter; it was brightest towards Venus's body, and gradually diminished in splendor at greater distances, but the whole was excessive white and faint. This radiancy round the planet seemed to him to be greater in Mr. Nairne's 2 feet telescope than in the 6 feet Newtonian reflector.

After the second or internal contact, Mr. Hirst left off observing with Mr. Dunn's 2 feet reflector, and had a sight of Venus in the 6 feet Newtonian reflector, in which he thought he perceived a glimmering of light about the upper part of the circumference of Venus, or that part of the planet which entered last into the Solar disc.

After Venus was got within the Sun's disc, a light a little weaker than that of the Sun, of a purplish colour, appeared to Mr. Horsley, to the left-hand of Venus, which is really to the right, the telescope inverting objects. This light he saw for six or seven minutes.

From  $7^{\text{h}} 28' 26''$  to  $7^{\text{h}} 28' 30''$  apparent time, Mr. Dunn saw a very faint rim of light at Venus's

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exterior limb. After Venus was wholly on the Sun, he saw a faint ring of light surrounding her, both with the  $3\frac{1}{2}$  feet telescope, and Mr. Nairne's 2 feet reflector.

When  $\frac{1}{3}$  of Venus's diameter was entered upon the Sun, Mr. Dollond first saw a light about the exterior limb of the planet: this light, during all the time of its continuance, appeared rather reddish, and in all respects like irregular refracted light. After Venus was wholly entered upon the Sun, he saw a faint ring surrounding her.

After Venus was wholly entered upon the Sun, and her exterior limb was near one of her semi-diameters distant from the Sun's circumference, Mr. Nairne saw a faint light round the planet, rather brighter and whiter than the body of the Sun.

Fortunately, the weather was as favourable for the observation of the eclipse of the Sun, the next morning, as it had been the evening before for that of the ingress of Venus upon the Sun; which is of the more consequence, as the comparison of it with the observations which may be made of it in the northern and eastern parts of the world will serve to settle the longitudes of those places, and consequently render the observations which may be made there of the transit more useful and valuable.

I observed the beginning of the eclipse at  $18^{\text{h}} 38' 54''$ , and the end at  $20^{\text{h}} 23' 30''$  apparent time, with the 2 feet reflector, using the magnifying power 90 times. And at  $19^{\text{h}} 29' 31''$  apparent time, I observed the greatest eclipse, at which time I found the remaining lucid parts of the Sun  $15' 15''$  with Dollond's micro-

31' 31'', whence the value of the scale of the micro-  
meter was determined for the present purpose. Hence  
the eclipsed parts of the Sun were 16' 16'' or  
6<sup>dig.</sup> 11',62 on the northern part of his disc.

Mr. Hitchins observed the beginning of the eclipse  
with a 3½ feet achromatic telescope magnifying 150  
times (the same with which Mr. Dollond observed  
the contacts of Venus), at 18<sup>h</sup> 38' 59'', and the end  
of the eclipse with the 6 feet reflector with the mag-  
nifying power 90, at 20<sup>h</sup> 23' 35'' apparent time.  
And Mr. Samuel Dunn observed the beginning of  
the eclipse at 18<sup>h</sup> 39' 9'', and the end at 20<sup>h</sup> 23' 33''  
with the other 3½ feet achromatic telescope, magni-  
fying 140 times, the same with which he observed  
the contacts of Venus. Several inequalities in the  
Moon's circumference, seen upon the Sun's disc  
during the eclipse, were distinctly discerned by all of  
us, the air being very clear, and the objects steady.

The whole series of measures of the lucid parts, which I  
took with the achromatic object glass micrometer applied to the  
2 feet telescope, was as follows ;

Apparent time.			Lucid parts.	
h	'	''	'	''
19	22	13	—	15 40,5
	24	21	—	15 26,5
	26	9	—	15 20,9
	28	26	—	15 15,6
	30	14	—	15 14,5
	31	44	—	15 16,4
	32	30	—	15 16,4
	33	19	—	15 19,8
	34	28	—	15 25,4
	36	19	—	15 35,9
	37	56	—	15 49,1