Moses Brown

AN

ACCOUNT

OF THE

OBSERVATION

OF

VENUS

Upon the

SUN,

The Third Day of *June*, 1769,

AT

PROVIDENCE, in *New-England*.

With some Account of the *Use* of those *Observations*.

By *BENJAMIN WEST*.

The Course of *Nature* is the Art of GOD.

PROVIDENCE:
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1769

To the HONOURABLE

Stephen Hopkins,

ESQUIRE,

Member of the PHILOSOPHICAL SOCIETY in the City of *Philadelphia*, and CHANCELLOR of the COLLEGE in the Colony of *Rhode-Iſland*.

SIR,

AS your Honour was pleaſed to accompany, and aſſiſt us the whole time that we were preparing for the obſervation of the TRANSIT OF VENUS; and conſidering with what alacrity our work went on, when encouraged by your actuating genius; and that your Honour muſt be very ſenſible of the great pains which were taken, in order that our work might be rendered as accurate as poſſible; I think myſelf bound in duty to publiſh the following account of our obſervation under your patronage.---Much might be ſaid with reſpect to your Honour's ſuperior abilities in mathematics and natural philoſophy; but, without flattery, theſe are the leaſt of your acquirements, when compared with your profound ſkill in civil police, and the wiſe government of a people.

Your Honour very well knows, that theſe obſervations of the Tranſit of Venus give the ſolution to a problem, that is not only curious in itſelf, but at once opens to our view, and gives us a deeper inſight into the amazing works of God.---From theſe obſervations we expect to diſcover the diſtance of the Earth, the Planets and Comets, from the Sun; and conſequently their magnitudes and quantity of matter will be known, as alſo their proportion of light and heat.---Theſe things being once known, Aſtronomers in future will be able, from the like obſervations, to diſcover whether the Earth and Planets approach the Sun, or recede çede from him; and whether the Sun be diminiſhed by its conſtant expence of light and heat. From a knowledge of all theſe things, methinks we ſhall have ſuch a demonſtration of the exiſtence of a GOD, who made and governs all things, that even the reformed atheiſt muſt tremble when he reflects on his paſt conduct.---I am

Your Honour's moſt obedient,

And moſt humble Servant,

BENJAMIN WEST.

VENUS upon the SUN.

THE TRANSIT OF VENUS OVER THE SUN'S DISK, the third day of June, 1769, did much engage the attention of the Astronomers in all the polite nations of Europe, not barely because it was a rare phænomenon, but because the noblest problem in all the celestial science is thereby expected to be resolved; to wit, that of discovering the Sun's horizontal parallax.

Kepler*, when he had constructed his Rudolphine tables (upon the observations of Tycho Brahe, a Danish nobleman) soon saw that the planets Venus and Mercury, at their inferior conjunctions with the Sun, would sometimes appear to pass retrograde over his disk. From his tables he predicted two transits of Venus to happen, one in the year 1631, the other in 1761, in a book he published in 1629, intituled, "Advice to Astronomers." Kepler did not live to the year 1631. In 1639 a transit of Venus happened, which, according to those tables, was to be invisible, and that which he predicted to happen in 1631 was looked for at Paris, by Gassendus, but none was to be seen. All this was owing to the imperfection of Kepler's numbers.

When

* "Kepler was a native of Wittemburgh, in Germany; he flourished in the beginning of the sixteenth century; was Mathematician and Astronomer to three Emperors; was the first who discovered the elliptic orbits of the planets, and that the squares of their periodic times are as the cubes of their mean distances from the Sun, and explained the general phænomena of solar eclipses."

When our English Astronomer, Mr. Jeremiah Horrox, came upon the stage, though a youth of but 20 years of age, yet his ingenuity and strength of reason were such, that he was able from his own observations to point out the errors in Kepler's tables, and immediately set himself to work in making such other observations as enabled him greatly to correct Kepler's numbers. By these numbers, thus corrected, he predicted the before mentioned transit, which happened the 24th of November, 1639.— He expected the conjunction would be at 3 h. 57 m. P. M. with 10′ south latitude. He waited with eager desire for the moment to see his prediction verified, and so extraordinary a phænomenon as that of Venus on the Sun. The day arrived, and agreeable to his expectation he saw Venus wholly entered upon the Sun at 3 h. 15 m. P. M.—The place of his observation was at Hool, about 15 miles to the northward of Liverpool. Mr. William Crabtree, of Manchester (an Astronomer, and particular friend to Mr. Horrox) was also looking for the transit, and first saw it at 3 h. 35 m; the Sun being in a cloud was the reason that he did not see it sooner. By a comparison of their observations they were found to coincide very well. This ingenious friend to Astronomy (Mr. Horrox) died the third of January, 1640-1, at the age of 25 years.

He has taken his tow'ring flight aloft,
To mingle with his Stars.———

It seems the grand discovery which was to be made from these transits, was not intended for Mr. Horrox, but was reserved for some future genius. Accordingly we find a paper in the Philosophical Transactions, No. 348, wrote by the learned Doctor Halley,

Halley*, our late Royal Aſtronomer, upon this matter; wherein the Doctor ſhows, that by obſervations made of Venus on the Sun, the diſtance of the

* "Dr. Halley was born the 29th of November, 1656, in the pariſh of St. Leonard, Shoredich. He had an uncommon ſkill in plane and ſpherical trigonometry, and all the various parts of mathematics, before he was 17 years of age.—At 19 he publiſhed a geometrical method of finding the aphelia and eccentricity of the planets; the want of which before was an opprobrium to Kepler's hypotheſis.—He diſcovered the time in which the Sun revolves on its axis by its maculæ. He was author of the geometrical method of conſtructing ſolar eclipſes, by which the parallactic method was ſuperſeded. In the year 1676 (at 20 years of age) he was ſent at the coſt of the government to St. Helena, in the South Seas, with letters of recommendation from King Charles the 2d to the Eaſt-India Company, to make obſervations of the fixed ſtars about the South Pole.—In 1678 he was made Maſter of Arts, and choſen a Fellow of the Royal Society.—In 168¼, from obſervation, he thought the forces of the planets towards the ſun decreaſed as the ſquares of their diſtances inverſely; but not being able to demonſtrate it, he applied to Mr. NEWTON, at Cambridge. who gave him ample demonſtration of the truth of what he ſuſpected. About this time he ſhewed a method of finding the elevation of mountains, ſteeples, &c. by the barometer.—In 1686 he explained why the water in the Mediterranean Sea never riſes any higher, although the current is continually ſetting in at the Straights mouth, beſides a large ſupply of water from nine large rivers, and many ſmall ones. The ſolution of this phænomenon gave the ſociety ſo much ſatisfaction, that he received their orders to proſecute the enquiries.—In 1699 he ſet out on a voyage in a ſhip, of which he had the command, in order to make obſervations of the variation of the compaſs; and after traverſing the Atlantic Ocean into both hemiſpheres, as far as the weather would admit him to go, and having touched at many coaſts and iſlands, he arrived at England in September, 1700; and from his obſervations he publiſhed a general chart, ſhewing at one view the variation of the compaſs in all thoſe ſeas where the Engliſh navigators were acquainted.—In 1703 he was appointed Savilian Profeſſor of Geometry at Oxford, in room of Dr. Wal-

the Sun from the earth may be found to the five hundredth part of the whole. I ſhall take the liberty in this place to quote ſome of the Doctor's own words (as we find them tranſlated into Engliſh in the before mentioned tranſactions) upon this ſubject.

The Doctor, after a previous introduction, ſaith, "about 40 years ago, when I was at the iſland of St. "Helena, where I was employed in obſerving the "fixed ſtars which ſurround the South Pole, I had "an opportunity of obſerving Mercury paſſing over "the Sun's diſk, which I did with the greateſt dili- "gence. I obtained moſt accurately, with an ex- "cellent tube of 24 feet, the moment in which Mercury,

lis, deceaſed, and had the degree of Doctor of Laws conferred upon him by that univerſity.—In 1713 he was made Secretary to the Royal Society, in room of Sir Hans Sloan.—In 1717 he wrote the paper in which he ſhewed the method of inveſtigating the Sun's parallax by the Tranſit of Venus over the Sun's diſk. —Upon the death of Mr. Flamſtead, in 1719, Dr. Halley was appointed to ſucceed him by his Majeſty King George the firſt. —Queen Caroline honoured him with a viſit at the Royal Obſervatory, and being pleaſed with the polite reception ſhe met with, and conſidering he had formerly ſerved the crown under commiſſion of Captain of the Navy, ſhe obtained of his Majeſty for him a grant of his half-pay for that commiſſion during his life.—In the ſpace of nine years (half of one plenian period) he obſerved the right aſcention of the Moon, as ſhe paſſed the meridian, 1500 times, which was a greater number of obſervations than were made by Flamſtead, Tycho Brahe, and Hevelius, together. When the Emperor, Peter the Great, viſited England, upon diſcourſing with Dr. Halley on Ship-Building, the Arts and Sciences, &c. he was ſo well pleaſed with the Doctor, that he made him one of his intimate friends during his ſtay in England.—The Doctor died the 14th of January, 1741-2; and ſince his death, in 1752, were publiſhed his aſtronomical tables, for computing the places of the Sun, Moon, Planets, and Comets: They were ſupplied with precepts by Mr. Gael Morris."

" Mercury, entering the Sun's limb, was ſeen to touch
" it within; and, in like manner, the moment in
" which, at going out, he touched the Sun's limb,
" making an angle of inward contact. Whence I
" was ſure of the interval of time, in which the
" whole body of Mercury appeared at that time
" within the diſk of the Sun, and that without the
" error of one ſecond of time. For the thread of
" the ſolar light, intercepted between the obſcure
" limb of the planet, and the bright limb of the
" Sun, ſlender as it was, appeared to ſtrike the eye,
" and in ſtriking the eye, the denticle made in the
" limb of the Sun by the entrance of Mercury
" vaniſhed, as that made by his going out began
" as it were in a moment. When this was known,
" I was immediately aſſured, that the Sun's paral-
" lax might be truly determined from this kind of
" obſervations, if only Mercury being nearer the
" earth ſhould have a greater parallax from the
" Sun. For this difference of parallaxes is ſo very
" ſmall, that it is always leſs than that of the Sun
" which we enquire after. Wherefore Mercury,
" though often to be ſeen within the Sun, will not
" be thought very proper for this buſineſs.

" There remains therefore the Tranſit of Venus
" over the Sun's diſk; her parallax being almoſt
" four times as big as that of the Sun's, will make
" very ſenſible differences between the ſpaces of time
" in which Venus will be ſeen to paſs over the Sun,
" in the different regions of our earth. Now from
" theſe differences, if obſerved after a due manner,
" I ſay the parallax of the Sun may be determined
" within a ſmall part of a ſecond." In ſuch obſerva-
tions, the Doctor ſaith, " nothing more is neceſſary

 than

" than faithful obſervators, good teleſcopes, and " common clocks, regulated to the revolutions of " the heavens, and that the times be reckoned " from the total ingreſs of Venus within the Sun's " diſk, to the beginning of its egreſs from the " ſame; that is, when firſt the opaque globe of Ve- " nus begins to reach the lucid limb of the Sun; " which moments, as I know by my own experi- " ence, may be obtained to a ſecond of time."

The Doctor then proceeds to mention the tranſit of 1761, and to make ſome curious calculations thereon; repreſents it as a ſuitable opportunity for the before mentioned obſervations; and being fully convinced of the certainty of this method of diſcovering the parallax of the Sun, ſeriouſly recommended it to the Aſtronomers that ſhould be then living, with all the power and elocution of an orator, not to ſlip ſo favourable an opportunity of promoting the ſcience of Aſtronomy; wiſhing them all poſſible ſucceſs, and that the magnitudes of the celeſtial orbs being then determined within more exact limits, may reward them with perpetual fame and glory.

The Doctor's credit was too great in the aſtronomic world, not to be taken proper notice of; and as this learned piece of his was wrote many years before the tranſit of 1761, and the Aſtronomers ſince his day having had time to fully weigh and conſider the matter, found his reaſoning too cogent to let paſs, without due notice, what he had ſo earneſtly urged upon them.

In conſequence of which we find, at the approach of the tranſit of 1761, the Aſtronomers of almoſt every civilized nation in Europe, emulouſly enga-

gcd

ged in this affair, of so much importance to science, His late Majesty, King George the second, and the French King, though in the midst of a vehement war, yet (from a sense of the utility of those observations) found time to consider of the matter, and each contributed largely towards carrying so noble a design into execution; "neither was the "Empress of Russia inactive on this singular occa-"sion."

In England, it was observed at Greenwich by the Rev. Dr. Bliss, the then Royal Astronomer; at Savile-House, in London, by the late Mr. Short, in presence of their Royal Highnesses the Duke of York, Prince William, and Prince Henry. Messieurs Ellicott and Dollond observed it at Hacney; and Mr. Canton at Spital-Square, London. It was likewise observed at Leskeard, in Cornwall, by the Rev. Mr. Richard Haydon. Abroad it was observed at Paris, in France, by Mr. De la Lande; and by Mr. Ferner, at Conflans. It was observed at Torneo, in Lapland, almost under the arctic circle, by Mr. Hellant; and this was the farthest north that observation was made. At Stockholm, the capital of Sweden, it was observed by Mr. Wargentin; and at Harnosend, in Sweden, by Mr. Gister. In Asia observation was made at Tobolsk, the capital of Siberia, by Mr. Chapp, a French Astronomer, sent thither at the request of the Academy of Sciences at Peterburgh, and under the protection of the Czarina. At Madrass, or Fort St. George, in the East-Indies, it was observed by the Rev. Mr. Hirst, under direction of the East-India Company of London. Observation was also made at Calcutta, near the mouth of the

Ganges,

Ganges, by Mr. William Magee; this was the farthest east. It was observed at the Cape of Good Hope, by Mr. Mason; and would have been observed at St. Helena (had not the intervention of clouds prevented) by Astronomers sent to those places, at the expence of his Majesty King George the second. It was observed nowhere farther south than at the Cape of Good-Hope. In America, it was only observed at St. John's, in Newfoundland, by JOHN WINTHROP, Esq; F. R. S. at the expence of the Massachusetts colony; and this was the farthest west.

These, and many more observations, to the number of forty odd, being collected, were submitted to Mr. Short, F. R. S. who duly examined them, and with incredible assiduity and labour solved the difficult problem; and found the Sun's parallax, on the day of the transit, to be 8″,55; the Sun being then nearly at his greatest distance from the earth. The parallax being always in a reciprocal proportion to the distance of the Sun, it follows from thence that the parallax, when the Sun is at a mean distance, is 8″,68 †.

By

† The horizontal parallax of the Sun being known, the distance of the Sun from the earth is found by the following proportion.

As tang. of 8″,68	5,6241119
is to 1,	0
so is radius tang. 45°	10,0000000
to 23763 semidiameters of the earth.	4,3758881

From the latest measurements, a mean semidiameter of the earth is found to be 3957 miles. Then 23763 × 3957 = 94030191 miles the distance of the Sun.

By this obſervation of Venus paſſing over the Sun, a certain principle in Aſtronomy was ſettled, which Dr. Halley, from certain obſervations, ſuſpected did obtain in the planetary ſyſtem, which is, that the nodes in the primary planets have a ſlow motion in antecedentia, or contrary to the order of the ſigns. From whence Aſtronomers were aſcertained that Venus would again tranſit the Sun's diſk the third day of June, 1769. I ſay aſcertained, becauſe, according to the old hypotheſis of the immobility of the nodes, it was doubtful; and by Dr. Halley's calculations * upon that hypotheſis, the center of Venus, as ſhe paſſed by the Sun, would appear to be in contact with its north limb. The Doctor ſaid, if at the tranſit in 1761 the nodes ſhould be found to go backwards, then it might be expected, that at the tranſit in 1769, the body of Venus would appear wholly within the orb of the Sun; and would afford a much better opportunity for inveſtigating the Sun's parallax.—What difficulties in ſcience are too great to be ſurmounted, when purſued by men of intereſt and underſtanding!

And now that nothing might be wanting to render the obſervations of this tranſit as perfect as poſſible, we hear that ample preparations were ſeaſonably made, and ſkilful Mathematicians diſperſed into thoſe diſtant regions of the earth, to make obſervation, where the tranſit was attended with the moſt favourable circumſtances. So that whatever was wanting to render the obſervations in 1761 compleat, was now to be fully ſupplied. We are informed

* Philo. Tranſ. page 436, Lowthrop's Abridgment.

formed that ſeveral obſervators were ſent into the South Seas, by the Royal Society in London, in order to get an obſervation where the whole duration of the tranſit was ſhorteſt; and that the Empreſs of Ruſſia ſent ſeveral companies into thoſe parts of her empire, where the viſible duration was of the greateſt length. The King of France did likewiſe ſend obſervers into foreign parts; but as yet we know not to what particular places.

It remains now to give an account of the preparations that were made in PROVIDENCE, for the obſervation of this tranſit. In doing of which I ſhall be as particular as poſſible, that the reader may the better judge of the merit of our work.

When it became more generally known that there would be a Tranſit of Venus in 1769, and the advantages which were like to accrue to Aſtronomy, and conſequently to Navigation and Chronology, from proper obſervations of it, Mr. JOSEPH BROWN*, a very reſpectable merchant of Providence,

* Mr. BROWN is a gentleman of a ſolid, active genius, ſtrongly turned to the ſtudy of mechanics and natural philoſophy, which has induced him to conſtruct and furniſh himſelf with as curious and compleat an apparatus for electrical experiments, as any perhaps in America; and of which he well knows the uſe.—Reading Mr. Winthrop's account of the tranſit in 1761, was what firſt occaſioned him to ſend for a teleſcope, fitted in the manner Mr. Winthrop there deſcribes; afterwards, taking notice of the application of the American Philoſophical Society to the Aſſembly of Pennſylvania, for an apparatus for obſerving the Tranſit of Venus, he found the orders he had ſent were incompleat: He then adviſed with the author, as mentioned, and thereupon ordered a micrometer to be added.—Mr. Brown's expence, in this laudable undertaking, was little leſs than One Hundred Pounds ſterling, beſides near a month's time of himſelf and ſervants, in making the neceſſary previous experiments and preparations.

vidence, being very desirous, if possible, to obtain an observation of it, was pleased to advise with me, concerning an apparatus suitable for such an observation, and to know if we should be able to observe the transit with the necessary precision for answering the important design?

As the proposal was new, and unexpected, my answer was not direct; as it required some time to consider of it. At length I gave him my opinion concerning an apparatus proper for such an occasion; and that I thought we could observe the transit with that accuracy as would render it worthy of notice, provided we could have such an apparatus as was described. My answer gave him so much satisfaction in the matter, that he immediately sent his orders to his correspondent in London, to procure the instruments; his orders were accordingly executed with fidelity and dispatch; they arrived in Providence about one month before the transit.—Our apparatus was made by Messieurs WATKINS and SMITH, London; it consisted of a three feet reflecting telescope, with horizontal and vertical wires for taking differences of altitudes and azimuths, adjusted with spirit-levels at right angles, and a divided arch for taking altitudes; a curious helioscope, together with a micrometer of a new and elegant construction, with rack motions, and fitted to the telescope.——Such a noble disposition in Mr. BROWN for promoting useful knowledge, certainly merits the applause of the public; and, in justice to him, I must acknowledge, our work could not have been done with equal accuracy, had it not been for his skill and contrivance therein.—Besides the before mentioned instruments, we had a sextant belonging to the government, made in Newport, by Mr. BENJAMIN KING, under the direction of JOSEPH HARRISON, Eſq; now Collector of his Majeſty's Cuſtoms for the port of Boſton; its limb was divided to five miles, and by a vernier index to five ſeconds *.—We had two good clocks, one of which was made in Providence, by Mr. EDWARD SPALDING.

We had nothing to learn reſpecting the apparatus, excepting our new catadioptric micrometer, which, I have lately learned, is of DOLLOND's conſtruction; not having any author by us, from which we could get the uſe of that curious inſtrument, we were obliged to have recourſe to experiments.——When the micrometer was fixed upon the teleſcope, it was found by trial, that objects could not be ſeen with the ſame focal diſtance as when it was off, but were obliged to ſcrew up the ſmall ſpeculum nearer to the eye; for which there is an optical reaſon.—From whence it was concluded, that objects ſhould always be obſerved in the moſt diſtinct point of view, the ſame with the micrometer on as when it was off. The next thing to be done was to find the apparent diameter of an object (or the angle ſubtended at the eye by two objects) by this inſtrument. In order to this, we ſtretched a cord, as ſtraight as poſſible, one thouſand feet in length; which was meaſured ſeveral times over, in order to avoid

* And here we muſt not forget the Honourable ABRAHAM REDWOOD, Eſq; of Newport, who, in order that Newport and Providence might both be ſupplied with a ſextant, for this ſingular occaſion, ordered one made at his own coſt, for the uſe of the Rev. Dr. STILES.——I am ſenſible Mr. Redwood, for ſo public ſpirited an action, will receive the thanks of every well-wiſher to ſcience.

avoid miſtake. At the end of the cord was ſet two circular objects, made of white paper, in a line perpendicular to the cord, and exactly ten feet apart; ſtanding at the other end of the cord, and by opening the micrometer, we could bring the two images into an exact coincidence, or could make one of the images appear like two, and by bringing their limbs into contact, the diſtance of their centers was ſhewn on the ſcale, to the five hundredth part of an inch. Now from the rules of trigonometry, the angular diſtance of the two objects was 34′ 22″,58; from thence it was known, how many inches and parts of an inch were anſwerable to that angle. Theſe experiments were repeated every fair day (for no other was ſuitable for theſe obſervations) till we could many times going find the diameter of a body to a ſecond of a degree.—From theſe obſervations we were enabled to make a table for the micrometer, as far as the ſcale extended.—Theſe experiments were carried yet farther, for, by looking at two bodies whoſe diſtance from each other was known, we could tell their diſtance from the place of obſervation, to a critical exactneſs; and this was proved by accurate menſuration. Theſe were certainly very diverting experiments to an inquiſitive mind!——The gentlemen who aſſiſted us through theſe experiments, and likewiſe in the reſt of our work, were the Honourable STEPHEN HOPKINS, Eſq; Mr. MOSES BROWN, Dr. JABEZ BOWEN, A. M. JOSEPH NASH, Eſq; and Capt. JOHN BURROUGH.

The regulation of our clocks, being of the utmoſt conſequence in this affair, was what next commanded our attention. In this part of the work, we endeavoured to arrive at as great a degree of certainty as the nature of the caſe would admit.—Several workmen, who were equal to the undertaking, were employed in laying a platform, of ſeaſoned pine plank, as ſmooth and level as art could make it: This was ſecured from rain, or other moiſture, that it might not warp when expoſed to the Sun. We examined this platform three times a day (when the weather would admit of it) with a very long level, made for that purpoſe, in order to keep its poſition from altering. On the ſouth ſide of the platform, and exactly perpendicular to it, we erected a ſtile ten feet high; this was likewiſe examined three times a day. We next perforated a piece of board, into which was fixed the glaſs of a ſcioptic ball, ſo that the center of the glaſs was exactly in the center of the perforation; this board was ſo cut, and let in at the top of the ſtile, that it turned upon an axis, in ſuch a manner, that the center of the glaſs did not alter its poſition. The Sun's rays were tranſmitted through the lens upon the platform, where they were formed into a bright ſpot, and very diſtinctly defined. From the center of the lens was let fall a perpendicular upon the platform; from that point, as a center, was drawn a great number of concentric circles, for taking correſpondent ſhades, in order to trace a meridian line; and, as our wiſhes would have it, the weather proved favourable for this work. When the line was drawn *, I found, from calculation, it reclined

* The magnetic needle, being placed on this exact meridian line, was found to differ from it 6° ½ weſtward.—That our obſervations might be as uſeful as poſſible, notice was given beforehand to the people (whoſe curioſity was excited by the preparations)

reclined 3″ in time, east of the true meridian; this error arose from the increase of the Sun's declination, between the times of forenoon and afternoon shades; this small equation of 3″ was allowed for in regulating the clocks.

As we were willing to have every corroborating circumstance to prove our work, we made use of another method, which seems to be most approved of by all the celebrated Astronomers in Europe and America; this was the method of corresponding altitudes of the Sun, forenoon and afternoon. The sextant and reflector were both employed in this business for several days preceding the transit (and the day following) in order to ascertain the going of the clocks. In the last method (as in that of corresponding shades) the equation of time, answerable to the increase of declination, ought by no means to be neglected. Through the whole process we conducted with the utmost caution, that no errors might escape our notice. We found, upon the whole, a surprizing agreement in these two methods of regulating clocks; they were seldom found to differ a single second.—In short, as truth was the point we aimed at, nothing was omitted by which it might be obtained.

Being in this readiness, the morning of the third of June was ushered in with that serenity the business of the day required; all was calm, and not a cloud to be seen. The gentlemen concerned in the business convened very early at the place of observation,

parations) that on the day before the transit, when the Sun came on the meridian, a cannon would be fired, which being done, most of the inhabitants marked meridian lines in their windows, or on their floors.

observation, to see that every thing was in order; and at the sight of such a morning, the gladness of their hearts was visibly expressed, by a pleasant aspect upon their countenance.

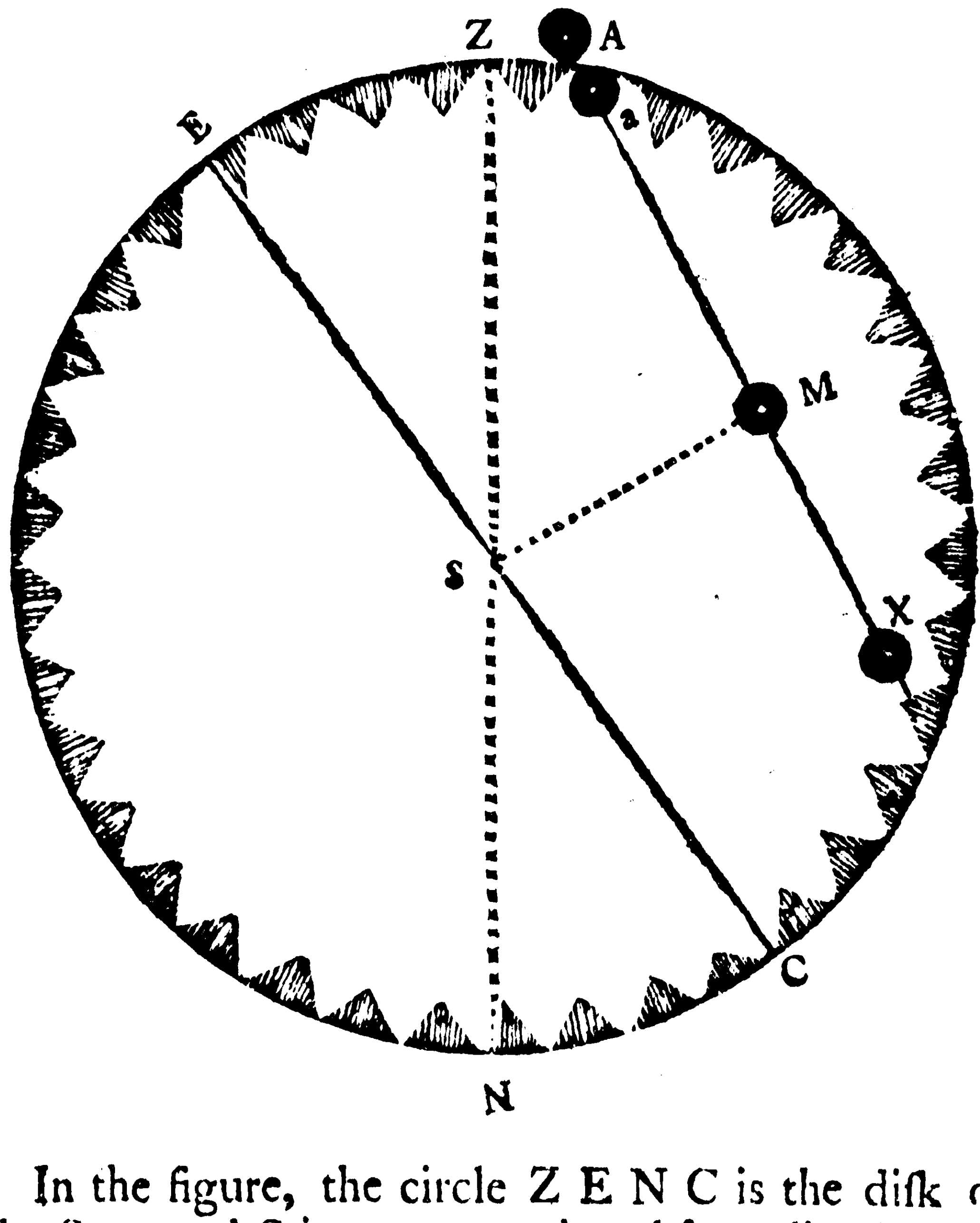
At noon we examined the going of the clocks, as the Sun passed the meridian, and found them very regular.

We began to look for the first contact of Venus with the Sun, at least 15 minutes before the time given by calculation, to get as early a sight of it as possible.—Venus was first perceived by making a dent upon the superior limb of the Sun at 2 h. 29 m. 43 sec. P. M. apparent time. But, as it is likely the exterior contacts will be given different, by different observators, they can be of but little consequence in this affair.—The greatest attention was given to the interior contact; this was at 2 h. 46 m. 35 sec. apparent time*. From a mean of a number of good observations, the apparent diameter of the Sun was 31′ 40″,66, and that of Venus 58″,66; though I could not make it myself more than 58″, which

* At the moment of interior contact, the Sun's altitude was taken, with the sextant, by Mr. MOSES BROWN, and by the stile by Capt. JOHN BURROUGH; and both gave the time with the clocks within two seconds.—The total ingress was not so instantaneous as I did expect it would be, but the bright cusps of the Sun, as they incompassed Venus, were much more obtuse, and there seemed to be a faint junction of their limbs for at least 4″; the moment this penumbral ligament broke, I proclaimed the time; at first I suspected the telescope was not adjusted to a proper focus; but afterwards, by looking at the solar spots, &c. I was convinced of the contrary. During the time we saw Venus upon the Sun, she appeared to be surrounded by a ring of a yellowish countenance; its width was about one tenth of the diameter of Venus. We saw nothing that might be taken for satellite.

which was the ſame we found it about a fortnight before the tranſit. The proportion of their diameters was nearly as 1 to 33. The neareſt approach of their centers, at the middle of the tranſit, was taken with the micrometer, and found to be 10′ 5″.

The following TYPE will give the reader ſome idea of the appearance of Venus, at her ſeveral ſtages on the Sun.



In the figure, the circle Z E N C is the diſk of the Sun, and S its center; the obſcure line Z S N a vertical paſſing through the Sun's center; E S C the

the ecliptic in its position at the middle of the transit; A a M X the orb of Venus; A is Venus at her first contact; a the interior contact; M the middle of the transit; and X her place at sunsetting.

The proportion of the distances of the Sun and Venus from the earth, at that time, was as 3,5143 to 1; then (allowing the Sun's parallax to be the same it was found the 6th of June, 1761) the parallax of Venus was 30″,04; the difference of their parallaxes 21″,49. The angle between the visible way of Venus and the ecliptic, 8° 34′ 17″; and the angle made by the axis of the ecliptic and equator, 7° 3′ 7″; their sum, 15° 37′ 24″, was the angle between the axis of the visible way of Venus, and the earth's axis. The transit line, from total ingress to the middle of the transit (measured in time by the visible motion of Venus) was 2 h. 55′ 36″; but Venus was more accelerated in her orbit (by parallax in longitude) at the middle of the transit, than at total ingress; this difference of acceleration was 1′ 33″; therefore from the total ingress to the middle of the transit was 2 h. 54′ 3″.

Thence I conclude, that the

	h.	′	″	
* First contact was at	2	28	0	app. time.
Interior contact	2	46	35	
Middle of the transit	5	40	38	

Venus's parallax in longitude, at the middle of the transit, was 18″,7; this was passed over by Venus's visible motion in 4′ 44″; so that the middle of

* When I calculated this transit, I supposed the longitude of our place to be much less than we have since found it by observation.—By correcting that error, the error in calculation will appear to be inconsiderable.

of the transit, as seen from the center of the earth, was at 5h. 43′ 8″ mean time. The true conjunction was 23′ 21″ before the middle of the transit, as seen from the earth's center; consequently the true conjunction was at 5h. 19′ 45″, mean time. At which time, the place of the Sun and planet was ♊ 13° 27′ 3″; and the geocentric latitude of Venus 10′ 19″,8 north. But her heliocentric latitude was 4′ 6″,51; and by the rules of spherical trigonometry, the ascending node of Venus was 1° 9′ 23″,5 in consequence of the Sun, or in ♊ 14° 36′ 26″,5.

From the foregoing calculation it appears, that the mean motion of Venus is 37″ forward of what it stands in Dr. HALLEY's tables, and her ascending node 2′ 41″.

It is probable Dr. HALLEY's solar numbers need some correction likewise; the following may not be far from truth, viz. add to Dr. HALLEY's mean motion of the Sun, for any year of the Christian æra, 25″, and to the apogee 6′ 18″; for each century after 1700 add 14″,666 to the mean motion, and to the apogee 3′ 53″; then by making use of the Parisian * equation of the Sun's center, his place may be had within a small matter of truth.

By taking the mean of a number of observations, the latitude of our observatory was found to be 41° 50′ 41″ north ‡. The longitude was obtained by

D observing

* According to the Parisian hypothesis, the eccentricity of the earth's orb is 1680 parts, of which the mean distance of the earth from the Sun is 100,000.

‡ The latitude of the place being of great consequence, and the sextant and stile not giving it exactly alike, the persevering Mr. BROWN contrived to make use of the micrometer as a lens, which he placed on his house, twenty-seven feet high, and exactly perpendicular to a center on a horizontal platform below, on which was drawn a meridian line; the Sun's image on this platform

obſerving the emerſions of Jupiter's ſatellites, compared with the correſponding obſervations made at Cambridge, in New-England, by Mr. WINTHROP, which he was ſo kind as to favour us with; and for which we return him our ſincere thanks.—Providence was found to be 16′ in longitude weſt from Cambridge; Mr. WINTHROP has hitherto found the longitude of Cambridge to be 71° 0′ weſt from the Royal Obſervatory at Greenwich; ſo that the longitude of Providence is about 71° 16′ from the Royal Obſervatory.

It is to be hoped the Commiſſioners, ſent abroad to obſerve that intereſting phænomenon, were favoured with a ſuitable air for that purpoſe, as there will not be another opportunity, for making the like obſervations of Venus, for more than a century to come. The next tranſit of Venus will be in the month of December, in the year 1874, at the aſcending node; and that will be ſucceeded by another, at the ſame node, in 8 years after it; then there will paſs 122 years without a tranſit, which will bring it to the year 2004, in the month of June.

I ſhall now give the reader a ſhort account of the parallax herein mentioned, and how the planets are affected thereby.

The horizontal parallax of the Sun is that angle at the Sun's center, which is included between two lines ſuppoſed to be drawn, one from the Sun's center to the center of the earth, the other from the Sun's

platform was ſeen to move very ſenſibly.—By this the latitude was finally determined. The Sun's meridian altitude, being taken for ſeveral days by this long ſtile, the latitudes thence found did not differ from each other more than 15 ſeconds.—At the time this was done, we had ſeen no account that a glaſs had been made uſe of, as here deſcribed; but ſince this went to the preſs, we learn from Dr. LONG's aſtronomy, that he found the latitude of Cambridge, in England, by the ſame method.

Sun's center to the ſurface of the earth. Or, in other words, it is the angle, under which the ſemi-diameter of the earth would appear to an eye, at the center of the Sun.—The way that parallax affects the Sun and Planets is, it makes them appear below their true places in the heavens, except they be in the zenith of the obſerver; in that caſe, parallax has no effect at all; and the reaſon is, becauſe the obſerver is in that right line which joins the centers of the earth and planet. Parallax may affect the planets places ſeveral ways; as if the obſerver ſhould view the planet upon a vertical, cutting the ecliptic at right angles; in this caſe, parallax will affect its place in reſpect to latitude only; but if the obſerver be ſituated in the plane of the ecliptic, it will then alter its place, in reſpect to longitude only; and if the planet be viewed in an oblique poſition, with reſpect to the ecliptic, parallax will affect its place both in longitude and latitude.——The horizontal parallaxes of the planets are to each other in a reciprocal proportion to their diſtances; that is, the planets which are neareſt have the greateſt parallax, and thoſe which are moſt remote, the leaſt.—Thence it follows, if two planets are viewed together, that which is neareſt will appear juſt ſo much below the other, as what the difference of their parallaxes is.—The nearer a planet is to the horizon of the obſerver, the greater is its parallax, and in the horizon it is the greateſt poſſible; and is then called the horizontal parallax.

Hence comes the method of inveſtigating the Sun's parallax, from obſervations of Venus on his diſk. At the time of the tranſit, the third day of June, Venus was much nearer to the earth than the Sun was, and, of conſequence, was much more affected

fected by parallax.—This effect was produced in a two-fold manner, in respect to us in the northern regions of our earth.—First, Venus was depressed upon the Sun, by parallax in longitude, bringing her to a conjunction with the Sun sooner to our point of view, than to a spectator at the center of the earth; in the second place, she was carried nearer to the center of the Sun, by parallax in latitude, thereby lengthening the transit-line; both which effects conspired to accelerate the time of first interior contact. Now to an observer in Great-Britain, parallax had a still greater effect, by what is said before:—That is, some minutes passed after the contact was formed to the observer there, before it was seen by us.—Now the difference of longitude, between the two places of observation, being accurately known, the effect of parallax, between the two places, is likewise known; for the difference of longitude, by these observations, will be considerably less than the true difference.

The method of calculating the Sun's parallax, from these observations, is by trial; the parallax will be supposed of that quantity, which the observations found it in 1761; hence the total effect of parallax, at each place of observation, must be computed; and if it should be the same as given by observation, it will prove the assumption to be just; but if, by observation, it should be greater or less than by calculation, the Sun's parallax will turn out to be greater or less in the same proportion.—When the Sun's parallax is known, the distance of the earth, and of all the planets, from the Sun, will be known likewise.

F I N I S.

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