INSTRUCTIONS

Relative to the

O B S E R V A T I O N

OF THE

Ensuing Transit of the Planet VENUS
Over the SUN'S Disk

On the 3rd of June 1769

BY THE

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Relative to the Observation of the ensuing Transit of the Planet VENUS over the Sun's Disk, on 3rd June 1769. By the Reverend NEVIL MASKELYNE, A.M., F.R.S. Astronomer Royal.

The Transit of the Planet Venus over the Sun's Disk is a curious Phænomenon in Astronomy, which does not happen above once or twice in a Century. The First which was ever seen since the Beginning of the World, was that which happened in the Year 1639, and was predicted by Mr. Jeremiah Horrox, an Englishman, and observed only by him and his Friend Mr. Crabtree, both living near Liverpool. The Second Transit of Venus was the late One of 1761, and was predicted by that great Astronomer Dr. Halley in 1716, who at the same Time pointed out to Astronomers a new and important Use that might be derived from it, viz. To determine to great Exactness the Sun's Parallax, and consequently his true Distance from the Earth, and the Dimensions of every Part of the Solar System, provided that the corresponding Observations were made of it by Astronomers in different Places for that Purpose. The Theory of the Motions of Venus being not known sufficiently in Dr. Halley's Time, it turned out that Venus in the last Transit passed over the Sun's Disk at a much greater Distance from his Centre than he had supposed it would, which very much altered the Circumstances of the Phænomenon, and rendered it much less advantageous for determining the Sun's Parallax than he had hoped for. Moreover, unfortunately, the Astronomers who were sent out by the English and French Nations to make the proper Observations were not

all able, through unavoidable Accidents, to reach the intended Places most suitable for drawing the greatest Use from the Observations, or were hindered from making them by bad Weather.

Therefore, though considerable Advantages were derived to Astronomy from the Observations of the last Transit made by Astronomers in various Places, yet we are still to expect to receive the full Benefit which this Phænomenon is capable of affording us, from the ensuing Transit, which will happen on the 3rd of June 1769 ; which is as well circumstanced for the Purpose as we can well desire, and indeed more favourably than the last Transit was expected by Dr. Halley to be.

But, in order to profit from those favourable Circumstances, endeavours must be used to have careful Observations made on this Occasion in as many various and different Places as we can, as well to obviate the Hazard of several Observations being defeated by unfavourable Weather, as to confirm the Truth from the Agreement and Concurrence of so many different Testimonies.

It may be added, that Observations of the Transit of Venus made in various Places, together with other Observations made there in Consequence of it, will have another greater Use in settling the Latitudes and Longitudes of the Places, and that even though the Observations thro' various Causes may not reach that absolute Precision which is required for deducing the astronomical Consequences before spoken of.

As many ingenious Persons who have turned their Minds to astronomical, mechanical, or mathematical Subjects, may be stationed in various Places where an Observation of this Kind would be very valuable, and may at the same Time be furnished with sufficient Instruments for the Purpose, but may be desirous of having some Instructions afforded them concerning the peculiar Nature of the Observations in Question, and other Attentions to be regarded both previous and subsequent thereto, in order to make their Labours useful, I shall here offer to them a few Hints on this

subject, which, I hope, may encourage them to exert their utmost Endeavours upon the Occasion, and I heartily wish them all possible good Fortune and Success. At the same Time, I think myself happy in thus concurring with the noble Views of the Royal Society, and the generous Encouragement which the Honourable Directors of the East India Company are pleased to afford to the Improvement of Science, by recommending the Observation of the Transit of Venus in 1769 as they did in 1761, to their Servants in their Settlements abroad, and thereby promoting Astronomy and Geography on which Navigation so greatly depends.

The Planet Venus, intirely divested of her Radiancy, will traverse the Sun's Face from East to West on the 3rd June 1769, in Form of a round black Spot, and will be seen, if the Weather be clear at the Time, to all Places of the Earth where the Sun is up. She will be visible to sharp Eyes without a Telescope, only defended by the Interposition of a dark Glass ; but will appear much more beautiful, and may be observed to much more Advantage, with the Help of a Telescope. Here the Precaution of interposing a dark Glass between the Eye and the Telescope is absolutely necessary to be taken, without which the Sight may be destroyed, or greatly impaired ; but, thus shielded, it will be perfectly secure from Danger or any Inconvenience. Venus will begin to enter the Sun's Disk to the North-East Part of the same, reckoning the Point of the Sun's Circumference or Limb nearest the North Pole of the World to be the North Point. Her Diameter will subtend near a Minute therefore, as that of the Sun is about $31^1/_2$ Minutes, her Diameter will be about $^1/_{32}$d of that of the Sun. She will move a space of about 4 Minutes or 4 Times her own Diameter in and hour, along a Line or Chord, which at its nearest Approach is 10 Minutes Distance from the Sun's Centre. Thus she will take about 6 Hours and 20 Minutes (exclusive of the Effect of

Parallax) to move over the Sun's Disk, from first making a small Impression in the Limb on the N.E. Point, to her going

out of the Sun's Disk on the N.W. Point, and leaving the Sun's Limb there intire again. The First least visible Impression made by Venus's inner Limb upon the Sun's Limb is commonly called the First external Contact ; though, properly speaking, the true external Contact of Venus, and the Sun's Limb, happens a few Seconds of Time sooner before the least Particle of Venus has entered upon the Sun.

After this, Venus gradually makes a deeper and deeper Impression or Notch in the Sun's Limb, and in about 9 Minutes Half her Opaque Body will be seen upon the Sun's Body eclipsing an equal part of the same, the other half of her body being without the Sun's Disk, and therefore invisible ; in 9 Minutes more, the whole Body of Venus will be introduced within the Sun's Disk, and her outer Limb will touch the Sun's Limb internally, or form what is called the First internal Contact.

She will now recede from the Sun's Limb, by approaching nearer to his centre, and in about 2 H. 52 M. more will be found at the nearest Distance of 10 Minutes from the Centre ; she will then recede from the Centre again, and in 2 H. 52 M. more, her outer Limb will touch the Sun's Circumference, and form the second internal Contact ; she will now be leaving the Sun, and in 9 Minutes her Centre will appear upon the Sun's Limb, and about 9 Minutes after that her inner Limb will touch his Limb externally, or make the second external Contact: And the Impression made by her Body in the Sun's Limb being become gradually imperceptible she will go entirely out of the Sun.

The most important Observations of the Transit of Venus are those at the Contacts of her Limbs with the Sun's, particularly the internal Contacts.

The best Telescopes must be used that can be procured ; refracting Telescopes of 15 or 20 Feet, reflecting Telescopes of 18 inches, or 2 Feet Focus, or achromatick Telescopes, of a new Construction, of 5 or 10 Feet, with double Object Glasses, or those of $3^1/_2$ Feet, with treble Object Glasses, being such as are chiefly used for the Obser-

vations of the Eclipses of Jupiter's Satellites, will be very convenient for this Purpose.

The exact Times of the Contacts should be set down according to a Clock, regulated by observations of the Sun of fixed Stars made on the Day of the Transit, and also on several Days before and after, according as the Weather shall permit.

The Observation of next Importance after the Contacts, is that of the nearest Distance of Venus from the Sun's Centre, which is best done by the new divided Object Glass Micrometer fitted to the End, either of a reflecting Telescope, or the new achromatick refracting telescope of $3\frac{1}{2}$ Feet above mentioned ; other Distances of Venus from the Sun's Centre may also have their Use. But the Observations of the Contacts alone may be sufficient for the Generality of Observers to attend to.

It has been remarked above, that dark Glasses should be used to defend the Eye from the Intensity of the Sun's Light. Transparent Glasses smoaked over the Flame of a Candle or Lamp, and applied to the Telescope, will give a more distinct and agreeable Vision of the Disks of the Sun and Venus than any tinged or coloured Glasses will do.

Provide some Pieces of clear Glass, not too thick (the common Crown Glass used for Windows may do as well as any) cut two of them into equal Rectangles of convenient Lengths, and wipe them clean and dry, and warm them a little by the Fire if the Weather be cold, to prevent their Cracking when applied to the Flame of the Candle ; then draw one of them gently, according to its whole Length, through the Flame, and Part of the Smoke will adhere to the Glass ; repeat the same Operation, only leaving a little Part at one End now untouched ; repeat the Operation, leaving a further Part at the same End untouched ; and so each Time leave a further Part of the same End untouched, till at last you have tinged the Glass with several Dies, increasing gradually in Blackness from one End to the other ; smoke the other Glass in like Manner, and apply the two Glasses one against the other, only separated

by a rectangular Border cut out of Brass or Card Paper, the smoked Faces being opposed to each other, and the deepest Tinges of both placed together at the same End ; and tie the Glasses firmly together with waxen Thread ; and they are ready for Use. The Tinge at one End should be the slightest possible, and at the other End so dark that you cannot see the candle through it. By this Contrivance applied between your eye and the Telescope, you will have the Advantage, not only of seeing the Sun's Light white, according to its natural colour, and his image more distinct than through common dark Glasses, but as you please, and the Clearness or Thickness of the Air requires it, by bringing a lighter or darker Part of this combined dark Glass before your Eye, which will be a great Convenience at all Times, but particularly when the Brightness of the Sun is liable to sudden Changes from flying Clouds. This dark Glass ought to slide in a Groove fixed to the Eye End of the Telescope, in order to relieve the Observer from the unnecessary Trouble of holding it in his Hand, and, when not used, should be kept in a dry Place, or well covered up from the Air, else the Moisture of the Air will penetrate between the Glasses, and spoil the Smoking. This Point should be examined, and the Glasses newly smoked, if necessary, a few Days before the Transit.

The Telescope will be easier managed, if it be supported upon a Polar Axis, than by an upright Pillar in the usual Manner. The same End will be answered by a Brass Socket fixed to the horizontal Top of a wooden Stand, under an Angle, equal to the Latitude of the Place, upon which the Telescope may also be supported. If the Axis of this Socket be directed to the elevated Pole, either by a Meridian Line or a magnetic Compass (allowing for the Variation) it will then be only necessary to turn one of the Screws of the Rack-Work, which governs the Telescope, in order to keep the cœlestial Object constantly in the Field of the Telescope, notwithstanding the diurnal Motion.

The wooden Stand of the Telescope should rest upon the Ground, and not upon any wooden Floor, if the Circumstances of the Place will admit of it. It is absolutely necessary that the Telescope should be adjusted to distinct Vision of the Eye of the Observer, previous to the Observation. This is done by turning the Side Screw one Way or the other in reflecting Telescopes ; but by sliding the Eye Tube backwards or forwards on refracting Ones, till you see the Object most distinct. A Mark may be made on the Eye Tube of the refracting Telescope, by which it must always be re-adjusted to the same Position after any Alteration. There is sometimes placed on the Side of the Tube of reflecting Telescopes, particularly those designed to be used with Dollond's Micrometer, a small Scale with a corresponding Vernier, the Telescope being adjusted to distinct Vision, the difference of (0) on the Vernier from (0) on the Scale, which is expressed by Divisions of the Scale, and the number of the Stroke of the Vernier which coincides with a Division of the Scale, is to be noted ; whereby the Telescope may at any Time be re-adjusted to Distinctness for the same Eye, after any Alteration, by turning the Side Screw , in order to bring the Vernier to the same Point of the Scale. For observing the Sun, the Telescope should be adjusted so as to show the Sun's Circumference, or rather his Spots, if he has any, with most Distinctness. This should be done, particularly by Way of precaution, some Days before the Transit of Venus. For observing the Eclipses of Jupiter's Satellites, and other cœlestial Phenomena, the Telescope may be conveniently adjusted, by noting when Jupiter's Limb, or rather his Belts, appear most distinct.

The Clock must be set up truly perpendicular, which may be done by making the Sides of the Case perpendicular, by means of a Plumb-line ; in some Clocks this may be done more exactly by bringing the lower End of the Rod of the Pendulum, when at Rest, over a sharp Point placed for that Purpose, or over the middle Point of a divided Arch, intended to show the Quantity of the Vibration of

the Pendulum each Side of the Perpendicular. Moreover, the Clock must be fixed very firm, by screwing the Back of the Case to wooden Plugs or iron Hold-fasts, driven in tight between the Joinings of a Stone or Brick Wall, or to an upright massy Plank, let two or three feet into the Ground at the Bottom. And supported by inclining Stays on the two Sides. If the Clock be not fixed up firm, it will go very irregular ; therefore it must not be set up against any common Wainscot, but fixed to the Wall itself. Some astronomical Clocks are made to go 8 Days without winding up, and others a Month. By turning a Handle, a Spring will be brought to act on the Wheels, which will keep them going during the Time of winding up the Weight ; these Clocks are usually wound up the contrary way to that of the common ones. They are furnished with Gridiron Pendulums, composed of Brass and Steel Rods intermixed, or some other equivalent Contrivance, which keeps the Distance between the Point of Suspension and the Centre of Oscillation to be always of the same length ; whereby they go nearly at the same Rate during all the Vicissitudes of Heat and Cold.

In making Observations of any Kind where the Time is required to be known, catch the Second from the Clock by your Eye a little before the Time, and keep counting on the Seconds by your Ear, while your Eye is applied to the Telescope, till the Instant of Observation arrives, then note the Minute by the Clock, and write it down, together with the Second at which the Observation happened ; and lastly set down the Hour. Otherwise, begin to count the Seconds by the Ear from the Moment of the Observation, till you can see the Time shewn by the Clock, from which subtract the number of Seconds which you counted, and you will have the Time of the Observation according to the Clock. It will be most convenient to count up to an even number of Seconds, as 20, 30, or 40 Seconds, or 1 Minute. If the Observer is at such a Distance from the Clock that he cannot hear the Beats, he should have an Assistant to stand near the Clock, and with an audible Voice count

the Seconds as they succeed one another in Order. The same End may be answered by setting an Assistant Clock which swings Seconds, and has a loud Beat, to the Time of the Astronomical Clock, and making the Observations by its Beats instead of those of the Other. The Astronomical Clock should be regulated to keep mean solar Time.

The readiest Method for occasional Observers to regulate their Clock is by taking equal Altitudes of a Star or the Sun's upper or lower Limb, on each side of the Meridian: But the nearer these Observations are made to the prime vertical, or that which passes through the East and West Points of the Horizon, the better, provided the cœlestial Body be not too near the Horizon.

The mean of the Times of the equal Altitudes of a Star as shewn by the Clock, gives the Time shewn by the Clock when the Star passes the Meridian. But the mean of the Times of the equal Altitudes of the same Limb of the Sun must be corrected by the Equation of corresponding Altitudes, to find the Time of the Centre passing the Meridian by the Clock, as will be shewn more particularly by-and-by.

These Observations should be made frequently, in order to know always the Error of the

Clock with respect to mean Time, and also the daily Rate of its going ; but particularly on the Day of the Observation of any principal Phaenomenon, and for some Days before and after.

The most exact Instruments for observing equal Altitudes, are the Astronomical Quadrant and the *Equal Altitude* Instrument. The former being of general Use in the Practice of Astronomy, on that Account deserves the Preference. I shall therefore explain here at length the Methods of adjusting it, and taking the Altitudes by it, as well off the meridian for finding the Time, as on the Meridian for finding the Latitude of the Place, as follows.

USE

OF THE

ASTRONOMICAL QUADRANT

In taking Altitudes

The Quadrant, whose Use I am about to describe, is one of the Construction of Mr. John Bird of 1 Foot Radius : It has two Sets of Divisions, the inner one of which divides the Quadrant into 90 Parts or Degrees and to every 20 Minutes ; and the outer one divides it into 96 Parts, and each of those Parts into 4 Parts ; Both Sets of Divisions are numbered so as to shew the distances from the Zenith, and each has its particular Vernier, that of the inner one carries the Subdivisions to every Minute, and that of the outer one subdivides each of the 4 Parts into 32 Parts. Hence a Table may be easily made to reduce the Zenith Distance given by the exterior Arch into Degrees, Minutes, and Seconds. The Micrometer is common to both, and gives a Number of Minutes and Seconds to be subtracted from the Zenith Distance, shewn by the Divisions and Vernier of either Set.

The moveable Telescope, which is used in taking Altitudes, turns round about the centre of the Quadrant, and carries the Micrometer and both Vernier Plates with it. The Instrument is supported on a brass Pedestal, which stands on 4 Screws, and ends in a Frustum of a Cone at Top decreasing upwards, a hollow Frustum of a Cone is exactly fitted to this, and turns smoothly upon it, and carries the Quadrant by an *Arm* round about along with it into different azimuths. Parallel to the Plane of the Quadrant is placed a Level, which is attached to the *Arm* ; its Use is to adjust the Axis of the Pillar perpendicular to the Horizon ; this may also be done by the Plumb-line independently of the Level.

At a small Distance from the Centre of the Quadrant, to the left, in a Line perpendicular to the Radius passing thro' the lowest point or (0), a fine Point is marked upon the central Plate with a Dart pointing to it ; at an equal Distance below from the Point (0) likewise to the left, such another Point is marked upon the Limb of the Quadrant, with a Dart likewise pointing to it. Over the two Points a fine Silver Wire is to be hung from a Notch, and stretched by a Weight immersed in Water to check its Vibration.

The Plate containing the Notch is bent at right Angles downwards ; and on this Part is applied to the Side of the Quadrant by a steady Pin, and by two Screws above it, having broad Holes under their Heads. The lower Screw is Screwed up, but the upper Screw only so much as to force the bent part of the Plate just mentioned, which springs, to a due Distance from the Side of the Quadrant, in order to bring the Notch into the proper Position, that the Plumb-line may hang over and bisect both Points.

By the Pressure of the Hand the Notch may be moved a little backwards or forwards, (the lower Screw being eased if necessary) till the Plumb-line appears to hang at a proper Distance from the Limb of the Quadrant, which it ought not to touch, but to approach very near to, as within one or two of its own Diameters, or so that the Shadow of the Plumb-line may be visible on the Limb opposite a Side Window, or the Light of a Candle held in a very oblique Position, to the Plane of the Quadrant.

Magnifying Glasses are provided, included in Tubes, for better discerning the Bisection of the Points by the Plumb-line, and also others for assisting the Eye in judging more exactly of the Coincidence that is to be made between a Division on the Limb and a Stroke on the Vernier. The Weight of the Plummet should be increased by putting Shot into it, till it is as great as the Plumb-line will bear without breaking.

There is a Screw fixed to the *Arm*, which, for the Sake of Distinction, I shall call simply the *Adjusting Screw*, which works in a Screw Hole depending upon the Qua-

drant, and is of Use to turn the Quadrant in the Direction of its own Plane, and consequently to bring the Radius passing thro' the Beginning of the Divisions to be parallel to the Axis of the Pillar and perpendicular to the Horizon, previous to an Observation, as will be explained by-and-by in its proper Place.

I shall now proceed to describe the Manner of preparing the Quadrant for making an Observation correctly ; that is to say, of adjusting its Parts to one another, and of fixing the Whole in a proper Position. But as there are several of these Adjustments, some of which must be repeated every Time the Quadrant is used, and others require to be made once for all, I shall treat them separately, and shall first explain the usual Procedure of adjusting the Instrument for Observations, together with the Method of making the Observations themselves, and shall afterwards describe those particular Adjustments, which, when once made, give the Observer no further Trouble.

Place the brass pedestal (carrying the Quadrant) upon a Wall or Pillar, or upon a firm wooden Support which itself stands upon the Heads of small Piles or large Piquets driven into the Ground, or at least on a Stone or Brick Foundation, and not upon any wooden Floor. Place the Plane of the Quadrant parallel to the Line joining two opposite Screws of the Pedestal, and ease one of these Screws, and screw up the other as much, till the Bubble of the Level rests equally between the two scratches made upon the Glass Tube with the Point of a Diamond. Then turn the Quadrant half round upon its Axis of Motion, till the plane is again parallel to the same Line of the Screws, and if the Bubble still agrees with the marks upon the Glass, it is well ; but, if otherwise, ease one of the two forementioned Screws of the Pedestal, and screw up the other a much, till the Bubble has moved over half the Space by which it differs from the Marks, and note toward which End of the Tube it inclines. Now turn the Quadrant 90° about its Azimuth, till the Plane of it be parallel to the Line of the other two opposite Screws, and if the

Bubble does not rest in the same Manner with respect to the Marks, as it did before, ease one of the Screws just mentioned, and screw up the opposite one till it does.

Then ease the two outer or pushing Screws, and screw up the middle Screw of those three Adjusting Screws of the Level which are at that End of the Tube to which the Bubble inclines, till the Bubble rests equally between the marks ; and the Axis of the Pillar is now set nearly perpendicular to the Horizon, and the Level (that is to say, the line which is a Tangent to the middle of the Bubble) is nearly perpendicular to the Axis, and is consequently nearly parallel to the Horizon. This may be called the Rough Adjustment. Then turn the Quadrant half round, so that the Plane of it may be parallel to the same Screws of the Pedestal as before ; and if the Bubble still rests equally between the marks, the Quadrant is adjusted right in this Position ; but if the Bubble does not agree with the Marks, ease one of the same pair of Screws, and screw up the other, so that the Bubble may move over half the Space by which it differs from the Marks. Turn the Quadrant half round back again ; and if the Bubble agrees with the marks, the Bubble is rightly adjusted in this Position ; if otherwise, alter the Screws of the pedestal and Level as before, and repeat the Operation, if necessary, till the Bubble agrees with the marks in both Positions of the Quadrant produced by turning it half round.

Now turn the Quadrant 90° about its Azimuth, or into its first Position, the Plane of the Quadrant being parallel to the Line between the two opposite Screws, and note whether the Bubble rests equally between the marks ; and if it does not, ease one of the corresponding Screws of the Pedestal, and Screw up the other till it does ; and the Axis of the Pillar is set truly perpendicular to the Horizon : For more Certainty, you may turn the Quadrant half round and see whether the Bubble still agrees with the marks, which it ought to do equally in these two opposite Positions

of the Quadrant, as it did before when the Plane of the Quadrant was placed parallel to the line of the other Screws.

Having thus adjusted the Axis of the Pedestal perpendicular to the Horizon, the Quadrant is now ready to be adjusted for Observation.

And in the first Place let the Plumb-line be hung on over the Notch, and stretched by the Plummet, immersed in Water, to prevent the oscillations which it would otherwise acquire from the least Pulse of Air, and carefully observe whether so hanging it bisects both the Points ; which if it does not, it is to be brought to do, partly by altering the *Adjusting Screw*, and partly by the Screw which adjusts the Spring that carries the Notch from which the Plummet hangs, as before described. This may be done most conveniently by first Altering the *Adjusting Screw*, if necessary, till the Plumb-line is parallel to the Line joining the Points, and then altering the Screw which governs the Notch till the Plumb-line bisects both points.

Next turn the Plane of the Quadrant about into the Vertical Circle, which the cœlestial Body will occupy in a few Minutes of Time forward, and set the Telescope at or near the Zenith Distance which you expect it will have in the Observation you are about to make, and observe whether the Plumb-line still bisects the lower Point ; if it does not, make it so to do, by turning the *Adjusting Screw* alone, and the Radius passing through the Beginning of the Divisions will be set truly perpendicular to the Horizon, and consequently as the Axis of the Pillar was set perpendicular to the Horizon before, the Instrument is properly prepared for Observation.

Then, if it be the Meridian Zenith Distance which is to be observed, turn the Quadrant gently about on its Axis, if necessary, so that the Star or Sun's Centre may be always found very near but not quite upon the vertical Wire of the Telescope, and turn the Micrometer Screw, so as to cause the middle horizontal Wire of the Telescope to bisect the Star, or be itself bisected by the Sun's upper or lower

Limb ; and as the Object diminishes in Zenith Distance in approaching the Meridian, keep turning the Micrometer Screw, so that the Wire shall always apply itself in the same Manner to the Object ; and when the Object ceases to change its Zenith Distance, the

Quadrant points out the Apparent Meridian Zenith Distance. It will be still more accurate, if the Observer brings the upper or lower Side of the Wire to be a Tangent to the Sun's Limb, and makes an allowance for the half Breadth of the Wire, which may be found by Observations taken from both the upper and lower Limbs of the Sun in this or any other Meridian Transit, using the Sun's Semidiameter as given in the Nautical Almanac.

The method hitherto described is proper for observing Meridian Zenith Distances before the going of the Clock is known ; but after that is found, keep turning the Quadrant about with respect to Azimuth, by means of the Screw which is fastened by a Clamp to the Azimuth Circle, and alter the Zenith Distance of the Telescope by means of the Micrometer Screw, so as always to keep the Object in the same Manner applied to the Wire as before directed, till the Clock shews the Time at which the Object should pass the Meridian, and the Quadrant will then point out the apparent Meridian Zenith Distance.

A third, and the most antient and best, but not always the most ready and convenient Method of taking Meridian Altitudes, is by bringing the Plane of the Quadrant into the Meridian by means of an exact Meridian Line ; for it is evident, that the Zenith Distance measured, when the Star or Sun's Centre passes the vertical Wire, will be the apparent Meridian Zenith Distance.

An experienced Observer may take the meridian Zenith Distance of one Limb of the Sun, and read it off, and then observe that of the other Limb within the space of two Minutes ; the second Observation he may read off at his Leisure.

The mean of these two Observations will give the Meridian Zenith Distance of the Sun's Centre more correctly

than it could be deduced from the Zenith Distance of one Limb only with the Sun's Semidiameter applied to it.

The general Rule for reading off the observed Zenith Distance is this ; set the Index of the Micrometer to (0) and turn the Screw that Way, which will cause the Figures of the divided Circle to pass by the Index in their proper Order, till the first Coincidence happens between a Stroke on the Vernier and one of the Divisions. From the Zenith Distance at which the Telescope now stands (shewn by the Divisions and the Vernier) subtract the Seconds shewn by the Micrometer, and you will have the Zenith Distance required. It may not be improper here to remark, that the Screw of the Micrometer ought, by Rights, to be turned the same way in reading off, which was done in the Observation ; else there be any Shake or Play in the Screw upon turning it different Ways (as is generally the Case) an Error will be incurred. It may perhaps be conducive to greater Certainty to repeat the Reading two or three Times, by turning the Screw of the Micrometer a little back each Time, and then screwing it forwards again, to produce a fresh Coincidence of the Vernier with the Divisions, as the Mean of the Numbers of the Micrometer so found will, in all

Probability, be more exact than a single Reading. In the Day Time it will be useful for the better reading off of the Observations to throw light by Reflection from white paper upon the Divisions and the Vernier, but in the Night they must be illuminated by a Candle or Lamp.

The Observations of Zenith Distances of the heavenly Bodies at a Distance from the Meridian is performed much in the same Manner as those on the meridian, except that the Telescope is generally set to some even Division, and the Times by the Clock of the Transit of the Star or both Limbs of the Sun across the horizontal Wire passing through the Centre of the Telescope are observed ; and also, if it is intended to find the Times by equal Altitudes on each Side of the Meridian, across such other Wires as

may be placed in the Telescope parallel thereto for this Purpose.

The Mean of the Times by the Clock of the Transit of a Star, when observed at the same Wire and with the Telescope fixed to the same Altitude on both Sides of the Meridian, gives the Time by the Clock of the Star passing the Meridian ; whence either the Apparent or Mean Time is easily computed, and consequently the Error of the Clock found ; But the Mean of the Times of the Transits of the same Limb of the Sun across the same Wire on different Sides of the Meridian must first be corrected by the Equation, commonly called by the Title of that of corresponding Altitudes (a Table of which is to be found at the End of these Remarks) in order to have the Time by the Clock of the Sun's Centre passing the Meridian, which is the Apparent Noon ; whence the Error of the Clock is also determined. The Method of deducing the Time from corresponding Altitudes is so much the more exact, as the Accuracy is not affected by any Uncertainties about Refraction or the Latitude of the Place, or even the Declination of the heavenly Bodies ; moreover it is rendered still more exact, if the Times of the Star or Sun's Limbs, passing the Wires of the Telescope fixed successively at several Altitudes, be observed ; the Number of Results for the Time of the Passage across the meridian being hereby multiplied, it may be presumed, that the Mean of all the Results will come much nearer the Truth than that of a single One.

The Observations made on the West Side of the Meridian follow one another in an inverted Order, with respect to their corresponding ones taken on the East Side. Thus the Time of the Transit of the Sun's upper Limb across the lower Wire is the first Observation in the Morning, but is the last in the Afternoon ; and the Transit of the Sun's lower Limb across the upper Wire is the last Observation of the Morning, but the first in the Afternoon ; Therefore it will be most convenient in Practice to set down the Observations made on the West Side of the meridian in an inverted Order to that in which they are made under those made on the East Side of the meridian, and thus they will immediately correspond to those which stand over them, and the Mean of each Pair of corresponding Ones will be readier seen. The Observer will not forget that the Telescope inverts Objects, so that the Limb which appears the upper Limb is really the lower Limb, and is to be called so, and the Limb which appears to be the lower One is really the upper One and is to be called so. Though the Method of finding the Time from equal Altitudes of the Sun or Stars observed on both Sides of the Meridian, be much more accurate and satisfactory than that of inferring it by Computation from single Altitudes, yet if by any Accident the corresponding Observations cannot be taken. The Time may be deduced nearly, in Case of Necessity, from the latter Method, the Latitudes of the Place being supposed known.

The Eastern and Western Azimuths of any cœlestial Body being equal when it has equal Altitudes on contrary Sides of the meridian, it will be easy to find by the Azimuth Circle belonging to the Quadrant, about what Azimuth to place the Quadrant on the West Side of the Meridian in order to make the corresponding Observations to those taken before on the East Side ; provided the Point (0) of the Azimuth Circle is set to agree truly or very nearly with the meridian, or at least the Error of its Position with respect to the Meridian is known.

The Azimuth Circle may also be of Use for placing the Quadrant in the Meridian for taking Meridian Altitudes, though this will be better done by the Means of a Meridian Mark. Such a Mark may be readily placed, as well as the Position of the Azimuth Circle determined, as follows : Having found from the repeated equal Altitudes of the Sun or fixed Stars how much the Clock differs from Mean Time, and also the Rate of its gaining or losing in a Day, make a Computation of what Hour, Minute, and Second by the Clock, the Sun or Star should pass the Meridian on any Day, and having directed the Telescope of the Quadrant to the Object a little before

the expected Time of its passing the Meridian, so that the vertical Wire of the Telescope may pass over the the Star or Sun's Centre, turn the Quadrant gradually about upon its Axis, by Means of the proper Screw, which in the Time of Observation is to be fastened by a Clamp to the Azimuth Circle, so as to cause the vertical Wire to keep equal Pace with the Sun or Stars diurnal Motion, and always to pass over its Centre till the Clock points out the computed Time at which the Object should pass the Meridian ; at that Instant the Plane of the Quadrant is placed truly in the Meridian; and then bring the lower End of the Telescope up towards the horizontal Line, and fix up some mark at a distance which may be covered or bisected by the vertical Wire of the Telescope, and it will be placed truly in the Direction of the Meridian ; so that whenever you want to set the Plane of the Quadrant in the Meridian for observing Meridian Altitudes, you have nothing to do but adjust the

Quadrant in the usual Manner, and turn it about till the vertical Wire in the Telescope bisects the Mark, and the Quadrant will be truly adjusted to the Meridian. Instead of following the Sun's Centre, it will be more convenient and exact to follow his Eastern or Western Limb with the vertical Wire of the Telescope till the computed Time happens by the Clock of the Limb passing the Meridian ; the Western Limb passes sooner, and the Eastern Limb passes the Meridian later than the Sun's Centre, by the Time that the Sun's Semidiameter takes to pass the Meridian, which may be found in the Nautical Almanac ; therefore this Quantity being subtracted from the computed Time by the Clock of the Sun's Centre passing the Meridian, gives the Time of the Western Limb passing the Meridian, or added to the Time of the Sun's Centre passing the meridian, gives the Time of the Eastern Limb passing the Meridian.

The Quadrant being once set truly in the Meridian, it will be easy to adjust the Point (0) of the Azimuth Circle to the meridian, or to note the Error of its Position.

But it should be carefully attended to, that the Qua-

drant cannot be adjusted truly to the Meridian, for future Observations, either by the Meridian Mark or Azimuth Circle, unless the Pedestal of the Instrument has a fixed Position in the Observatory, which may be best effected by having the Pillar or Stand on which you place the Brass Pedestal immoveable, and sinking little holes on the horizontal Top of it to receive the 4 Screws of the Pedestal, whereby it will be easy to replace the Pedestal in the same Manner again after any removal.

If the mark be only 1000 Feet distant, the Pedestal should be adjusted always to the same Position again with respect to the meridian within $^1/_{10}$ of an Inch, and nearer if the mark is less distant. A Post fixed firmly in the Ground, and set truly perpendicular by means of a Plumb-line or Carpenters Level, will be very proper for a meridian Mark, and if seen against the Sky should be painted black.

Hitherto I have supposed the Quadrant to be correct with respect to those Adjustments, which when once made, either by the Instrument Maker or Observer, are usually invariable, except the Instrument meets with any violent Concussion in Carriage or otherwise. As it is the Business of the Observer to verify these Particulars himself before he begins to make any Observations, I shall now offer to him a few Directions, as I proposed, for that Purpose.

In the First Place the Object-Glass and Eye-Glass of the Telescope must be set to a due Distance from one another, and from the cross Wires, that both the cœlestial Objects and the Wires be seen distinct by the Eye of the Observer, and at the same Time there may appear no Parallax or motion of the Object, with relation to the Wires, when the Eye is moved side-ways out of the Axis of the Tube. For this Purpose take off the Cover of the Tube near the Eye and direct the Telescope to some fixed Star or Planet, and draw the Eye-Glass a little further out, and push it gently a little further into the Tube, alternately, till by repeated Trials you have placed it in that Position in which it shews the cœlestial Object with the most Distinctness ;

and note whether at the same Time you see the cross Wires near the Place of their Intersection with more Distinctness than in any other Position of the Eye-Glass, and also whether the Object appears immoveable, with respect to the Wires, upon moving your Eye sideways ; if both these Circumstances concur (as they will do at the same Time, provided the Telescope with its Wires had been properly adjusted before to Distinctness for any Eye) your Telescope is now rightly adjusted for Distinctness for your Eye.

But if the Wires do not appear perfectly distinct to your Eye, or the Object appears to move, with respect to the Wires, when the Eye is moved sideways, it follows that the Distance, either of the Object-Glass or the cross Wires in the Tube, or both, must be altered ; it will be more easy and convenient to move the Wires, provided they are so placed as to admit of it : In this Case, carry them further from the Eye and bring them nearer to it, alternately, till you have placed them at that Distance at which you see them with the most Distinctness, and at the same Time there remains no Parallax of the cœlestial Object upon the Wires when the Eye is moved sideways.

But if the Wires are incapable of being moved, place the Eye-Glass at that Distance which will shew them most distinct, and then alter the Distance of the Object-Glass in the Tube, one Way or the other, till you can see the cœlestial Object most distinct, and at the same Time there shall be no Parallax of the Object upon the Wires ; and the Telescope is fitted to Distinctness for your Eye ; and, it is evident, will require no adjustment of this Kind another Time, except in the process of Time the Form of the Eye should suffer any alteration : In this Case, or if any other Person more short-sighted or long-sighted in any considerable Degree, should have Occasion to use the Quadrant, all that is necessary to be done is to alter the Place of the Eye-Glass in its Tube till the cœlestial objects appear more distinct.

In the next Place, the Wire which, in taking Altitudes, is brought to the Star or the Sun's Limb, should lie truly ho-

rizontal when the Plane of the Quadrant has been adjusted perpendicular to the Horizon by the Method related above. Direct the Telescope to any small well-defined Object or Mark upon the Land, or if none such can be found, fix One up at a convenient Distance, and having bisected it carefully with the Wire that ought to be horizontal, turn the whole Quadrant a little about in Azimuth, and if during this Motion, the Mark is continually bisected by the different Parts of the Wire, as they are successively applied to it, the Wire is truly horizontal ; but if the Wire ceases to bisect, or leaves the Mark, press the Two Screws, One of which is on the upper and the other on the under Side of the Telescope, near the Eye, and which enter into the Place in which the cross Wires are fixed, between your Finger and Thumb, and turn them sideways, but in contrary Directions, till the horizontal Wire, upon Re-examination, on moving the Quadrant, always agrees with the Mark. A small white Circle placed upon a black Ground, or a black Circle placed upon a white Ground, will be a proper Mark for this Purpose. One of the First Sort will be formed by a Hole cut in a Board painted black, and seen against the Sky. Otherwise the Wire may be adjusted by a Star, in or near the Equator passing the Meridian, which ought to continue bisected by it all the while it is passing the Field of the Telescope. Or, without waiting for the Star's running over the whole length of the Wire, turn the Quadrant a little about, at or very near the Star's passing the Meridian ; and note whether the Wire continues in the Parts near the Centre of the Telescope to bisect the Star.

The last Adjustment, which it is incumbent on the Observer to verify, is that of setting the Line of Collimation or Line of Sight, which joins the Centre of Refractions in the Object-Glass, and the Intersection of the Wires of the Telescope, parallel to the Radius passing through the First Stroke of the Vernier.

I shall mention Two Methods of doing this by means of terrestrial Objects, and One by Observations of the Stars.

First Method. Set the Telescope to the horizontal Radius of the Quadrant, so that the First Stroke of the inner Vernier may agree with the Division or Zenith Distance marked 90° on the inner Arch or the Quadrant, and that the First Stroke of the other Vernier may agree with the Division marked 96 on the outer Arch.

Make two Marks on a Board (as Two small white Circles the Board being painted black, or Two black Circles the Board being painted White) at a Distance exactly equal to the Difference of the Altitudes of the Telescope, arising from inverting the Quadrant.

Place the Board at a Distance, and set the Line joining the two Marks truly perpendicular to the Horizon by means of a Plumb-line, and at such a Height that the Intersection of the cross Wires of the Telescope may appear exactly coincident with the Centre of the upper Circle, the Plumb-line of the Quadrant at the same Time being made to bisect both the Points marked with Darts.

Then invert the Quadrant, and hanging on the Plumb-line again, from an apparatus contrived to be fitted occasionally upon the Arch, cause it to pass over and bisect both points, by turning the *Adjusting Screw*, and if the intersection of the cross Wires covers the Centre of the lower Mark, the Line of Collimation of the Quadrant is correct. But, if otherwise, set the Index of the Micrometer to (0), and turn its Screw one Way or the other, till the Intersection of the Wires covers the Centre of the lower Mark, and the Angle moved over by the Telescope, which is indicated by the Number of Seconds run over by the Index of the Micrometer, is equal to double the Error of the Line of Collimation. If the Error be but small, it may be as convenient to allow for it in the Observations ; but if it be large, correct it as follows : Turn the Micrometer Screw back, so as to point out Half the double Error which it shewed, and ease one of the small screws, and screw up the opposite One of those Two upon the Telescope which governs the cross Wires, till the Intersection of the Wires covers the Centre of the lower Mark ; and

the line of collimation should now be correct. For greater Certainty, repeat the Operation thus ; set the Telescope again to the 90th Degree as before, and examine anew whether the Plumb-line continues to bisect the Points, and if it does not, make it to do so by turning the *Adjusting Screw*, and alter the Height of the Board with the Marks, till the Centre of the Lower Mark is covered by the Intersection of the cross Wires ; then turn back the Quadrant into its first Position, and causing the Plumb-line again to bisect the Points, by turning the *Adjusting Screw* if necessary, examine whether the Intersection of the cross Wires covers the Centre of the upper Mark. If it does, the Line of Collimation is correct ; but if it does not, it may be corrected, or the Quantity of the Error found, in the Manner described above.

This Examination must be repeated in the same Manner, by inverting and replacing the Quadrant, till the Line of Collimation appears correct, or till the Quantity of the Error is found. If it should be thought more expedient to allow for the Error in the Line of Collimation, take the following Rule for the Manner of applying it : If, after the inversion of the Quadrant, the lower Mark appears through the Telescope lower than the intersection of the cross Wires, or if, after replacing the Quadrant in its first Position, the upper mark appears higher than the Intersection of the Wires, the Error of the Line of Collimation is of that kind as to give the Zenith Distances greater than the Truth, and consequently the Error must be subtracted from the observed Zenith Distances ; but if, in the First Case, the lower Mark appears through the Telescope higher, or in the Second Case lower than the Intersection of the Wires, the Error of the Line of Collimation gives the Zenith Distances too little, and consequently the Error must be added to the observed Zenith Distances.

Otherwise the Error of the Line of Collimation may be more readily found as follows, without taking the Trouble of placing the marks at such a Height as to agree with the

Intersection of the cross Wires, while the Telescope is always set to the Zenith Distance of 90 Degrees. Measure the Zenith Distance of the upper Mark by the Divisions, Vernier and

Micrometer ; then, inverting the Quadrant, take the Zenith Distance of the lower mark ; add the Two Zenith Distances together, and Half the Difference of the Sum and 180 Degrees is the Error of the Line of Collimation, which is to be subtracted from or added to all Observations, according as the Sum of the Two Zenith Distances was here found to be greater or less than 180 Degrees. It may be added, that Half the Difference of the Two Zenith Distances found in the Two Positions of the Quadrant is the Altitude of the upper Mark.

The other method of examining the Line of Collimation by terrestrial Objects is this : Set the Telescope to the 90th Degree and 96 Divisions, and having caused the Plumb-line to bisect the Points, set up some Mark at a Distance, so that the Intersection of the cross Wires may bisect it ; then remove the Quadrant and Mark into each other's Place, so that the Centre of the Telescope and the Centre of the Mark may be mutually and precisely interchanged ; and the Plumb-line being re-adjusted to the Points, note whether the Intersection of the Wires covers the Centre of the Mark ; if it does not, set the Index of the Micrometer to (0), and turn the Screw till it does ; you will thus have to read off the apparent Zenith Distance of the Mark ; from which subtract the number of Seconds of an Arch of a great Circle of the Earth answering to the Distance of the Quadrant from the Mark (at the Rate of 102 Feet for each Second) the Difference of the Remainder, and 90° is double the Error of the Line of Collimation ; hence the Line of Collimation may be rendered correct (if required) by a Manner much like that described in the Use of the former Method.

The Error of the Line of Collimation will be of that Kind as to shew the Zenith Distances too great or too little, according as the Zenith Distance of the Mark observed from the Second Station lessened by the Distance turned into

Seconds of an arch or a great Circle is greater or less than 90°.

The Third Method of verifying the Line of Collimation is by taking Zenith Distances of fixed Stars with the Face of the Instrument turned East and West alternately ; for which Purpose, the Arch is continued and divided for a few Degrees beyond a Quadrant ; and in one Position of the Quadrant the Zenith Distance of some Star is observed with the Telescope contained within the Quadrantal Arch, and in the other Position of the Quadrant the Zenith Distance of the same Star is taken with the Telescope falling upon the Arch of Excess ; if both the Zenith Distances agree together, the Line of Collimation is correct ; but if they differ, Half the Difference is the Error of the Line of Collimation, which added to the least Zenith Distance of the two, or subtracted from the greatest, gives the correct Zenith Distance.

And according as the Zenith Distance, when the Telescope falls within the Quadrantal Arch, is greater or less than the other, the Error of the Line of Collimation is to be subtracted from or added to all Zenith Distances taken in this Position of the Quadrant, and applied in a contrary Manner to Observations made with the Telescope falling without the Quadrant. It is hardly necessary to remark, that these Observations made with the Telescope falling without the Quadrant turned contrary Ways, must fall within the Compass of a few Days, else there will be an Allowance to be made on amount of the Variation of the Star's Declination.

It may not be an improper Caution to give the Observer, that the Object-Glass of the Telescope must not be taken out or removed from the Tube, on any Account, after the Line of Collimation has been corrected, or the Error of it determined, because such Removal would disturb the same. Therefore the Object-Glass must be cleaned, when necessary, without Violence, on the Outside only ; the inner Surface, which is secured from the Air, being not commonly subject to acquire much Soil, except in a long space of Time.

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There are some particular Circumstances relative to the Observations of Stars near the Zenith which I shall take the Opportunity of mentioning in this Place.

I. To ease the Observer from the Trouble of looking up so high, there are metallic Speculums provided, to be placed occasionally on the Tube of the Telescope between the Eye-Glass and the Eye, making an angle of 45° with the Axis of the Tube, which will consequently reflect the Field of the Telescope, and the cœlestial Objects, together with the Wires, directly to the Eye of the Observer, looking horizontally against the Speculum and the Side of the tube.

II. As the Telescope must always be set to its Altitude before the Plumb-line is adjusted, lest the Alteration of its Pressure upon the Pedestal, arising from moving it, should disturb the Plumb-line ; and as the Telescope, when placed near the Zenith, will interfere with the Plumb-line, if suspended in its usual Position ; therefore an Apparatus is provided to be fastened upon the horizontal Side of the Quadrant, containing a Notch, from which the Plumb-line is to be hung in such Cases, and it is to be carried to the Right or Left, partly by means of a Screw which governs the Notch, and partly by the *Adjusting Screw*, till it is brought to hang directly over and bisect two Points marked with Darts, one of which is on the Side of the Quadrant immediately under the Notch, and the other on the Limb of the Quadrant, and are set off exactly equidistant from the Centre and the Extremity of the Radius passing through (0) as the other two Points marked with Darts were, but on the contrary Side.

III. In reading off the Zenith Distance, when observed on the Arch of Excess, instead of the Number of the Vernier, which is made to coincide with a Division, read its Complement to 32, and instead of subtracting the Seconds shewn by the Micrometer, add them to the Zenith Distance thus given by the Divisions and the vernier.

There are Two remaining Adjustments of the Quadrant which I shall only mention, without laying any great Stress

upon them, because the Effect of a small Error in them is of less Consequence, and that they are moreover generally rendered correct by the Instrument Maker in the Construction. The first is the setting the Line of Collimation parallel to the Plane of the Quadrant ; the other is the placing the Plane of the Quadrant parallel to the Axis of the Pillar. The Observer may, if he pleases, adjust these Particulars also, provided there is any Liberty left for it in the Construction of the Instrument.

I have now finished the Description of the Use of the Astronomical Quadrant of Mr. *Bird's* Construction — Instruments made by other Artists may differ from his in several Particulars, and among these in the Adjustments ; but whoever well understands the foregoing amount will, I think, hardly be at a Loss to know how to adjust and use any of these Quadrants, as the Points to be adjusted are the same, and therefore the Differences of the Contrivances designed for the same Purpose will appear upon the Face of the Instrument.

Here follows a TABLE serving for the Reduction of the Divisions and Vernier of the exterior Arch of Mr. BIRD's Quadrants of One Foot Radius into Degrees, Minutes and Seconds.

	Grand Divisions											Subdivisions			Vernier		
	°	'	"		°	'	"		°	'	"		M.	S.		M.	S.
1	0	56	15	33	30	56	15	65	60	56	15						
2	1	52	30	34	31	52	30	66	61	52	30	1	14.	3,7	1	0.	26,4
3	2	48	45	35	32	48	45	67	62	48	45	2	28.	7,5	2	0.	52,2
4	3	45	0	36	33	45	0	68	63	45	0	3	42.	11,2	3	1.	19,1
5	4	41	15	37	34	41	15	69	64	41	15				4	1.	45,5
6	5	37	45	38	35	37	45	70	65	37	45				5	2.	11,8
7	6	33	45	39	36	33	45	71	66	33	45				6	2.	38,2
8	7	30	0	40	37	30	0	72	67	30	0				7	3.	4,6
9	8	26	15	41	38	26	15	73	68	26	15				8	3.	30,9
10	9	22	30	42	39	22	30	74	69	22	30				9	3.	57,3
11	10	18	45	43	40	18	45	75	70	18	45				10	4.	23,7
12	11	15	0	44	41	15	0	76	71	15	0				11	4.	50,0
13	12	11	15	45	42	11	15	77	72	11	15				12	5.	16,4
14	13	7	30	46	43	7	30	78	73	7	30				13	5.	42,8
15	14	3	45	47	44	3	45	79	74	3	45				14	6.	9,1
16	15	0	0	48	45	0	0	80	75	0	0				15	6.	35,5
17	15	56	15	49	45	56	15	81	75	56	15				16	7.	1,9
18	16	52	30	50	46	52	30	82	76	52	30				17	7.	28,2
19	17	48	45	51	47	48	45	83	77	48	45				18	7.	54,6
20	18	45	0	52	48	45	0	84	78	45	0				19	8.	21,0
21	19	37	30	53	49	37	30	85	79	37	30				20	8.	47,3
22	20	37	30	54	50	37	30	86	80	37	30				21	9.	13,7
23	21	33	45	55	51	33	45	87	81	33	45				22	9.	40,1
24	22	30	0	56	52	30	0	88	82	30	0				23	10.	6,4
25	23	26	15	57	53	26	15	89	83	26	15				24	10.	32.8
26	24	22	30	58	54	22	30	90	84	22	30				25	10.	59,2
27	25	18	45	59	55	18	45	91	85	18	45				26	11.	25,6
28	26	15	0	60	56	15	0	92	86	15	0				27	11.	51,9
29	27	11	15	61	57	11	15	93	87	11	15				28	12.	18,3
30	28	7	30	62	58	7	30	94	88	7	30				29	12.	44,6
31	29	3	45	63	59	3	45	95	89	3	45				30	13.	11,0
32	30	0	0	64	60	0	0	96	90	0	0				31	13.	37,4

But should the Observer be unprovided with the Astronomical Quadrant, he may find the Time nearly by equal Altitudes of the Sun, taken with a *Hadley's* Quadrant, from the Horizon of the Sea, if he is near to it ; but much better by taking the double Altitude by Reflection from a Bason of Water, Quicksilver, Oil, or Treacle. In the use of this latter Method there are Three Observations to be taken with the same Setting of the Quadrant ; namely, the Time when the Sun's upper Limb, as reflected by the Quadrant, touches the Sun's lower Limb, as it appears in the Bason, the Time of the Two Suns reflected from the Quadrant and the Bason appearing centrally conjoined together ; and the Time of the lower Limb, as reflected from the Quadrant, touching the Upper Limb, as it appears in the Bason. These are the Times at which the double Altitudes of the Sun's upper Limb, Centre, and lower Limb are equal to the Degrees and Minutes marked by the Quadrant ; and this is the Order in which the Three Observations follow one another in a Morning, but in an Afternoon the Order is reversed. The Mean of the Times of equal Altitudes of the same Limb gives the Time of Noon as usual ; the same is given by the equal Altitudes of the Centre ; thus, One Setting of the Quadrant gives Three Results for the Time of Noon, the Mean of which may be taken, and must be corrected by the Equation of corresponding Altitudes in the common Manner. The Observation of the Contacts of the Two Limbs is rather more certain than that of the Conjunction of the Centres. A dark Glass must be held near the eye to darken both Images of the Sun together.

It is evident that the Latitude of the Place may also be found by taking the double Altitude of the Sun's upper Limb, lower Limb, or Centre, at the Time of his passing the Meridian. Half the double Altitude thus found is to be corrected for Refraction as usual.

By way of a last Resource, the Time of Noon may be found by a Meridian Line drawn with the Help of a Gnomon, and the latitude may also be deduced from the same. Make a small Hole in a Plate of Metal, placed so

that the Sun's Rays may fall perpendicularly upon it at Noon about the Time of the Equinoxes, and at as great a Height as possible above an even Floor that is well levelled. Hang a Plumb-line through the Centre of the Hole, and mark the Point on the Floor which lies directly under the Point of the Plummet (which should be turned truly conical, at least on the lower Part) for the Centre of the Gnomon, from which describe several concentric Arches upon the Floor. On the Day of the Solstice, or not many Days from it, the Sun's Light being admitted through the Hole in the Plate, mark the Place of the Centre of his Image when it passes each of the concentric Arches in the Morning, and repeat the same Operation in the Afternoon. Bisect the Portion of any Arch intercepted between the Two correspondent Stations of the Sun's Centre in the Morning and Afternoon, and the Line drawn through the Point of Bisection, and the Centre of the Gnomon is the Meridian Line.

In like Manner the meridian Line will be found by Means of the Points marked upon the other concentric Arches, which ought all to agree together; but if there is any Difference, a Line may be drawn whose Position is taken at a Medium between them all for the true Meridian Line. Whenever the Sun's Centre passes this Line at any Time of the Year it is Noon. To find the Latitude of the Place, measure with a good Ruler or Scale of equal Parts the exact Distance between the Centre of the Hole in the Plate and the Centre of the Gnomon, which is called the Height of the Gnomon, and when the Sun passes the Meridian upon any Day, mark the Centre of his Image image upon the Meridian Line, and measure its Distance from the Centre of the Gnomon, and say, as this Distance is the the Height of the Gnomon, so is the Radius 100000 to a natural Tangent, which being sought for in the Tables, and a Proportion being made if necessary, will give the apparent Altitude of the Sun's Centre, whence the Latitude may be found according to the usual Methods. If the Latitude be thus found on several other Days, and at other Times of the Year,

the mean of all being taken will come still nearer to the Truth.

I now return to add some further Remarks concerning the Transit of Venus over the Sun's Disk. It may be difficult to catch the Instant of the First External Contact ; but as it may be expected (from Calculation) that the First Impression of Venus upon the Sun's Limb will fall about 37 Degrees to the East of that Point of the Sun's Circumference which is nearest the North Pole of the World, the Observers will do well always to keep this Part of the Sun's Limb, as near as they can estimate it, not far from the Middle of the Field of their Telescope, and to regard it principally, yet so as not to neglect the Parts adjacent. There was a Circumstance taken notice of by the Rev. Mr *Hirst*, F.R.S. who observed the last Transit of Venus at *Madras*, which if we could depend on its taking place at the next Transit, would prove a good Help towards catching the Point of Immersion and the true Instant of it. This was a kind of Penumbra or dusky Shade, which preceded the First external Contact 2 or 3 Seconds of Time, and was so remarkable that Mr. *Hirst* was thereby assured that the Contact was approaching, which happened accordingly. If the like Phænomenon should occur to any Person who attends the ensuing Transit, this Hint will prepare him to make proper Use of it ; yet I think it necessary to caution him not to keep his eye intirely fixed on that Part of the Sun's Limb where such an Appearance may happen, lest his Imagination may deceive him, and thereby take his Attention from other Parts of the Sun's Circumference, and consequently from the Point where the external Contact may really happen. Several Astronomers at the last Transit observed a luminous Crescent at the Times of the Ingress and Egress, which enlightened that Part of Venus's Circumference which was off the Sun, so that the Whole of her Circumference was visible : This was also observed by one Person in the Middle of the Transit. Mr. *Dunn*, with a *Newtonian* reflecting Telescope of 6 Feet, magnifying 220 Times, observed a very narrow waterish Penumbra round Venus, while she was wholly on the Sun, which somewhat disturbed the Distinctness of the Termination of her Circumference : Something of the same Kind was taken Notice of by some other Observers. If these Phænomena should be fully confirmed by the Observations of the next Transit, they will probably be allowed to be the Effect of an Atmosphere about that Planet. Four able Astronomers at *Upsal*, furnished with good Telescopes, saw Venus's external Limb about the Time of the first internal Contact, to be united to the Sun's Limb by a black Protuberance or Ligament, which was not broke by the Entrance of the Thread of Light till several Seconds after that the regular Circumference of Venus seemed to coincide with the Sun's : In these Observations the Sun was only $3\frac{1}{2}$ Degrees high ; and the Indistinctness of Vision, occasioned by Vapours near the Horizon might have been thought to be Cause of this Appearance ; but that the like was observed (though less plain and remarkable) at the Second internal Contact, when the Sun's Altitude was considerable.

Something of the same Kind was also seen by Mr. *Rumouski* at *Selengisk*, in an unfavourable State of Air, at the Second internal Contact ; and by Mr. *Hirst* at *Madras* at both internal Contacts. Mr. *Thorbern Bergman*, who was one of the Observers at *Upsal*, relates that Venus seemed to cohere to the Sun by a Ligament at the Second external Contact also. Such Effects might be produced by an Atmosphere about Venus, Imperfections of a Telescope, or a bad State of Air ; but from the Accounts published it does not appear to me that there was any Fault in the Telescopes.

Dr. *Halley* had supposed that the internal Contacts would be in a Manner instantaneous, or at least that they might be observed without a greater Error than one Second of Time ; but in fact this supposition was not verified by the Observations of the last Transit. The Thread of Light between the Limbs of Venus and the Sun was not

broke off in an Instant, at the Second internal Contact, as he had suppose it would, but gradually, with an Uncertainty of some Seconds ; and the Observations made by experienced Observers in the same Place, or in Places not far distant, and reduced to the same Meridian, differed accordingly from one another more than was expected. Part of these Differences might arise from the Difference of Judgment in estimating the Contact, some noting the Time when the Thread of Light became invisible, and others the Time when the Circumference of Venus seemed to coincide with the Sun's. It is therefore to be wished, that those who observe the next Transit will in the Account of their Observations mention particularly in what Manner they judged of the internal Contacts.

After the Observation of the Contacts, that of the nearest Distance of the Centres of the Sun and Venus being the next in Importance, it is recommended to those who shall be situated in Places where the Middle of the Transit is visible, and be furnished with the proper Instruments, to attend to this Point also.

The common Micrometer having a moveable Wire parallel to a fixed one, and a Third perpendicular to both, may be made use of in this Occasion ; but the Instrument, which is by far the most convenient and exact for this Purpose, is the divided Object-Glass Micrometer, commonly called *Dollond's* Micrometer, fitted to the Object-end either of a reflecting Telescope, or an Achromatic refracting Telescope of $3\frac{1}{2}$ Feet, with a treble Object-Glass. The Method of using this Micrometer is very simple and easy ; it may, however, be proper to give a brief Description of it. The Two Semicircles into which the Object-Glass is divided are separated from each other by turning an Handle, and the Distance of their Centres is measured by a Scale of equal Parts divided into Inches and 20ths of an Inch, with the Addition of a Vernier, which subdivides the 20ths of an Inch of the Scale into 25 Parts, or the 500th Parts of an Inch. The Rays of Light passing through each Semicircular Glass will exhibit a particular

Image of an Object to an Eye looking through the Telescope. When the Semicircles are brought together, so that their Centres coincide, and they form as it were One Glass, the Two Images being united together, only One Image will be seen ; but in proportion as the Glasses ate separated from each other by turning a Handle, the Two Images will be seen to separate also. To measure the angular Distance of the Two Objects (not exceeding the Extent of the Micrometer) bring the Image of One Object formed by One of the Semicircles to coincide with the Image of the other Object formed by the other Semicircle, which is to be done, partly by turning the Handle which separates the Two Glasses, and partly by turning the other Handle which will carry the common Diameter dividing the Two Glasses into the Plane pasing through the Two Objects ; and read off the Numbers from the Scale of the Vernier, and you will have the apparent Distance by the Scale, which is to be turned into Minutes and Seconds by means of a Table formed for that Purpose. To measure the apparent Diameter of a Planet the Two Images must be separated till their Circumferences touch one another externally.

The First Thing to be done, in order to fit the Instrument for Observation, is to adjust the Telescope, with the Micrometer applied to it, to the most perfect Vision of the Object to be observed. Cover One of the Semicircles, so as to intercept One of the Images of the Object, and alter the Focus of the Telescope both Ways several Times, till you have adjusted it, to shew the other Image formed by the Glass that is uncovered with the greatest Distinctness. The Sun's Limb, or Spots, or the opaque Body of Venus during the Transit, are very good Objects for this Purpose.

If there is a Scale with a Vernier placed on the Side of the Telescope (as is usual) repeat the Adjustment of the Telescope several Times, and note the Number indicated by the Scale and Vernier each Time, the Mean of all the Numbers is that according to which the Telescope must be adjusted, or the Adjustment restored at another Time, if

it should have suffered any Alteration. Great Care is necessary to be used in this Point, as a very small Error therein will occasion a sensible Alteration in the Angle as measured by the Micrometer Scale.

The next Thing to be done is to find the Error of the Adjustment of the Micrometer Scale. Both Micrometer Glasses being now exposed to the Object, turn the Handle which moves the Glasses with respect to each other, till both Images of the Object are conjoined in One, and the Numbers shewn by the Scale and Vernier is the Error of the Adjustment. This Object may be any of the celestial Bodies, or even a distant well-defined Land Object, and, the Experiment being repeated several Times, the Mean of all should be taken for the true Quantity of the Error, and if (0) on the vernier falls before or to the Right Hand of (0) on the Scale, the Error is to be subtracted from all Observations, otherwise to be added.

There is another Method of finding the Error of Adjustment, which seems rather preferable in point of Accuracy to the common Method just related. This consists in measuring the apparent Diameter of any small Object (as Jupiter’s equatorial Diameter or the longest Axis of Saturn’s Ring) with the Point (0) on the Vernier placed alternately to the Right Hand and left of (0) on the Scale; only taking Care in the latter Case, instead of the Number shewn by the Vernier, to take the Complement to 25 ; Half the Difference of the Two Diameters thus found is the Error of the Adjustment; which is subtractive or additive to all Observations, according as the Diameter measured with (0) of the Vernier advanced upon the Scale, or to the Right Hand of (0) on the Scale, is greater or less than the Diameter measured with (0) on the Vernier falling behind or to the Left of (0) on the Scale. It is evident that Half the Sum of the Two Diameters, as immediately given by the Measures of the Scale, is the True Diameter of the Object. This therefore is the just and proper Method of measuring the apparent Diameters of all the primary Planets. It is also the Method that should be used in

measuring the apparent Diameter of Venus on the Sun, especially as it gives at the same Time the Error of the Adjustment, as just now explained.

The Error of the Adjustment may now be taken away if required, by setting the Vernier to the Quantity of the Error found in the Manner above-mentioned, and easing the Screw which fixes the Vernier to the Plate beneath it, and sliding the Vernier till (0) thereon agrees exactly with (0) on the Scale; after which the Screw should be tightened again, but if it be small it may be convenient to allow for it in the Observations.

The Third Point to be determined is the value of the Scale of the Micrometer expressed in Minutes and Seconds. This may be found very readily and with sufficient exactness by measuring the Sun's horizontal Diameter, and comparing it with that given in the Nautical Almanac, or Astronomical Tables, Allowance being made, as before directed for the Error of the Adjustment. On the Day of the ensuing Transit of Venus the Sun's Diameter will be 31 Minutes and 31 Seconds, supposing the apogeal Diameter to be 31'. 28" as was determined by Mr *Short* with a Divided Achromatic Object-Glass, and it will be decreasing at that Time at the rate of 1 Second in 5 Days. Hence, if the horizontal Diameter be measured on the Day of the Transit, or within a Fortnight before or after it, the Value of One Extent of the Scale will be known in Minutes and Seconds ; whence the Value of any other Extent may be found by Proportion, and a Table be made accordingly to facilitate the Reduction of the Observations. To find what the Sun's Diameter should be at any Time of the Year, in Proportion to the Apogeal Diameter assumed 31'. 28", as above-mentioned, always subtract 3"from the Semidiameter given by the Nautical Almanac, or *Mayer*'s Tables, the Remainder doubled is the Diameter required. The Value of the Scale might also be determined, if thought necessary, by several other Methods independent of any Hypothesis as that of the Sun's

Diameter. I shall only mention One, which is very simple and perhaps as exact as any other. Adjust the Telescope without the Micrometer with great Care for distinct Vision for the Planets Jupiter or Saturn, then put on the Micrometer, and find by several Trials the Distance at which a proper Object, suppose a printed Paper, should be placed before the divided Object-Glass that it may appear most distinct through the Telescope, whose Adjustment must remain unaltered. This is the focal Length of the Object-Glass, and must be measured with great Care from the outer Surface of the Glass to the Object, to which, if you please, you may add One-third of the Thickness of the Glass, if double and equally convex. Then say, as this Sum is to any Extent of the Scale : : so is the Radius 100000 : to twice the Tangent of Half the Angle answering to the separation of the Glasses measured by that Extent of the Scale ; or, in Practice, it may be sufficiently exact if you say, as this Sum is to any Extent of the Scale (both being reduced to Measures of the same Denomination) so is 206265 Seconds, to a Number of Seconds contained in the Angle answering to the Separation of the Glasses measured by the proposed Extent of the Scale ; whence a Table of Reduction may be readily constructed.

The Instrument being thus prepared for Observation, let it be required to find by it at any Time the Distance of Venus from the Sun's Centre. This is to be done by measuring the Distance of Venus's exterior Limb from the nearest Limb of the Sun, and the horizontal Diameters of the Sun and Venus ; for the said Distance subtracted from the Difference of the Semidiameters gives the Distance of Venus's centre from the Sun's Centre, which was required. This Observation if made at the Middle of the Transit will give the nearest Approach of the Centres of the Sun and Venus : But the best Way will be to measure the actual Distance of the nearest Limbs of the Sun and Venus, repeatedly, beginning some time before the nearest Approach of the Centres, and continuing the Observations till that Time is past (which will appear by the Distance of Venus

from the Sun's Limb, after becoming stationary, decreasing) as well as to be sure of hitting the true Time, as to obtain the greater Certainty from taking a Mean of several Observations taken within a little Space of one another. It will be very expedient, soon after the nearest Approach of Venus to the Sun's Centre has been measured and is past, to measure the Diameter of the Sun several Times in the same Direction, which will be effected near enough for the Purpose by using the Micrometer as left by the last Observation of the Distinctness : that if there is any Difference in the inclined Diameters of the Sun from the horizontal One, you may obtain the true least Distance of the Centres of the Sun and Venus notwithstanding ; agreeable to a Hint of Mr. *Mollet*, Astronomer to the King of *Sweden* at Upsal. Half the Sun's Diameter thus found lessened by the Sum of the nearest Distance of the Limbs of the Sun and Venus, and the Semidiameter of Venus, gives the true Distance of the Centres. In measuring other Distances than these about the Middle of the Transit, you may take the mearest Distance of Venus from the Sun's Limb, the Sun's Diameter and Venus's, in order one after another ; not forgetting however to observe the Sun's horizontal Diameter also, for determining the Scale of the Micrometer. In order to be sure that you always take the Distance of Venus's Limb from the nearest Part of the Sun's Circumference, turn the Micrometer round about by Means of the proper Handle, and Venus will apply herself successively to different Parts of the Sun's Circumference ; and when, during this Motion she is carried either parallel to the nearest Part of the Sun's Circumference, or so as to continue to form a perfect internal Contact with the Sun's Limb for some Space, that is the proper Position of the Micrometer for measuring the Distance of the nearest Limbs of Venus and the Sun : Therefore after this, as soon as possible, by separating or bringing the Semicircles nearer to each other, cause Venus's Limb to form an accurate Contact with the Sun's Limb ; then reading off the Numbers from the Scale you will have the

measure of the Distances of Venus's near Limb from the Sun's. The Times should be noted by the Clock, as usual.

If several of these Observations are made during the Transit, the Path of Venus over the Sun may thereby be traced or calculated. Moreover, if some are taken not very far distant from the Time of the Contacts, they may enable us to find the said Times by Calculation, supposing they could not be observed. It will however be proper to leave off these Measures when Venus is distant from the Sun's Limb by her whole Diameter, before the Second internal Contact, in order to prepare the Telescope for the same, by taking off the Micrometer and adjusting the Telescope without it to distinct Vision. If there is not much Time to spare before the Contact, it will be better to adjust the Telescope by Means of the Scale and Vernier placed at the Side of it, according to Experiments made before by looking at the Sun. It will indeed be highly proper to settle the Adjustment of the Telescope by several Trials, both without the Micrometer, and with the Micrometer applied to it, some time before the Day of the Transit, and to note down the Numbers of the Vernier on the Side of the Telescope, or make Marks on the Eye-Tube, whereby the Telescope may be re-adjusted at once to its proper Focus, according as the Micrometer is applied to it or not.

It will also be very proper to prepare the Instruments for Use in every Respect some Days before the Transit, and at the same Hours on which Venus will appear the next Day upon the Sun, that if there be any Defects in the Apparatus of the Instruments, or any local Obstacles to the Use of them, arising from the Position of the Sun, or Inconveniences of the Place, they may be removed in time.

It will be highly proper for the Observers, who attend the ensuing Transit of Venus, to make Observations, in order to determine the Latitudes and Longitudes of the Places where they are stationed. For finding the Latitude

they should take the meridian Altitudes of the Sun, and also of Stars both to the North and South of the Zenith. For settling the Longitude they may observe any of the following celestial Phenomena, or as many of different Kinds as the Instruments they may be furnished with and other Circumstances may permit ; for the nearer this Point is determined the more useful and valuable will their Observations of the Transit prove.

1. Eclipses of the Sun and Moon.
2. Immersions and Emersions of Jupiter's Satellites ; but principally of the First Satellite.
3. Occultations of fixed Stars and Planets by the Moon's Limb, and their Emersions from the same.
4. Differences of Right Ascension between the Moon's enlightened Limb and Stars lying near her Parallel of Declination, by means of moveable Wires placed in the Focus of a Telescope.
5. Transits of the Moon's enlightened Limb over the meridian compared with the Transits of the principal Stars of the First and Second Magnitude lying nearest to the Equator.
6. Corresponding Altitudes of the Moon's upper or lower Limb compared with

corresponding Altitudes of fixed Stars.

7. Altitudes of the Moon's upper or lower Limb, when she is upon or near the Meridian, and her Declination varies at least 3 Degrees in 24 Hours. The Time of the Observation should be noted by the Clock, and Meridian Altitudes of fixed Stars near the Moon's Parallel of Declination should be also observed, if convenient, before and after the Moon's Transit.
8. The internal and external Contacts of the Planet mercury with the Sun's Limb, whenever he passes over the Sun. An Opportunity of this Kind will happen on *Nov*. 9, 1769. The Ingress will happen at 7h. 40m. and the Egress at 12h. 32m. apparent Time by the Meridian of *Greenwich*. This Transit will be principally visible in *America*.

The 5th, 6th and 7th Methods are peculiarly adapted for the Use of those Astronomers who shall observe the ensuing Transit of Venus in high Northern Latitudes ; as they may be observed with proper Instruments, notwithstanding the perpetual Day which will then reign at those Places, and which will deprive them of the benefit of almost ever other celestial Phenomenon. It may be proper to remark, that in the Use of the 6th Method it will often happen that the Altitude of the Moon's upper Limb must be taken on One Side of the meridian, and the Altitude of her lower Limb on the other Side ; but the Quadrant must be set to the same Altitude for both Observations.

Those who propose to observe the ensuing Transit of Venus over the Sun will do well to make themselves expert in the Use of all their Instruments, as applied to all the different Kinds of Observation, before the Transit happens ; and, if they have not been much versed in Astronomical Calculations, they need not be solicitous to reduce their Observations of the Transit and other Phænomena to Time, but had better send their original Observations, with all their Circumstances, to the Royal Society or some learned and skillful Astronomer, who may afterwards deduce the proper Circumstances from them, at Leisure. Two general Tables are here added, taken from Mr. *Lalande*'s Astronomy, for computing the Equation of corresponding Altitudes to any Latitude. The Use of them is as follows :

On account of the Sun's Change of Declination, the middle Time between the equal Altitudes of the Sun observed in the Morning and in the Afternoon is not the true Time of Noon, except on the Days of the Two Solstices, and is therefore to be corrected by an Equation, commonly called by the Title of that of Corresponding Altitudes, which is here given by the Sum or Difference of the Two Tables. Subtract the Time shewn by the Clock at the Altitude observed in the Morning, from that shewn by the Clock at the Altitude observed in the Afternoon, increased by 12 Hours, and you will have the Interval between the Observations according to the Clock ; take its Half, add it to the observed Time of the Altitude in the Morning, and you will have the Time of Noon by the Clock, but uncorrect. Then enter the First Table, or Part I. of the general Equation with the Sun's Longitude at Noon on the Side, and Half the Interval of the Observations at the Top of the Table, and take out the Number which stands at the common Meeting of the horizontal and vertical Lines (making a proportion, if necessary) and note whether it is additive or subtractive. In like manner take a Number out of the Second Table, or Part II. of the general Equation, which multiply by the natural Tangent of the Latitude (to the Radius Unity) and note whether it is additive or subtractive by the Table, which is suited to a Northern Latitude ; but if the latitude be South, for subtract read add, and for add read subtract : Lastly, If the Two Numbers thus found are both of the same Kind, viz. both additive or both subtractive, take their Sum, and apply it with the common Title or Sign to the Time of Noon uncorrect ; but if the Numbers are of different Kinds, viz. one additive and the other subtractive, take the Difference, and apply it with the Sign of the greater of the Two to the Time of Noon uncorrect, and you will have the true Time of Noon by the Clock, or the Time shewn by the Clock at the Instant of the Sun's passing the Meridian.

EXAMPLE.

Suppose that equal Altitudes of the Sun's upper Limb should be taken on 3d of June 1769, in Latitude 58° 56' N. and in Longitude 6h. 19m. 40s. to the West of *Greenwich*, at 8h. 14m. 8s. in the Morning, and 3h. 42m. 38s. in the Afternoon by the Time of a Clock ; let it be required to find the Time of Noon by the Clock. To 3h. 42m. 38s. add 12h. and from the Sum subtract 8h. 14m. 8s. the remainder is 7h. 28m. 30s. and its

Half, 3h. 44m. 15s. is Half the Interval between the Observations, which added to 8h. 14m. 8s. gives 11h. 58m. 23s. for the Time of Noon uncorrect. The Sun's Longitude at Noon at the given Place, or at 6h. 19m. 40s. after Noon at *Greenwich*, will be 2*. 13° 18' with which and the Half Interval, 3h. 44m. 15s. you will find by the First Table the Number +1,20s. or additive, and by the Second Table —5,31s. but this latter Quantity is to be multiplied by the Tangent of the latitude 58° 56' or by 1,66 whence the Number deduced from the Second Table is —8,81 or subtractive. The Difference of 1,20" and 8,81 because one is additive and the other subtractive is —6,61 or subtractive for the Equation of the corresponding Altitudes, because the subtractive Quantity is the greatest ; therefore 6,61 subtracted from 11h. 58'. 23" leaves 11h. 58m. 16,4s. for the true Time of Noon. If the latitude be supposed 58° 56' South, instead of North, and the Half Interval between the

Observations 2h. 20m. the First Part of the Equation would be +1.60 or additive, and the Second Part, as taken out of the Table —4,81 or subtractive, which multiplied by 1,66 the Tangent of the Latitude, and changing the Sign, because the latitude is South, becomes +7,98s. or additive, as well as the First Part ; therefore the Sum of the Two, viz. 1.60s. equal to +9,58 is the Equation of corresponding Altitudes to be added to the middle Time between the Observations.

A General TABLE of the Equation of sorresponding Altitudes.

PART I.

Half the Interval between the Observations

Longit	☉	1h. 40'.	2h. 0'	2h. 20'	2h. 40'	3h. 0'	3h. 20'	3h. 40'	4h.0'
O	0	0" 00	0" 00	0" 00	0" 00	0" 00	0" 00	0" 00	0" 00
add	10	0.96	0.93	0.89	0.85	0.80	0.75	0.69	0.62
add	20	1.89	1.76	1.69	1.61	1.53	1.43	1.30	1.17
I	0	2.49	2.41	2.32	2.21	2.09	1.95	1.76	1.61
subtr.	10	2.90	2.81	2.70	2.58	2.43	2.27	2.08	1.87
subtr.	20	2.97	2.88	2.77	2.64	2.49	2.32	2.13	1.92
II	0	2.68	2.59	2.50	2.38	2.25	2.09	1.92	1.73
add	10	2.02	1.96	1.89	1.80	1.70	1.58	1.45	1.31
add	20	1.10	1.06	1.02	0.97	0.92	0.86	0.79	0.71
III	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
subtr.	10	1.10	1.06	1.02	0.97	0.92	0.86	0.79	0.71
subtr.	20	2.02	1.96	1.88	1.79	1.70	1.58	1.45	1.31
IV	0	2.66	2.58	2.48	2.37	2.24	2.08	1.91	1.72
add	10	2.94	2.85	2.74	2.62	2.47	2.30	2.11	1.90
add	20	2.87	2.78	2.68	2.56	2.41	2.25	2.06	1.86
V	0	2.47	2.40	2.31	2.20	2.08	1.94	1.78	1.60
subtr.	10	1.81	1.75	1.68	1.60	1.52	1.32	1.29	1.16
subtr.	20	0.95	0.92	0.89	0.85	0.80	0.74	0.68	0.61
VI	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
add	10	0.96	0.93	0.89	0.85	0.80	0.75	0.69	0.62
add	20	1.84	1.78	1.72	1.65	1.56	1.46	1.24	1.20
VII	0	2.55	2.47	2.38	2.27	2.14	2.00	1.83	1.65
subtr.	10	3.00	2.91	2.80	2.67	2.52	2.35	2.15	1.94
subtr.	20	3.10	3.01	2.89	2.76	2.61	2.43	2.23	2.01
VIII	0	2.83	2.74	2.64	2.52	2.38	2.21	2.03	1.83
add	10	2.15	2.08	2.00	1.91	1.80	1.68	1.54	1.39
add	20	1.17	1.13	1.09	1.04	0.98	0.91	0.84	0.75
IX	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
subtr.	10	1.07	1.13	1.09	1.04	0.98	0.91	0.84	0.75
subtr.	20	2.15	2.09	2.01	1.92	1.81	1.69	1.55	1.39
X	0	2.84	2.76	2.64	2.56	2.39	2.22	2.04	1.84
add	10	3.13	3.03	2.91	2.78	2.62	2.45	2.25	2.02
add	20	3.02	2.93	2.82	2.69	2.54	2.37	2.16	1.95
XI	0	2.57	2.49	2.40	2.29	2.16	2.01	1.85	1.66
subtr.	10	1.86	1.80	1.73	1.65	1.56	1.46	1.33	1.20
subtr.	20	0.97	0.94	0.90	0.86	0.81	0.76	0.69	0.63

A General TABLE of the Equation of sorresponding Altitudes.									
PART II.									
Half the Interval between the Observations									
Longit	⊙	1h. 40'.	2h. 0'	2h. 20'	2h. 40'	3h. 0'	3h. 20'	3h. 40'	4h.0'
O	0	15" 53	15" 78	16" 09	16" 37	16" 74	17" 17	17" 66	18" 23
subtr.	10	15.25	15.50	15.80	16.08	16.44	16.86	17.35	17.91
subtr.	20	14.56	14.80	15.09	15.35	15.70	16.10	16.56	17.10
I	0	13.49	13.71	13.97	14.22	14.54	14.91	15.34	15.83
subtr.	10	12.03	12.23	12.47	12.69	12.97	13.30	13.69	14.13
subtr.	20	10.20	10.37	10.57	10.76	11.00	11.28	11.61	11.98
II	0	8.02	8.15	8.31	8.45	8.64	8.86	9.12	9.41
subtr.	10	5.53	5.62	5.73	5.83	5.96	6.12	6.29	6.50
subtr.	20	2.82	2.87	2.93	2.98	3.05	3.12	3.21	3.32
III	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
add	10	2.82	2.87	2.92	2.97	3.04	3.12	3.21	3.31
add	20	5.51	5.60	5.71	5.81	5.95	6.10	6.27	6.48
IV	0	7.98	8.11	8.27	8.41	8.60	8.82	9.08	9.37
add	10	10.11	10.28	10.48	10.66	10.90	11.18	11.51	11.88
add	20	11.94	12.17	12.37	12.59	12.87	13.20	13.58	14.02
V	0	13.37	13.59	13.85	14.10	14.41	14.78	15.21	15.70
add	10	14.42	14.66	14.94	15.20	15.55	15.94	16.41	16.93
add	20	15.09	15.34	15.64	15.92	16.27	16.69	17.17	17.72
VI	0	15.37	15.63	15.93	16.21	16.58	17.00	17.49	18.05
add	10	15.26	15.52	15.81	16.09	16.46	16.87	17.36	17.92
add	20	14.75	15.00	15.29	15.56	15.91	16.31	16.78	17.32
VII	0	13.82	14.05	14.32	14.57	14.90	15.28	15.74	16.23
add	10	12.46	12.66	12.91	13.14	13.43	13.78	14.17	14.63
add	20	10.76	10.84	11.05	11.25	11.50	11.80	12.14	12.53
VIII	0	8.46	8.59	8.76	8.91	9.12	9.35	9.62	9.93
add	10	5.87	5.83	6.08	6.19	6.33	6.49	6.63	6.89
add	20	3.01	3.06	3.12	3.18	3.25	3.33	3.43	3.54
IX	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
subtr.	10	3.02	3.07	3.13	3.18	3.25	3.34	3.43	3.54
subtr.	20	5.89	6.00	6.10	6.36	6.50	6.67	6.86	6.92
X	0	8.42	8.64	8.80	8.96	9.16	9.39	9.67	9.98
subtr.	10	10.74	10.91	11.12	11.32	11.58	11.90	12.21	12.61
subtr.	20	12.56	12.77	13.01	13.24	13.54	13.88	14.29	14.74
XI	0	13.94	14.17	14.45	14.70	15.03	15.41	15.86	16.37
subtr.	10	14.90	15.14	15.43	15.71	16.06	16.47	16.94	17.48
subtr.	20	15.37	15.63	15.93	16.21	16.57	17.00	17.49	18.05

Apparent Times of the external and internal Contacts of VENUS with the Sun's Limb at several Places, as they may be expected to happen on 3d June 1769

	1st Ext Contact	1st Int Contact	2d Int Contact	2d Ext Contact	Latitude	Supposed Longitude from Greenwich
	h. m.	h. m.	h. m.	h. m.		h. m. s.
Greenwich	7 6	7 25	——	——	51 29 N	0 0
Edinburg	6 53	7 12	——	——	55 58 N	0 13 13 W
Dublin	6 41	7 0	——	——	53 20 N	0 24 54 W
Tornea	8 43	9 2	14 56	15 15	65 51 N	1 36 48 E
Kittis	8 43	9 2	14 56	15 15	66 48 N	1 36 48 E
Attengaard	8 39	8 58	14 51	15 10	69 59 N	1 32 27 E
Wardhus	9 12	9 31	15 24	15 43	70 35 N	2 5 36 E
North Cape	8 51	9 10	15 3	15 27	71 23 N	1 44 48 E
Bear Island	8 12	8 31	14 24	14 43	74 32 N	1 5 36 E
Spitzbergen, Bell Sound	7 57	8 16	14 8	14 27	77 15 N	0 51 2 E
Peterberg	——	——	15 21	15 40	59 56 N	2 1 20 E
Tobolski	——	——	17 53	18 12	58 12 N	4 32 51 E
St John's, Newfoundland	3 40	3 59	——	——	47 32 N	3 31 13 W
Quebec	2 29	2 48	——	——	46 55 N	4 39 36 W
Hudson's Bay	0 49	1 8	6 54	7 13	58 56 N	6 19 40 W
Boston	2 26	2 45	——	——	42 25 N	4 42 29 W
Williamsberg	2 3	2 22	——	——	37 20 N	5 6 20 W
Jamaica, Port Royal	2 4	2 23	——	——	18 0 N	5 7 2 W
Mexico	0 19	0 38	6 14	6 33	20 0 N	6 54 40 W
Cape Corientes	13 * 48	0 6	5 44	6 3	20 50 N	7 25 40 W
Cape St. Lucar	23 * 31	23 * 50	5 28	5 47	23 15 N	7 41 40 W
Cape Conception	22 * 34	22 * 53	4 33	4 52	35 30 N	8 37 40 W
Fernambuca, Brazil	4 50	5 9	——	——	8 13 S	2 20 8 W
Conception, Chili	2 24	2 43	——	——	36 43 S	4 50 44 W
Bombay	——	——	18 9	18 28	19 18 N	4 47 48 E
Madras	——	——	18 41	19 0	13 13 N	5 20 9 E
Calcutta	——	——	19 14	19 33	22 30 N	5 53 43 E

N. B. The Contacts marked with Asterisks belong to the 2nd Day of June 1769 according to Astronomical Time.

ECLIPSES of the First Satellite of Jupiter, which will happen in the First Nine Months of the Year 1769, according to apparent Time by the Meridian of the Royal Observatory at Greenwich.

N.B. Those marked with an Asterisk will be visible at Greenwich

	January		March		May		July		September
	Immers.		Immers.		Immers.		Emersion		Immers.
	h ' "		h ' "		h ' "		h ' "		h ' "
1	19 17 18	1	4 43 8	2	3 34 20	1	9* 50 18	1	8 41 11
3	13 44 49	2	23 11 52	3	22 3 5	3	4 18 44	3	3 10 31
5	8 12 21	4	17 40 58	5	19* 31 47	4	22 47 11	4	21 39 51
7	2 39 54	6	12 9 27	7	11* 0 27	6	17 15 40	6	16 9 12
8	11 7 28	8	6 38 17		Emersion	8	11* 44 11	8	10 38 33
10	15* 35 3	10	1 7 9	9	7 36 50	10	6 12 43	10	5 7 53
12	10 2 38	11	19 36 1	11	2 5 31	12	0 41 16	11	23 37 13
14	4 30 16	13	14* 4 54	12	20 34 12	13	19 9 50	13	18 6 33
15	22 57 57	15	8 33 47	14	15* 2 51	15	13 38 26	15	12 35 52
17	17* 25 41	17	3 2 41	16	9* 31 29	17	8 7 5	17	7* 5 11
19	11 53 27	18	21 31 35	18	4 0 5	19	2 35 46	19	1 34 31
21	6 21 15	20	16* 0 30	19	22 28 40	20	21 4 29	20	20 3 50
23	0 49 5	22	10 29 25	21	16 57 12	22	15 33 13	22	14 33 9
24	19 16 57	24	4 58 20	23	11* 25 42	24	10* 1 58	24	9 2 28
26	13 44 51	25	23 27 16	25	5 54 10	26	4 30 44	26	3 31 46
28	8 12 48	27	17* 56 13	27	0 22 36	27	22 59 31	27	22 1 3
30	2 40 49	29	12* 25 11	28	18 51 3	29	17 28 20	29	16 30 18
31	21 8 53	31	6 54 10	30	13* 19 30	31	11 57 10		
	February		April		June		August		
	Immers.		Immers.		Emersion		Emersion		
2	15* 37 0	2	1 23 8	1	7 47 57	2	6 26 2		
4	10 5 8	3	19 52 5	3	2 16 23	4	0 54 55		
6	4 33 18	5	14* 21 1	4	20 44 47	5	19 23 50		
7	23 1 30	7	8 49 57	6	15 13 9	7	13 52 47		
9	17* 29 44	9	3 48 53	8	9* 41 30	9	8* 21 46		
11	11 58 1	10	21 47 49	10	4 9 51	11	2 50 48		
13	6 26 31	12	16* 16 44	11	22 38 12	12	21 19 52		
15	0 54 44	14	10* 45 41	13	17 6 33	14	15 48 59		
16	19 23 10	16	5 14 36	15	11* 34 55	16	10 18 8		
18	13* 51 37	17	23 43 30	17	6 3 16	18	4 47 19		
20	8 20 6	19	18 12 23	19	0 30 37	19	23 16 30		
22	2 48 38	21	12* 41 15	20	18 58 58	21	17 45 42		
23	21 17 12	13	7 10 7	22	* 27 1913	23	12 14 54		
25	15* 45 48	25	1 38 59	24	7 56 41	25	7 44 7		
27	10 14 27	26	20 7 51	26	2 25 4	27	1 13 20		
		28	14* 36 43	27	20 53 28	28	19 42 35		
		30	9* 5 33	29	15 21 53	30	14 11 52		