

XXXV. *Some Observations of the Planet Venus, on the Disk of the Sun, June 6th, 1761; with a preceding Account of the Method taken for verifying the Time of that Phænomenon; and certain Reasons for an Atmosphere about Venus: By Samuel Dunn.*

Read Nov. 5,
1761.

AS soon as I heard, that several mathematicians were to go abroad, and observe the transit of Venus over the disk of the sun, from foreign parts, I purposed to observe the same at Chelsea, and to compare my observation with the more accurate ones, which I expected would be made at the Royal Observatory at Greenwich. Supposing, that if my observation at Chelsea was made with equal care, and as good instruments for ascertaining time, as the instruments to be used by the observers abroad, it might be useful, as a kind of proof, how exact the observations had been made abroad, where the observers had less conveniencies for ascertaining time, than at the Royal Observatory.

Mr. Dollond (a member of the Society) had, some time before, newly ground, and fitted up for me, a Newtonian reflecting telescope, six feet in length; which so far exceeded expectation, that by it the Reverend Mr. Maskelyne (who is now at St. Helena) and myself, had several times observed how long Jupiter's satellites dwell on the limb of Jupiter, entering on the body. And I was provided with an eight-

eight-day clock, having a second-hand, an iron pendulum, and an adjusting screw at its bob.

Altitude instruments of wood and brass, adjusted by spirit levels, had engaged my attention; but having found several of these defective, by comparing their results with meridian altitudes, and the time by the clock; and having many times examined the clock by double altitudes of the sun, taken with a Hadley's quadrant, having a nonius to minutes, and an artificial horizon of sweet oil in a tea-saucer, I determined to depend on such an instrument and horizon, for ascertaining the error of the clock, and correctness of my meridian.

An artificial horizon of water, and even of quicksilver, I had found to be too easily disturbed, and therefore had, some time before, introduced oil, and found it vastly preferable. And in taking altitudes, I always observe, when the sun, or other celestial body, is as near the prime vertical, or east and west azimuth, as possible; and generally take either five double altitudes, half a minute of time asunder each, or three double altitudes, a minute of time asunder, dividing the sum by either ten or six, as the case is, for a mean single altitude, corresponding to the mean time of those observations by the clock. And in taking the sun's transit across the meridian, I take a mean of the times of appulse to several parallel and equidistant lines on each side of the meridian, and it generally gives the transit to less than a second of time.

The daily tables of the sun's declination, equation of time, &c. which I use, are those in the ephemerides of the Abbé de la Caille; and the latitude of

my place is $51^{\circ} 29' 5''$ N. and $41''$ of time west of the observatory at Greenwich, between the physic-garden and Chelsea hospital.

Several observations * for verifying the quadrant, meridian, clock, &c. made at different times of the year, were as follow; viz.

22d December 1760. Altitude sun's upper limb on the meridian $15^{\circ} 6' 30''$. Error by calculation $2''$ of a degree.

26th December 1760. Altitude sun's upper limb on the meridian $15^{\circ} 12' 15''$. Error by calculation $8''$ of a degree.

2d January 1761. Altitude sun's upper limb on the meridian $15^{\circ} 20' 42''$. Error by calculation $3''$ of a degree.

18th February 1761. Altitude sun's upper limb on the meridian $27^{\circ} 22' 45''$. Error by calculation $4''$ of a degree.

6th February 1761. Sun on the meridian, by the clock, at $12^{\text{h}} 14' 35''$. Error by equation table $0''$ of time.

11th February 1761. morning, at $10^{\text{h}} 20$, per elock. Altitude sun's upper limb $20^{\circ} 23'$. Error of clock $0''$ of time.

11th February 1761, noon, sun on meridian, per clock, at $12^{\text{h}} 14' 44''$. Error by equation table $0''$ of time.

11th February 1761, afternoon, at $6^{\text{h}} 37' 30''$ per clock. Altitude sun's upper limb $6^{\circ} 37' 30''$. Error of clock $0''$ of time.

* A great number of others were made, although not inserted in this paper.

From 18th February to 11th March, the clock had gained of equal time $37''$, which is near $2''$ of time per day.

11th March to 10th April, the clock had gained of equal time $15''$, which is near $3''$ of time per day.

4th June, afternoon, at $4^h 52'$ per clock. Altitude sun's centre $27^\circ 40' 14''$, which is near $3''$ of time per day.

6th June, afternoon, at $5^h 40'$ per clock. Altitude sun's centre $24^\circ 29' 5''$, which is near $3''$ of time per day.

8th June, afternoon, at $5^h 20'$ per clock. Altitude sun's centre $23^\circ 45' 53''$, which is near $3''$ of time per day.

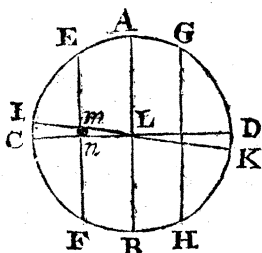
9th June, noon, sun on the meridian, per clock, at $12^h 59' 32''$, which is near $3''$ of time per day.

These latter observations, shewing the gain of the clock $3''$ of time per day, surprized me, as being contrary to my expectation; for the clock had lost two or three seconds per day in winter, and therefore, I concluded it would lose more in the spring and summer, by the lengthening of the pendulum; but it happened quite the contrary, and the cause thereof I could not determine.

For ascertaining the diameter of Venus, and also the position and distance of the solar maculæ from Venus, I had caused to be constructed an instrument *, much like one which has been already described to the So-

* Angular micrometer.

ciety, with this addition, which was originally designed for that instrument; namely, EF and GH, two silver wires parallel to the diameter AB, and distant therefrom $30^\circ = AE = AG = BF = BH$, the three parallel wires EF, AB, and GH, being fixed, whilst the moveable wires CD and IK



opened to any angle, as ILC for intercepting the diameter mn of Venus, whilst CD was perpendicular to AB, and the planet was divided into two equal parts by the wire EF. This micrometer was placed in the eye-piece of a two feet Gregorian telescope, which magnified 55 times, and through the field of view, of which the sun passed in 118 seconds of time.

I had two eye-glasses to the six feet Newtonian * reflector; one of which, being six tenths of an inch focus, magnified 110 times; and the other, being three tenths of an inch focus, magnified 220 times, or four times that of the Gregorian reflector. The greater of these two glasses I purposed to trust to, having often experienced its superiority in viewing the occultations of Jupiter's satellites and the solar maculæ.

The idea I had formed of the internal contact was, that the planet would touch the edge of the sun in an instant, like two drops of quicksilver meeting on a plane, and that in an instant the black contact would appear; but in this I was deceived, the particulars of the phænomenon being as follows; viz.

* The diameter of the great speculum of this telescope was six inches.

June 6th, a cloudy morning, till about six o'clock, when the clouds began to dissipate, but not enough to afford a plain sight of Venus on the sun, till more than half past seven, and the planet got nearer the limb of the sun, than I had desired to see it first on the disk.

By repeated trials, the time in which the planet was passing from the internal to the external contact, with the wire of the micrometer was $3\frac{3}{4}$ seconds of time, and the angle ICL of the angular micrometer was 8° .

With the six feet Newtonian reflector, and its magnifying power of 110, and also of 220 times, I carefully examined * the sun's disk, to discover a satellite of Venus, but saw none; for I had a very clear dark glass next my eye, and the sun's limb appeared most perfectly defined; but a very narrow waterish penumbra † appeared round Venus, by which its limb was not perfectly defined, and at the distance of about a sixth part of Venus's diameter from its edge, was the darkest part of Venus's phasis, from which to the centre, an imperfect ‡ light increased, and illuminated about the centre.

At $8^h 16'$ per clock, I was prepared to observe the internal contact; and as Venus drew nearer to the limb of the sun, the penumbra near the limb of Venus

* After the transit, till two o'clock afternoon the same day, I continued observing the disk with this telescope, but saw no satellite pass over the sun.

† This penumbra could not by any means be made to disappear, although I tried to make it vanish, by altering the focus of the telescope a great number of times.

‡ This could not arise from any imperfection of the telescope, as the solar maculæ appeared sharply defined, as through a refractor.

became

became darker, and threatened to obscure the point of contact at the instant it would happen; the circumstances of which, for each of the moments of time, are imperfectly delineated, on account of the nearness of the lines, but more truly described as follows; (a right line representing that part of the sun's limb near where the contact happened, and an arch the approaching limb of Venus, for each three seconds of time, from the loss of the thread of light.)

A diagram, representing the approach of Venus to the sun's limb, for each three seconds of time. [*Vide Tab. VII.*]

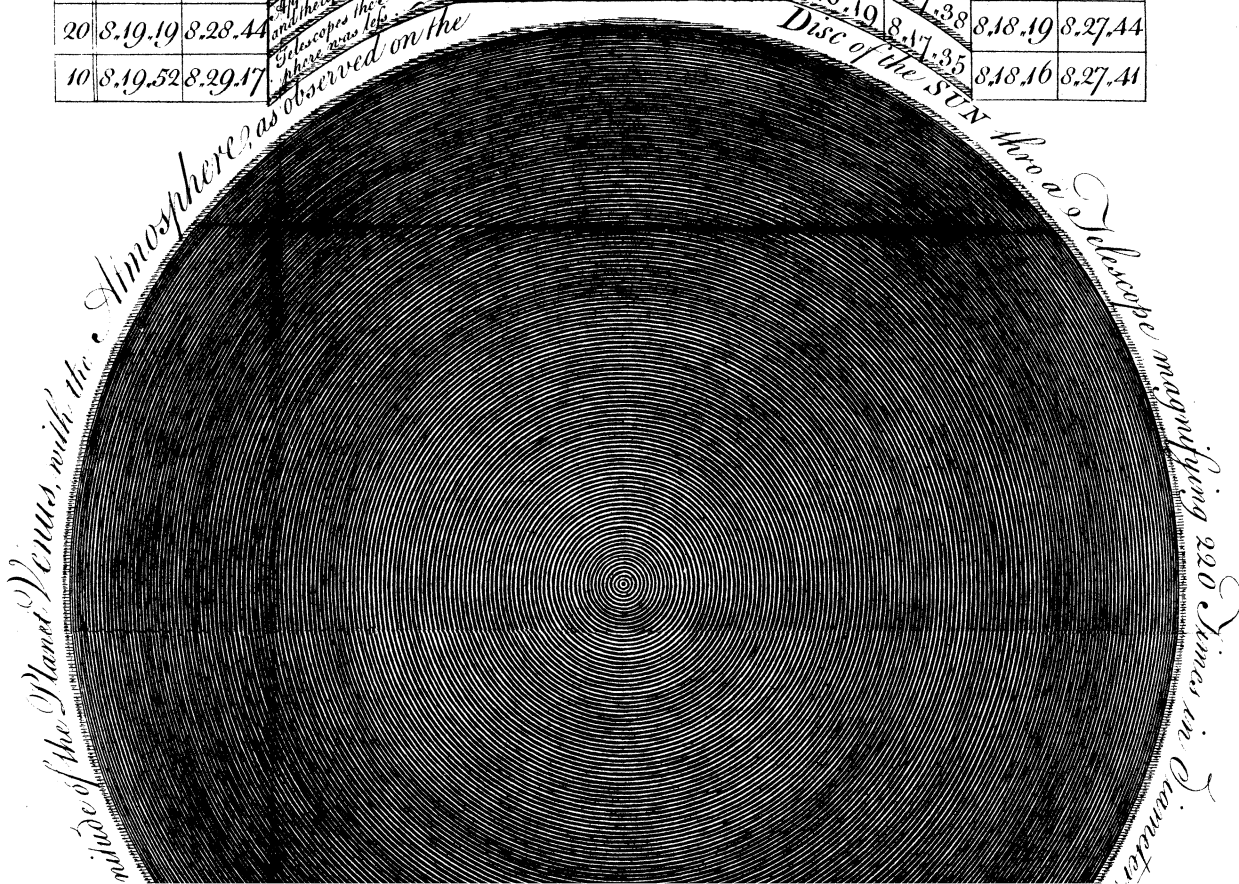
In this diagram, the black segments represent Venus, and the right lines drawn nearly at contact to them, represent a small part of the sun's limb, as seen through a dark glass; the intermediate spaces white, represent the sky. In words, (for each second of time by the clock) thus:

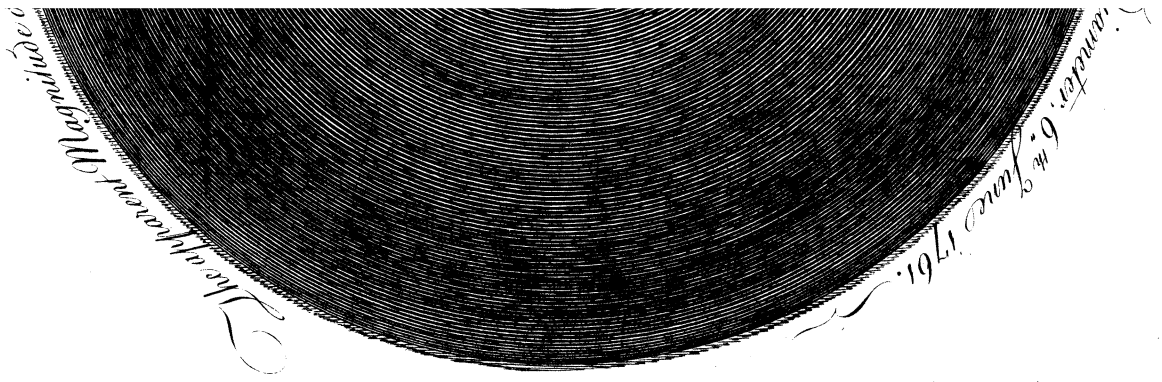
| | | | | |
|------|----|----|---|--|
| At 8 | 16 | 41 | } No diminution of light between the limb of Venus and that of the sun. | |
| 8 | 16 | 42 | | } Slight penumbra, or diminution of light, near where the contact was to be. |
| 8 | 16 | 43 | | |
| 8 | 16 | 44 | | } Penumbra almost brown, and the thread of light very narrow, and almost lost. |
| 8 | 16 | 45 | | |
| 8 | 16 | 46 | | } Penumbra more brown, and the touch the smallest possible. |
| | | | | |

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VENUS with an Atmosphere, as seen on the Face of the SUN. 6th June 1761, thro' a Telescope magnifying 220 times in Diameter. Also the Approaches of the Planet toward the Sun's Limb, & the Circumstances referred to other Telescopes & to the Royal Observatory at Greenwich. By Samuel Dunn.

| Paris, p. S. D. | Approaches of the Planet toward the Sun's Limb, at the Internal Contact. | | Paris Observatory. | Greenwich. | Approach of the Planet toward the Sun's Limb, at the Internal Contact. | Paris Observatory. | Greenwich. | Approach of the Planet toward the Sun's Limb, at the Internal Contact. | Paris Observatory. | Greenwich. | Approach of the Planet toward the Sun's Limb, at the Internal Contact. | Paris Observatory. | Greenwich. | Approach of the Planet toward the Sun's Limb, at the Internal Contact. | Paris Observatory. | Greenwich. | Approach of the Planet toward the Sun's Limb, at the Internal Contact. | Paris Observatory. | Greenwich. | Approach of the Planet toward the Sun's Limb, at the Internal Contact. | Paris Observatory. | Greenwich. | | | |
|-----------------|--|-------------------|--|------------|--|--------------------|------------|--|--------------------|------------|--|--------------------|------------|--|--------------------|------------|--|--------------------|------------|--|--------------------|------------|--|--|--|
| | Greenwich Observatory | Paris Observatory | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | Broader black Contact. | | | | | | | | | | | | | | | | | | | | |
| | | | | | Broader black Contact. | | | | | | | | | | | | | | | | | | | | |
| 150 | 8.18.21 | 8.28.10 | 8.28.35 | 8.19.10 | Black Contact. | | | | | | | | | | | | | | | | | | | | |
| 100 | 8.18.53 | 8.28.18 | 8.28.27 | 8.19.2 | Brown Contact. | | | | | | | | | | | | | | | | | | | | |
| 75 | 8.18.55 | 8.28.20 | 8.28.19 | 8.18.54 | Grey Contact. | | | | | | | | | | | | | | | | | | | | |
| 60 | 8.18.57 | 8.28.22 | 8.28.11 | 8.18.46 | Atmosphere untouched. | | | | | | | | | | | | | | | | | | | | |
| 55 | 8.18.58 | 8.28.23 | 8.28.3 | 8.18.38 | No Loss of Light now. | | | | | | | | | | | | | | | | | | | | |
| 50 | 8.18.59 | 8.28.24 | 8.27.55 | 8.18.30 | No Loss of Light now. | | | | | | | | | | | | | | | | | | | | |
| 45 | 8.19.0 | 8.28.25 | 8.27.47 | 8.18.22 | | | | | | | | | | | | | | | | | | | | | |
| 40 | 8.19.2 | 8.28.27 | 8.27.39 | 8.18.14 | | | | | | | | | | | | | | | | | | | | | |
| 35 | 8.19.5 | 8.28.30 | 8.27.31 | 8.18.6 | | | | | | | | | | | | | | | | | | | | | |
| 30 | 8.19.8 | 8.28.33 | 8.27.23 | 8.17.58 | | | | | | | | | | | | | | | | | | | | | |
| 25 | 8.19.12 | 8.28.57 | The above Numbers denote the corresponding Approaches of the Planet toward the Sun's Limb, at the Internal Contact, as observed on the | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 8.19.19 | 8.28.44 | Telescopes used, and therefore in different Telescopes, as observed on the | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 8.19.52 | 8.29.17 | Disc of the SUN thro' a Telescope magnifying 220 Times in Diameter. | | | | | | | | | | | | | | | | | | | | | | |





At 8^h 16' 47" } Penumbra almost black, and the touch
 } a little broader.
 8 16 48 } Slight black in the point of contact,
 } and the edges a little broader.
 8 16 49 } True black in the point of contact,
 } and the edges a little broader.

| | | |
|---------|----------|---|
| 8 16 50 | More so. | } Here I concluded with myself, that observers would differ in their judgments about the moment of contact, some seconds of time, or that some would estimate the contact sooner than others. |
| 8 16 51 | More so. | |
| 8 16 52 | More so. | |

From these observations, I concluded, that the thread of light in the point of contact was so obscured, as to be undiscernible at 8^h 16' 46", and that true black did not succeed in the same point, till 3" after, namely, 8^h 16' 49"; and from * both of these properties,

* As the six feet Newtonian telescope magnified four times as much as that of the two feet Gregorian telescope, and the vanishing of the thread of light, from its least degree of duskyhness to a true black, was about 3 seconds of time by the six feet telescope, the time in which the thread of light was vanishing from the least degree of duskyhness to a true black, by a two feet Gregorian reflector, may be supposed to have been 4 times 3 = 12 seconds of time; and hence an error, or rather difference, of pronounciation, but not of judgment, may have arisen among good observers, if some estimated the contact by the invisibility of the thread of light, and others by an apparent blackness in the point of contact, or, which is the same thing, the time when the planet had made the least apparent dent in the sun's limb,

erties, I concluded, that the real internal contact was at $8^{\text{h}} 16' 47''$ by the clock; which makes $8^{\text{h}} 16' 11''$ equal time, and $8^{\text{h}} 18' 2''$ apparent time, at Chelsea; and $8^{\text{h}} 18' 43''$ apparent time, at Greenwich.

Whilst Venus was on the sun's limb, no other penumbra appeared between the limb of Venus and the sun, than had appeared before on the sun's disk; and therefore, I concluded there must be an atmosphere about Venus, which, receiving weak impressions of light between the limbs of Venus and the sun, occasioned the uncertainty of ascertaining the exact instant of the internal contact, as above described; and because my Newtonian reflector shewed objects clearer than the generality of Gregorian reflectors, I concluded, that the foregoing property was what no two feet reflector was capable of examining, the atmosphere being so narrow.

At $8^{\text{h}} 35'$ per clock, the external contact was near, and not incumbered with such a penumbra, or partial light, as the internal contact had been. At $8^{\text{h}} 35' 4''$, the least dent possible, quite black, appeared in the sun's limb. And at $8^{\text{h}} 35' 6''$, the limb was restored to its perfect form, there having been a small trembling light, between the narrow watery border of Venus and the vanishing point of contact in the sun's limb for these two seconds of time. From which the

of the same colour, through a dark glass, as the sky. This was verified by a two feet Gregorian reflector, in the contact above-mentioned, and possibly may have occasioned greater differences in estimating the contact, with lesser telescopes, to no less than half a minute of time.

external

external contact at Chelsea was $8^h 34' 30''$ equal time, and $8^h 36' 21''$ apparent time; which makes $8^h 37' 2''$ apparent time at Greenwich.

From the foregoing circumstances, it appeared to me, that the external contact was more easily to be determined than the internal one, which was contrary to what I had before expected; and because the point of contact must have appeared through such a telescope as I observed with, in its proper colour, dark or black, sooner than through a smaller magnifying power of equal light, I concluded, that, through my telescope, the internal contact was visible, sooner than through a two foot reflector, ten or twelve seconds of time.

And, considering the aforesaid penumbra, or border of partial light, surrounding Venus, as an atmosphere of that planet, with the time of its vanishing, $2\frac{1}{2}$ seconds of time; and reducing this to the diameter of Venus, with due allowance for the oblique direction over the sun's limb, the atmosphere of Venus comes out $8\frac{1}{2}$ thirds of a degree, which is nearly about $\frac{1}{7\frac{1}{2}}$ th part of Venus's diameter; which diameter being nearly equal to the earth's diameter, the atmosphere of Venus comes out nearly 50 geographical miles.

As these observations were made with care and attention, I have lain them before the Society only; and the more readily, as they reconcile a seeming contradiction in Mr. Short's * numbers of the internal
contact;

* It having been 3 seconds of time from the instant when the thread of light between Venus and the sun became so indistinct, as not to be properly termed light, to the instant when the black
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contact

contact; and, whilst I am very certain with respect to the particulars of the external contact, cannot determine why they differ from that ingenious observer's numbers, or any other's.

Samuel Dunn.

* * * When the limb of Venus was almost clear of the sun's disk, I perceived a difficulty would occur at the last contact, as the limb of the sun, and also that of Venus, which was to make the

contact appeared through a telescope magnifying 220 times, the limits of time in which it continued in a like apparent state, by a telescope magnifying $\left\{ \begin{matrix} 140 \\ 55 \end{matrix} \right\}$ times, may be supposed to have been $\left\{ \begin{matrix} 5 \\ 12 \end{matrix} \right\}$ seconds of time; and as $\left\{ \begin{matrix} \text{Savile-House is } 30'' \\ \text{Chelsea is } - 41'' \end{matrix} \right\}$ west of Greenwich, the black contact, by the above observation, with Mr. Short's telescope at Savile-House } was at $\left\{ \begin{matrix} 8^h 18' 18'' \\ 8 18 58 \end{matrix} \right\}$ the telescope at Greenwich observatory } observations at those places being $\left\{ \begin{matrix} 8^h 18' 21\frac{1}{2}'' \\ 8 19 0 \end{matrix} \right\}$ And, for other telescopes, the limits above-mentioned may be supposed to have been nearly as in the following table.

| Magnifying power. | Limits. |
|-------------------|-------------|
| 200 times. | 3" of time. |
| 100 | 7 |
| 80 | 8 |
| 60 | 11 |
| 50 | 13 |
| 40 | 16 |
| 35 | 19 |
| 30 | 22 |
| 25 | 26 |
| 20 | 33 |
| 20 | 66 |

last dent, approached so near to a right line. This led me to consider, that the spherical external angle of contact, by the six feet telescope, would be but an * eighth part of the same angle by the two feet telescope, the eye judging of the same relative distance in one telescope as in the other; and that, therefore, as the versed sine of the dent in the sun's limb was but a fourth part as large in one telescope as the other, and the last contact vanished in about $2\frac{1}{2}$ seconds of time, the last contact might possibly be estimated, by a two feet Gregorian telescope, about twice $2\frac{1}{2}$, or $5''$ or $6''$, seconds of time later than with a six feet Newtonian telescope; which allowance being made, the apparent time of the two contacts, as reduced to a Gregorian reflector, magnifying 55 times: by such a telescope, the contacts at Greenwich observatory were, viz. internal contact $8^h 18' 55''$, external contact $8^h 37' 7''$. The accounts which have been published of the observations made at Greenwich being, internal contact $8^h 19' 0''$, external contact $8^h 37' 9''$; and the difference in each within five seconds of time, an error answering to about a 500th part of the sun's distance from the earth.

* As the spherical angle of contact in the limb of Venus, and also of the sun, was four times as great in one telescope as in the other, the sum of both is eight times; which, being diminished by four times the apparent magnitude of the versed sine of the least visible dent in the one telescope, what it was in the other telescope, leaves the one double to that of the other.

VENUS with an Atmosphere, as seen on the Face of the SUN 6th June 1761, thro' a Telescope magnifying 220 times in Diameter. Also the Approaches of the Planet toward the Sun's Limb, & the Circumstances referred to other Telescopes & to the Royal Observatory at Greenwich. By Samuel Dunn.

| Time | Approaches of the planet toward the Sun's Limb, at the Internal Contact. | | Apparent time for Paris by a Telescope of 220 times magnification. | Apparent time for Greenwich by a Telescope of 220 times magnification. | Apparent time for the Observations at Paris. |
|------|--|-------------------|--|--|--|
| | Greenwich Observatory | Paris Observatory | | | |
| | | | 8.18.58 | 8.18.54 | 8.18.55 |
| 150 | 8.18.21 | 8.28.10 | 8.18.55 | 8.18.51 | 8.28.20 |
| 100 | 8.18.53 | 8.28.18 | 8.18.52 | 8.18.48 | 8.28.17 |
| 75 | 8.18.55 | 8.28.20 | 8.18.49 | 8.18.8 | 8.28.14 |
| 60 | 8.18.57 | 8.28.22 | 8.18.46 | 8.18.5 | 8.28.11 |
| 55 | 8.18.58 | 8.28.23 | 8.18.43 | 8.18.2 | 8.28.8 |
| 50 | 8.18.59 | 8.28.24 | 8.18.40 | 8.17.59 | 8.28.5 |
| 45 | 8.19.0 | 8.28.25 | 8.18.37 | 8.17.56 | 8.28.2 |
| 40 | 8.19.2 | 8.28.27 | 8.18.34 | 8.17.53 | 8.27.59 |
| 35 | 8.19.5 | 8.28.30 | 8.18.31 | 8.17.50 | 8.27.56 |
| 30 | 8.19.8 | 8.28.33 | 8.18.28 | 8.17.47 | 8.27.53 |
| 25 | 8.19.12 | 8.28.37 | 8.18.25 | 8.17.44 | 8.27.50 |
| 20 | 8.19.19 | 8.28.44 | 8.18.22 | 8.17.41 | 8.27.47 |
| 10 | 8.19.52 | 8.29.17 | 8.18.16 | 8.17.35 | 8.27.41 |

