GREENWICH

ASTRONOMICAL OBSERVATIONS,

1853.

INTRODUCTION.

I. *Personal Establishment and Arrangements.*

AT the commencement of the year 1853, the establishment of Assistants in the Astronomical department of the Observatory consisted of the following persons:—The Rev. Robert Main, M.A., First Assistant; Mr. John Henry, Mr. William Rogerson, Mr. Edwin Dunkin, Mr. Hugh Breen, and Mr. John Charles Henderson.

Mr. William Rogerson died on April 26, and was, after a short interval, succeeded by Mr. William Ellis, previously observer at the Durham Observatory. No other important change took place during the year 1853.

The duties of the establishment are distributed in the following manner:—

Mr. Main, in the absence of the Astronomer Royal, is empowered to act in all respects as his representative, and to conduct confidential as well as routine business. In the ordinary transactions, Mr. Main superintends the calculations generally, and observes, occasionally, with any of the instruments; principally, however, with those which are not employed in the daily routine of meridional observations. The observations made by Mr. Main are distinguished by the signature M.

Mr. Henry has the general charge of the Transit-Circle, with which the meridian observations have been made during the year 1853. Mr. Dunkin has the superintendence of the Altazimuth, which is specially devoted to extrameridional observations of the Moon. The observations with both these Instruments have been generally made by Mr. Henry, Mr. Rogerson or Mr. W. Ellis, Mr. Dunkin, and Mr. Henderson: Mr. Breen having occasionally observed with the Transit-Circle near the time of Lunar conjunction, or at other times when the Moon was not to be observed on the meridian during his watch. The signatures of these observers are,— H., D., R., E., J.H., and H.B. Other persons who have occasionally observed with the Instruments above-mentioned are:—Mr. John William Breen, Mr. George Criswick, and Mr. Frank Taylor, all employed as computers to the establishment; their signatures are J.B., C., and F.T. In addition to the persons connected with the establishment, Mr. Todd, Assistant at the Cambridge Observatory, observed transits on May 18, and M. Bouvy, Assistant at the Observatory of Brussels, observed transits from November 27 to December 4, in connexion with the operations for determining respectively the longitudes of the Observatories of Cambridge and Brussels. Professor C. Piazzi Smyth also observed transits on August 17, for the purpose of determining his personal equation relatively to the Greenwich observers.

The duties relating to the receiving, issuing, and rating of Chronometers, the raising of the Signal Ball in preparation for its fall at 1 o'clock, and the computations belonging to the same, are performed by Mr. Henry and Mr. Rogerson or Mr. Ellis.

With regard to the reduction of the observations, Mr. Breen is placed in immediate superintendance of the staff of extra computers usually employed, and exercises a general supervision of all computations performed, and of the passing of the results through the press. Mr. Henry attends chiefly to the reduction of the Zenith-Distance observations made with the Transit-Circle, and Mr. Henderson to that of the Transit observations, while Mr. Dunkin attends exclusively to the reductions of the Altazimuth observations, and to the reading of the proof-sheets of those observations when printed. The observations relating to the determination of Micrometer values, intervals of wires, flexure, errors of division, &c., of the Transit-Circle or Altazimuth, are usually made by Mr. Dunkin.

The observations with the Equatoreals are not distinctly appropriated to any special observers.

The whole of these works are under the immediate direction of the Astronomer Royal, who is responsible for every part.

Correspondence relating to the affairs of the Observatory, not transacted by the Astronomer Royal himself, is managed by the First Assistant, but only at the command of the Astronomer Royal.

The course of observations and the succession of observers are arranged every Monday by the Astronomer Royal. In general, the Assistant who makes the observations with the Transit-Circle is charged with all the observations that may occur from 15^{h} mean time (3 o'clock in the morning) to the next 15^{h}; and it is established as a rule, to be adhered to as closely as circumstances permit, that no Assistant be occupied on two successive days with astronomical observations. And it is always arranged, if possible, when the Moon's time of transit passes 15^{h}, that the same Assistant should not be required to observe the Moon and accompanying stars late in the night when the Moon passes last before 15^{h}, and early in the morning when the Moon passes first after 15^{h}.

For many particulars relating to the internal constitution of the Observatory, reference may be made to the "Regulations of the Royal Observatory" forming Appendix II. to the Greenwich Observations, 1852.

II. *Instruments.*

The principal Instruments used by Halley, Bradley, Bliss, and Maskelyne are still preserved in the Royal Observatory: namely, Halley's Transit, with pivots unequally distant from the Telescope; Bradley's Transit; the Zenith Sector of Bradley and Maskelyne; and the two Mural Quadrants, mounted on their pier; the Quadrant on the Western side of the pier being now included in the safe or fire-proof room of the Observatory. The ancient instruments first mentioned, together with the Telescopes for investigating the parallaxes of α Aquilæ and α Cygni, formerly attached respectively to the West side of the pier of Troughton's Mural Circle, and to the Quadrant pier, are now with proper labels suspended on brackets on the Western wall of the Transit-Circle Room.

Troughton's Transit Instrument and Mural Circle, used to the end of the year 1850, were dismounted in the year 1851, and are suspended, the one on the West and the other on the East wall of the Transit-Circle Room. The object-glass of the Transit Instrument is now inserted in the Reflex Zenith Tube.

The 25-feet Zenith Sector was dismounted, and its tube was divided (at its joints) into several parts, in May 1848; and the separate portions of the instrument are preserved in frames constructed to hold them, in the Octagon Room. The object-glass, as will shortly be mentioned, has been removed from the tube, to be used for the Collimator of the Altazimuth.

Jones's Cape Circle was transferred in November 1851 to the Observatory of Queen's College, Belfast.

The Instruments now in use are the following:—

The Great Transit-Circle, constructed by Messrs. Ransomes and May, as engineers, and by Mr. Simms, as optician, erected in the year 1850.

A detailed description of this instrument, illustrated by Plates, is given in Appendix I. of the volume for 1852. The following particulars may be given here. The center of the instrument is about $7\frac{1}{2}$ feet South and 19 feet East of the old transit-instrument. The length of the telescope of this instrument is nearly 12 feet, and the clear aperture of the object-glass is about 8 inches. The length of the axis between the extremities of the pivots is 6 feet. The axis of the instrument is of cast iron, in two similar pieces: each half includes half the central cube, one cone, and the pivot which terminates it. The mould of the pivot was made of iron, for the purpose of hardening it by the process technically called *chilling;* the moulds for the other parts were sand. The two halves are connected by bolts through flanges at the junction-plane in the middle of the cube. The two portions of the telescope tube (also of cast iron, with the exception of the object-glass cell and the eyepiece work) are bolted on the cube. The diameter of each pivot is 6 inches. For examination of the form of the pivots, each is perforated; within the hollow of the eastern pivot there is fixed a plate of metal perforated with a very small hole, behind which a light can be placed for illumination; and in the hollow of the western pivot there is fixed an object-glass at a distance from the perforated plate equal to its focal length. This combination forms a collimator revolving with the instrument. It is viewed by a telescope of 7 feet focal length, which, when required, is placed on Y's, one of them planted in the opening of the western pier, and the other in a hole made for that purpose in the western wall of the room. By a series of most careful observations in the autumn of 1850, and again in 1851 and 1852, no appreciable error could be discovered in the form of the pivots. The wire frame contains (besides the horizontal wire, to be noticed shortly) seven vertical wires; the whole frame and whole system of vertical wires are moved by a micrometer screw, whose graduated head is locked up in a small box attached to the eyepiece, to prevent inadvertent disturbance of the micrometer after it has been set to the reading which is adopted for the line of collimation. The micrometer head is on the eastern side of the eyepiece, and the readings increase as the wire is moved towards the micrometer head.

For determining the error of collimation, two horizontal telescopes of about 5 feet focal length and nearly 4 inches aperture, with their object-glasses turned towards the center of the instrument, are mounted on Y's which are carried by massive brick piers, one on the north and one on the south side of the transit-circle. The height of the axes of these telescopes is as nearly as possible the same as that of the axis of the transit-circle. Each telescope is furnished with wires in its principal focus, to be used as collimating marks; and each telescope may be used as a collimator for the other, or for the transit-circle-telescope. The system of wires is the same in both, consisting of two parallel wires inclined to the vertical at an angle of about $2\frac{3}{4}^{\circ}$, two other parallel wires at right angles to the former, and therefore inclined to the horizontal line at the same angle (the intersection of this pair with the former producing a square), and a fifth wire parallel to the two last mentioned, and at a distance from the nearest of about ten times the side of the square. The middle of the portion of the fifth wire, which is included by the two nearly vertical wires, is in the same vertical with the middle of one of the nearly vertical sides of the square; and these middle points are the points adopted for observation. Those wires are finer than the others. For adjustment of these North and South Collimators accurately on each other, the plates carrying the wires are moveable by micrometer-screws: that of the North Collimator in altitude only, and that of the South Collimator in azimuth only. Each micrometer head, when not in use, is locked up in a box attached to the eyepiece. In order to view either collimator by the transit-circle-telescope, it is only necessary to direct the transit-circle-telescope towards that collimator; but in order to view one collimator with the other, it is necessary to raise the transit-circle so far that there shall be no impediment to a direct view. A mechanical apparatus is provided for the express purpose of sufficiently raising the transit-circle.

The process of adjusting the Collimators, and of using them for determining the line of collimation of the Transit-Circle-Telescope, is then as follows :—

On Monday of each week, the transit-circle is raised, and, a proper illumination being given to the North Collimator, the eye is applied to the eyepiece of the South Collimator, and the systems of wires in both are distinctly seen: the nearly vertical lines of one being inclined about $5\frac{1}{2}°$ to those of the other. By means of the micrometer screw, the middle of the nearly vertical side of the square of one is made to coincide with that of the other, and the micrometer-reading is taken. This operation is usually repeated six times, and, the mean of all the readings being found, the micrometer is left in the position indicated by that mean. The geometrical line in each telescope, passing through the focal center of its object-glass and through the adopted point of the delicate wire, being considered as the axis of the telescope: it is plain that the axes of the two telescopes are in the same line, or at least are strictly parallel to each other: and, therefore, when the transit telescope is employed to view the two collimators, the images of the adopted points of their wires will in all respects represent two objects at infinite distance and exactly opposed to each other.

The observation for collimation of the transit telescope is then made by bringing, by means of its micrometer, the central vertical wire several times in succession upon the proper point of the nearly vertical fine wire of the North Collimator, and several times upon the corresponding point of the South Collimator, and reading the micrometer for each coincidence. The mean of the readings for the North and South Collimators gives the reading for the position of the line of collimation.

The observation admits of extreme accuracy, since the eye can judge with great delicacy of the equality of the two acute-angled triangles formed by the central transit wire and the collimator-wires in the process of observation.

Tables of the weekly micrometer-readings of the South Collimator-wire for coincidence with North Collimator-wire, and of the daily readings of the Transit-Micrometer for coincidence with Collimators, are given at the end of the Transit observations.

The instrument is not well adapted to the application of a spirit level or other contrivance for determining the difference of level of the surfaces of the pivots. The error of level is ascertained by the use of a Bohnenberger's eyepiece with three lenses and glass reflector; a trough of quicksilver being placed below, the image of the central wire is seen by reflection at the same time as the wire itself: by means of the micrometer-screws the images are made to coincide or to touch alternately on the two sides: the mean of the micrometer readings is taken; and the difference between the mean reading and the reading corresponding to the line of collimation is the error of level. This process is perhaps in every case preferable to the use of a spirit level.

The graduated vertical circle for zenith distance observations is fixed on the cylindrical basis of the axis-cone on the west side of the central cube. It is of cast iron, 6 feet in diameter, and has two sets of divisions: the one set, on its western side, cut upon a band of silver, which is let into a dished or flat internal conical surface, is accurately divided to five-minute spaces, and is read by the microscopes; the other set, on its eastern side, is roughly divided by points to every 5′, and is intended for setting the telescope to any object by means of two pointers reading respectively North Polar Distances and Zenith Distances. The reading microscopes, six in number, are simply inclined perforations through the pier, having their eyepieces at the back of the western pier arranged in a circle whose center is 5 feet 2 inches above the floor, and diameter about 21 inches, and their object-glasses on the other or eastern side of the pier, arranged in a circle of about 5 feet in diameter, pointing to the divisions of the circle. The pointer-microscope is between the two lowest reading-microscopes, and is a similar inclined perforation through the pier: it has a large field of view and is furnished with a single wire parallel to the divisions of the limb at which it is pointed. The divisions under the microscopes are illuminated by means of a central gas-light at the central opening at the back of the pier, which throws light upon the proper divisions through six illuminating holes corresponding to the six microscopes, and this light is reflected from the divided limb accurately into the microscopes without any need of illuminating-reflectors.

The circle is completely shielded from the Sun by the steps which are used for ascending to the upper part of the pier.

The eyepiece of the telescope contains only one horizontal wire, moveable by a micrometer, with which all observations of zenith distance are made. For every observation, therefore, it is necessary to combine the value of the micrometer-reading with that of the readings of the microscope-micrometers. When the telescope points vertically upwards, the head of the micrometer is on the north side; and the micrometer readings increase as the wire is moved towards the head.

The reading (consisting of the combination of microscope readings and telescope-micrometer reading), corresponding to the nadir position of the telescope, is found by the use of the Bohnenberger's eyepiece and the trough of mercury; the direct and reflected images of the horizontal wire being made to coincide or to touch alternately on the two sides, and the mean of the readings of the micrometer being taken.

The shutters of the Transit-Circle Room leave an opening of 3 feet in width. The north and south wall shutters are each in one piece; the opening in the roof, along the ridge, 36 feet in length, is covered by four shutters.

Other explanations necessary for the understanding of the process of reduction of the observations will be given under the proper heads.

The Altazimuth, constructed by Messrs. Ransomes and May (as engineers), and by Mr. Simms (as instrument-maker and optician), and erected in 1847.

This instrument is mounted in a tower (now called the South Dome), which is built on the walls of what was formerly called the Advanced Building (the same in which

Flamsteed's Mural Arc and Equatoreal Sector were mounted), and is raised to such a height that the instrument commands the horizon in all directions above the buildings of the Observatory, except the East Dome and the Octagon Room. Its center is about 28 feet West and 32 feet South of the old Transit Instrument, and about 47 feet West and 24½ feet South of the new Transit-Circle. Within the Tower is built a three-rayed pier, the rays being carried up nearly to the floor of the Dome, and a central cylindrical mass, 3 feet in diameter, being carried through the floor. Upon this cylindrical mass is planted the Azimuthal Circle, upon which the lower pivot for azimuthal rotation rests. For the support of the upper pivot, a horizontal iron triangle is carried by the three-rayed pier; on each side of this there is mounted a vertical iron triangle; and the three vertices of these are connected by an upper horizontal iron triangle: three radial iron bars, supported on its angles, carry, at their point of union, the Y in which the upper pivot of the vertical axis turns. The frame revolving in azimuth consists of a top and bottom connected by two vertical cheeks, all of cast iron: the microscopes for viewing the divisions of the horizontal circle are cast in the same flow of metal with the bottom piece, and those for viewing the divisions of the vertical circle are cast in the same flow with one of the vertical cheeks. The vertical circle and telescope are of gun-metal; the side of the circle which carries the graduated limb, the ends of the telescope, and one of the pivots, being cast in one flow; and the other side of the circle with its pivot being cast in another flow. The diameters of both circles (horizontal and vertical) are 3 feet; the length of the telescope is 5 feet; the aperture of its object-glass 3¾ inches. The top carries two levels and the bottom carries two levels, parallel to the axis of the vertical circle: the vertical cheek which carries the microscopes carries also two levels parallel to the plane of the vertical circle. No important parts are connected by small screws; and no part whatever admits of adjustment; except that the coarse screws on the ends of the upper radial bars are sometimes touched, to bring the vertical axis to a position conveniently near to exact verticality.

For a detailed account of this Instrument, illustrated by engravings, and for a description of the processes gone through in its adjustment, I refer to the Volume of Astronomical Observations for 1847.

It was intended, in the original plan of observations with this instrument, to determine the zero of azimuth of the horizontal circle, for each day or group of days, solely by the observations of stars in azimuth. The individual results obtained by this method were discordant, and I thought it desirable therefore in the spring of 1850 to establish a fixed mark of reference. No distant terrestrial object can be seen with the Altazimuth, and I therefore mounted (what is very much more convenient and more generally useful, especially at night,) a collimator. The object-glass for the collimator is the object-glass of 5 inches aperture and 24 feet 6 inches focal length, which was formerly used for the 25-feet Zenith Sector. It is planted in the north wall of the tower of the South Dome; a brass tube about 1 foot long is fixed by Roman cement in the wall, and the object-glass cell is screwed to a flat bearing upon a ring within the tube; a small penthouse on the outside of the wall protects it from rain. The mark is the image of a small circular hole, as formed by a lens of short focus. The hole is a perforation $\frac{1}{50}$ inch in diameter, in a small circular piece of metal fixed in a larger circular piece of ivory which is attached to an opaque plate. At the distance of about 7 inches from this perforation is a lens of 1-inch focal length: and the image of the perforation therefore has a diameter of about $\frac{1}{300}$ inch; this image is in the focus of the $24\frac{1}{2}$-feet object-glass, and is in fact the mark viewed with the telescope of the Altazimuth. The perforated plate and the lens are carried by a very strong brass tube about an inch in diameter (a piece cut from the tubular standard of the Royal Astronomical Society), and this is fixed by strong iron thumb-screws into an iron frame which is strongly bolted to the west side of the west wall of the Computing Room. The iron frame is in fact higher than the ceiling of the Computing Room; but is below the ridge of the roof of the Passage Room (part of the ancient Quadrant Room). The mounting of the mark is thus entirely protected from the Sun and from the weather: and although the separation of the mark and the collimator object-glass on two unconnected buildings is not unobjectionable, yet the other circumstances of mounting are here as favourable as it is possible to find. The perforation is illuminated by a small gas-light: and its image as viewed through the telescope of the Altazimuth then appears as a very well-defined round point, admitting of most accurate bisection by a wire either in the horizontal or in the vertical direction, surrounded at a little distance by a fainter ring of light. For viewing this mark, the telescope of the Altazimuth is pointed downwards at an inclination of 12°. 18′ below the horizon.

The 5-feet Equatoreal, constructed by Ramsden.

This instrument was the property of Sir George Shuckburgh, and is fully described by him in the Philosophical Transactions for 1793. It was presented to the Observatory in the year 1811. It was intended to be mounted in what is now called the East Dome, as an Altitude and Azimuth Instrument; but its mounting (similar to that of the Palermo Circle) was found so unsteady that it was never once used; and it was then mounted as an Equatoreal in the North Dome (formerly called the North-Eastern Dome), where it has since remained. The situation of this dome is most unfavourable, as the whole South-Western sky to the altitude of 35°, and a considerable extent to the altitude of 53°, is concealed by the Octagon Room. The position of the instrument is about 52 feet West and 90 feet North of the old Transit Instrument, or 71 feet West and $97\frac{1}{2}$ feet North of the new Transit-Circle. This Equatoreal is one of that class in which the two pivots of the polar axis are at the two extremities of the polar axis, and the two pivots of the declination-axis are at the two extremities of the declination-axis: the telescope and declination-circle being between the pivots of the declination-axis, and the declination-axis being within the frame of the polar axis, and the complete polar axis and hour-circle being between the polar supports. The whole length of the polar axis, between the extremities of the pivots, is about 9 feet. These pivots turn in Y's (having proper adjustments), which are carried by two piers on opposite sides of the Dome. The North pivot is at the center of a circular frame; the South pivot is at the apex of a cone; and the polar frame consists of six pillars, connecting the base of this cone with the circular frame. Three pillars are united by intervening bars to form the Eastern side of the polar frame, and three to form the Western side: they carry the Y's for the declination-axis and the microscopes for reading the declination-circle. The length of the declination-axis between the extremities of its pivots is about 2 feet 2 inches; the diameter of the declination-circle is 4 feet, and the circle is divided to 5′ of arc. The telescope is 5 feet 4 inches in length, and has an object-glass of 4·1 inches aperture. The hour-circle is connected with the cone; its diameter is 4 feet, and it is divided to 10′ of arc: these divisions are read by fixed micrometer-microscopes.

The Equatoreal in the Eastern Dome (formerly called the South or South-Eastern Dome).

This instrument was erected in the year 1838. The aperture of the object-glass is about 6·7 inches, and its focal length about 8 feet 2 inches. The object-glass was made by M. Cauchoix, of Paris, and was presented to the Observatory by the Rev. R. Sheepshanks. Its definition is good: a small quantity of colour from the secondary spectrum, and a diffusion of light from brilliant objects, being the principal defects. It is mounted in the Eastern Dome, 38 feet East and 6 feet South of the old Transit Instrument, or 19 feet East and 1½ feet North of the Transit-Circle, with a mounting similar in general form to that of the Dorpat Telescope. A stone pier is erected, whose extreme breadth from East to West is 1 foot 4 inches, and from North to South is 5 feet 4 inches: the southern part of the upper surface of this pier is sloped so that its plane produced passes through the celestial pole: upon the surface is fixed a cradle of cast iron, having the lower bearing of the polar axis in a projection from its lower end, and the upper bearing at its upper end: the distance between the two bearings is 3 feet 7 inches. The axis is of cast iron; its form is nearly conical: the end which rests in the lower bearing is a more obtuse cone. The diameter of the axis, where it turns in the upper bearing, is 6 inches: it rests here in a Y upon two plates of agate. At a small distance below the upper bearing, a strong circular plate, parallel to the equator, 14 inches in diameter, is fixed to the axis; and close above it, another plate of the same size is mounted, parallel to the former, turning freely round the axis; in that surface of each of these two plates which is nearest to the other plate, a dove-tailed groove is turned, and a moveable clamping-piece has one clamp in the groove of one plate, and the other clamp in the groove of the other plate. By means of this clamping-piece, the two circular plates can be fixed together at pleasure, in any relative position. The moveable circular plate is inseparably connected with a long flat arm, or sector, of 24 inches in length (measured from the circumference of the plate) in the plane of the equator: the edge of this sector is cut into teeth, in which works the endless screw carried by the clock, which is fixed to the North side of the pier. Therefore, if the clamping-piece above mentioned is not fixed to either plate, or is fixed to only one, the action of the clock-work upon the sector, though it turns the moveable circular plate, does not turn the fixed circular plate; but if the clamping piece is fixed to both plates, the action of the clock-work on the sector carries the moveable plate and the fixed plate (now connected with it), and therefore turns the polar axis, and the telescope, &c., which is supported by the polar axis. Between that part of the clamping-piece which is connected with the fixed plate, and that part which is connected with the moveable plate, there is a slow-motion screw, turned by means of a hook's joint and a long handle. Immediately above the upper bearing, the polar axis carries the hour-circle, 12 inches in diameter; it is divided on its edge to 1^{m} of time, and is read off to 2^{s} by two verniers. Above this, a square box is firmly fixed to the axis; perforated in one direction parallel to the equator for the insertion of the declination-axis. The diameter of the declination-axis at each of its two bearings is about four inches; it is supported at each by a Y. To one end of the declination-axis is fixed the cradle, carrying the telescope; to the other is fixed the declination-circle, and the counterpoise. The diameter of the declination-circle is 11 inches; it is divided on its edge to $15'$ of arc, and is read off to $30''$ by two verniers attached to the square box. The telescope-tube is of wood; its form is square in the middle, chamfered off towards the ends so as to become octagonal: several stops, or transversal plates with holes of the proper magnitude, are fixed in it; it is very firm and free from tremors. Upon a large ring which is fixed to the square box there turns with stiff friction another ring, carrying two sector arms, graduated at their extremities; these graduations are read by micrometer-microscopes, carried, one by the eye-end of the telescope-tube and one by the object-end: the use of this graduated double sector is, to measure small differences of declination (not exceeding $10°$) with great accuracy; as, being brought by the hand under the telescope, it is then retained in its position by friction, and is not affected by the motion of the telescope. Upon another ring, which is fixed to the square box, there turns a ring-clamp, or brake, that admits of being fastened to it in any position; with this ring-clamp the telescope-cradle is connected by means of a slow-motion screw, which fixes the telescope in declination, or gives the means of imparting to it a slow motion in declination. The speed of the clock is regulated by two balls, suspended to the ends of a horizontal arm of $4\frac{3}{4}$ inches in length, which is carried by a vertical spindle; when the velocity is so great as to cause the suspending-rods to make a certain angle with the vertical, small projections, carried by the balls, are thereby made to rub against the lower surface of a fixed horizontal ring, and the friction thus caused prevents the weight which urges the clock from increasing the velocity. This mounting was constructed by Mr. T. Grubb, of Dublin. Besides several negative eyepieces unfurnished with wires, this telescope has a wire micrometer, a comet-eyepiece with thick wires, and a double-image micrometer constructed on the principles explained in the Memoirs of the Royal Astronomical Society, vol. xv., page 199.

The Reflex Zenith Tube, constructed under my direction by Mr. Simms. In a future volume I propose to give a detailed account of this instrument; in this place the following account will suffice: The object-glass (formerly the object-glass of Troughton's Transit Instrument) is mounted upon a fixed tube, which is in a vertical position; upon this tube it can be turned in azimuth. To the cell of the object-glass is firmly fixed the micrometer frame, revolving with the object-glass when the object-glass is turned. The moving frame of the micrometer A carries the resting-point of the micrometer-screw of the micrometer B. The eye-piece is a 4-glass diagonal eye-piece, so placed that it can receive rays of light from the direction of the nadir, and can transmit them horizontally to the eye. The lens furthest from the eye, and the diagonal prism, are placed nearly over the center of the object-glass, carried by arms which are fixed to the large tube; the small tube carrying the remaining lenses of the eye-piece is supported by the large tube, and does not project over any part of the object-glass. At a distance below the object-glass, equal to half its focal length, is a trough of quicksilver. The image of the star, as it passes near to the zenith, is formed in the plane of the micrometer wires. These particulars will probably suffice for enabling the reader to understand the reductions. It will easily be seen that, for accuracy of result, no firmness of construction is requisite in this instrument, except in the connection between the micrometer and the object-glass.

Two detached telescopes, one of which is 46 inches in focal length, and the other 30 inches; the former is usually kept in the Transit-Circle Room, and the other in the Magnetic Observatory. The diameters of the object-glasses of these telescopes are 3·6 inches and 2·7 inches respectively. The telescope formerly belonging to the Western Equatoreal has also been mounted for use as a detached telescope; its focal length is 36 inches, and the aperture of its object-glass 3·6 inches. It is proper to mention that the object-glass of the 62-inch telescope mentioned in former years is now appropriated for the North Collimator to the Transit-Circle; and that of the transit instrument formerly used as a collimator to Troughton's transit, is now fixed in the South Collimator. The other achromatic telescope, mentioned in former years, has been given to the Quebec Observatory.

Finally, there are two reflectors, the largest being one of 10 feet, by Sir W. Herschel.

The Transit Clock, constructed by Hardy, and originally furnished with Hardy's escapement. A dead-beat escapement was substituted for this by Dent in the year 1829. The jewelled holes were removed by Dent in 1836, and the pivots now turn in brass holes. This clock was transferred from the old Transit Room to the Transit-Circle Room in December, 1850.

c 2

A clock in the North Dome, marked Arnold 1; one in the East Dome, marked Earnshaw; one in the South Dome (the place of the Altazimuth), marked Graham; one in the new Reflex Zenith Tube Apartment, marked Mudge and Dutton, which was presented in the year 1846 to the Observatory by the Rev. Charles Turnor; one marked Graham 2, and one marked Arnold 2, generally preserved in the passage that was formerly part of the Quadrant Room. There is also a clock marked Graham 3, shewing mean solar time, and formerly used for the daily dropping of the Time-signal Ball at 1^{h}; and another, marked Dent, used for the daily comparisons of chronometers. Besides these there are some journeymen or assistant clocks now rarely used, and a watchman's clock.

There is also a galvanic "motor clock," which by means of galvanic wires gives action to four sympathetic clocks, used for various purposes. Of these one has a large dial exposed to public view on the east boundary wall of the Observatory; one is in the Chronometer Room; one is in the Computing Room; and the remaining one is in the hall of the Astronomer Royal's dwelling house. It may be also proper to state in this place, that the motor clock closes a circuit precisely at 1 o'clock, and by the intervention of electro-magnets releases automatically the detent which supports the trigger of the ball apparatus, and thus drops the Signal-Ball. A general description of the galvanic apparatus, and especially of that part of it by which transits are now ordinarily recorded (October 1854) is not necessary here, because the recording apparatus was not brought into use at all in the year 1853.

The Transit Clock, and the other ordinary clocks in daily use, are wound up every Monday.

III. *Subjects of Observation in the Year* 1853.

The Sun and Planets have been observed on the meridian at every practicable opportunity, except on Sundays: the Moon and moon-culminating stars have been observed at every opportunity without exception.

In the meridional observations of the stars, it has been considered as the first object to establish with indisputable accuracy the places of those included in the Nautical Almanac list (as far as they are visible in this latitude). For this purpose the number of observations of each star made in the two preceding years is ascertained, and the additional number necessary to make up this to twenty is considered to be the number due from the present year. In far the greater number of instances this number is exceeded: in a few (especially of stars so near the pole that their transits are considered valueless unless Polaris or δ Ursæ Minoris is observed above and below on the same day), the just number is not completed.

The other stars observed are principally: A list of Stars, whose right ascensions have been well determined, used, in conjunction with the Nautical Almanac Stars, for determining clock-error; Stars remaining from lists of former years, including Stars to complete previous catalogues, moon-culminating Stars, Stars compared with Mars at the opposition of 1852, Stars to complete the list of all as low as the 4th magnitude, and

Stars observed at the request of Professor Chevallier; Stars compared with newly discovered small planets; Stars suspected of having or known to have large proper motions; Stars compared with Sirius; and finally, Stars observed in connection with the operations for determining the longitudes of the Observatories of Cambridge and Brussels.

The Altazimuth has been used for observations of the Moon on every day when the Moon could be seen, without exception; and for the observations of stars necessary for instrumental adjustments.

The Reflex Zenith Tube has been used for observations of γ Draconis during the whole of the year.

The East Equatoreal has been used for a few observations of the Third Comet of 1853, which are not worth reduction; for observations of occultations of stars by the Moon, and of phenomena of Jupiter's satellites; and, in conjunction with a double-image micrometer, for measures of Saturn's rings (printed in the Volume for 1852), and of γ Virginis.

The North Equatoreal was used only for observations of occultations of stars by the Moon.

On account of the unfavourable situation of Jupiter, scarcely any phenomena of the satellites have been observed.

IV. *Explanation of the Printed Observations.*

§ 1. *Transits observed with the Transit-Circle and Computations of Apparent Right Ascension*, page [2] to [80].

The *first* column on each page contains the day, which is always supposed to commence with the transit of the Sun.

The *second* column contains the numbers for convenience of reference.

The *third* column contains the name of the object observed. With respect to the Sun, Moon, and Planets, the limb whose transit is observed is always mentioned. If no limb is mentioned it is to be understood that the estimated center was observed: this, however, is generally stated unequivocally, except where omitted from inadvertence. The center is observed only when the planet's disc is so small and so round as to make it easier to estimate the center than to determine with accuracy the place of the limb. With regard to the stars, it is to be remarked, that the proper names which have commonly been used in the Greenwich Observations and the Nautical Almanac are adopted in preference to other names. For other stars, the names have been taken in the following order of preference:—

1. The Greek or Italic letter of Bayer, as adopted in Baily's Flamsteed, with the name of the constellation.
2. Flamsteed's number, with the name of the constellation.
3. The number in the Catalogue of the British Association.

4. Piazzi's hour and number.
5. The number in Groombridge's Catalogue.
6. The number in Bessel's Bradley.
7. The number in Baily's edition of Flamsteed's Catalogue.
8. The number in Santini's Catalogue of 1677 Stars, published in the Memoirs of the Royal Astronomical Society, vol. xii.
9. The hour and number in Weisse's Catalogue of the Stars in Bessel's Zones.
10. The number in the Catalogues of Lalande and Lacaille, published by the British Association.
11. The number in Rümker's Catalogue of 12,000 Stars.
12. The number in Oeltzen's Catalogue of Argelander's Zone Observations between 45° and 80° North Declination, published in vols. i. and ii. of the Annals of the Observatory of Vienna, 3rd Series.
13. The North Polar Distance; which is generally accurate within a minute of arc.

In observing a double star, the brighter star (if it is not otherwise expressed) is always observed.

The *fourth* column contains the initials of the observer's name.

The *next seven* columns contain the seconds and decimals of seconds of time at which the object was observed to pass each of the wires.

With regard to the general method of observing, it may be sufficient to remark that it is the practice to take a second from the clock-face before the transit over the first wire, and to preserve the counting by listening to the beats, and not to look again at the clock-face till the transit is finished. In observing the planets, this rule is not always adhered to; the observer looking at the clock between the transits over the different wires. The fraction of the second is noted by remarking the place at which the object is seen at the successive beats of the clock. Errors in the hours and minutes are seldom alluded to in the notes of the printed observations; but every alteration of the seconds is carefully recorded.

The *twelfth* column contains the concluded transit, giving the hour and minute of the meridian passage (which have not been given in the preceding columns), as well as the mean of the seconds.

When transits have been observed over all the seven wires, the mean of the seven is taken. When transits have not been observed over all the seven wires, a correction is applied to the mean of those actually observed, in order to give the mean of the transits as they would have been observed on all the seven wires, supposing the observations free from error. In either case the transits are referred, with no error except that of observation, to a certain imaginary line corresponding to the mean of the seven wires.

For the determination of the intervals of the seven transit wires, the South Collimator was employed in the following manner:—The eyepiece of the Transit-Circle was turned round 90°, so as to bring the transit-wires into a sensibly horizontal position, and with the head of the micrometer upwards when the telescope was directed towards the South.

Each of the transit-wires in succession was then brought upon a determinate point of the image of one of the nearly horizontal wires of the South Collimator, partly by turning the instrument in the ordinary way round its horizontal axis, and partly by turning the screw of the Right Ascension Micrometer, and, the instrument being clamped, the six microscopes of the Zenith Distance Circle were read, as well as the Right Ascension Micrometer.

In the first part of the year, the intervals are used which result from the observations made on 1852, November 20. It is unnecessary to give in this place the details of those observations, as the whole process is minutely described in the Volume for 1852, and the resulting intervals admit of no reasonable doubt. It is sufficient, therefore, to give the results, which are as follows:—

Distance in arc of each wire from the mean of all,

		′ ″
For Wire I	+	10. 21·65
II	+	6. 54·55
III	+	3. 27·34
IV	—	0·24
V	—	3. 27·28
VI	—	6. 54·63
VII	—	10. 21·40

Hence, for an Equatoreal star, the interval in time for the star's passage from any wire to the mean of all is as follows:—

		s
For Wire I	+	41·443
II	+	27·637
III	+	13·823
IV	—	0·016
V	—	13·819
VI	—	27·642
VII	—	41·427

For λ Ursæ Minoris, declination = 88°. 51′ + n''.

		m s				s
I	+	34. 32·77	+	n	×	0·520
II	+	22. 59·30	+	n	×	0·344
III	+	11. 29·02	+	n	×	0·171
IV	—	0·82				
V	—	11. 28·82	—	n	×	0·171
VI	—	22. 59·58	—	n	×	0·344
VII	—	34. 31·93	—	n	×	0·520

For Polaris, declination = 88°. 30′ + n″.

		m s	s
I	+	26. 26·70 + n ×	0·302
II	+	17. 36·78 + n ×	0·201
III	+	8. 48·18 + n ×	0·100
IV	−	0·62	
V	−	8. 48·02 − n ×	0·100
VI	−	17. 37·00 − n ×	0·201
VII	−	26. 26·07 − n ×	0·302

For Cephei 51 (Hevelii), declination = 87°.14′ + n″.

		m s	s
I	+	14. 19·15 + n ×	0·087
II	+	9. 32·71 + n ×	0·058
III	+	4. 46·39 + n ×	0·029
IV	−	0·34	
V	−	4. 46·31 − n ×	0·029
VI	−	9. 32·83 − n ×	0·058
VII	−	14. 18·80 − n ×	0·087

For δ Ursæ Minoris, declination = 86°.35′ + n″.

		m s	s
I	+	11. 35·69 + n ×	0·057
II	+	7. 43·81 + n ×	0·038
III	+	3. 51·94 + n ×	0·019
IV	−	0·27	
V	−	3. 51·88 − n ×	0·019
VI	−	7. 43·90 − n ×	0·038
VII	−	11. 35·41 − n ×	0·057

For ε Ursæ Minoris, declination = 82°.16′ + n″.

		m s	s
I	+	5. 7·98 + n ×	0·011
II	+	3. 25·38 + n ×	0·007
III	+	1. 42·72 + n ×	0·004
IV	−	0·12	
V	−	1. 42·69 − n ×	0·004
VI	−	3. 25·43 − n ×	0·007
VII	−	5. 7·87 − n ×	0·011

For ζ Ursæ Minoris, declination $= 78°.14' + n''$.

		m s				s
I	+	3. 23·23	+	n	×	0·0047
II	+	2. 15·52	+	n	×	0·0032
III	+	1. 7·78	+	n	×	0·0014
IV	—	0·08				
V	—	1. 7·77	—	n	×	0·0014
VI	—	2. 15·55	—	n	×	0·0032
VII	—	3. 23·14	—	n	×	0·0047

For γ Cephei, declination $= 76°.47' + n''$.

		m s				
I	+	3. 1·26	+	n	×	0·0038
II	+	2. 0·88	+	n	×	0·0025
III	+	1. 0·46	+	n	×	0·0013
IV	—	0·07				
V	—	1. 0·44	—	n	×	0·0013
VI	—	2. 0·90	—	n	×	0·0025
VII	—	3. 1·19	—	n	×	0·0038

On January 23, the fifth wire was found to be missing, and a new one was inserted. On February 16, the intervals were again determined by means of the South Collimator, by precisely the same process which has been previously explained. The resulting intervals, which were used from February 9 to November 5, are as follows:—

Distance in arc of each wire from the mean of all—

		′ ″
I	+	10. 21·66
II	+	6. 53·98
III	+	3. 27·00
IV	+	0·04
V	—	3. 27·36
VI	—	6. 54·53
VII	—	10. 20·78

Hence, for an Equatoreal Star, the interval in time for the star's passage from any wire to the mean of all is—

		s
For Wire I	+	41·444
II	+	27·599
III	+	13·800
IV	+	0·003
V	—	13·824
VI	—	27·635
VII	—	41·385

For λ Ursæ Minoris, declination = 88°. 51′ + n″.

		m s		s
I	+	34. 32 ·80	+ n ×	0 ·520
II	+	22. 57 ·35	+ n ×	0 ·344
III	+	11. 27 ·86	+ n ×	0 ·171
IV	+	0 ·14		
V	−	11. 29 ·09	− n ×	0 ·171
VI	−	22. 59 ·24	− n ×	0 ·344
VII	−	34. 29 ·81	− n ×	0 ·520

For Polaris, declination = 88°. 31′ + n″.

		m s		s
I	+	26. 44 ·57	+ n ×	0 ·305
II	+	17. 47 ·25	+ n ×	0 ·203
III	+	8. 53 ·24	+ n ×	0 ·101
IV	+	0 ·10		
V	−	8. 54 ·19	− n ×	0 ·101
VI	−	17. 48 ·67	− n ×	0 ·203
VII	−	26. 42 ·37	− n ×	0 ·305

For Cephei 51 (Hev.), declination = 87°. 14′ + n″.

		m s		s
I	+	14. 19 ·16	+ n ×	0 ·087
II	+	9. 31 ·91	+ n ×	0 ·058
III	+	4. 45 ·91	+ n ×	0 ·029
IV	+	0 ·06		
V	−	4. 46 ·42	− n ×	0 ·029
VI	−	9. 32 ·69	− n ×	0 ·058
VII	−	14. 17 ·93	− n ×	0 ·087

For δ Ursæ Minoris, declination = 86°. 35′ + n″.

		m s		s
I	+	11. 35 ·70	+ n ×	0 ·057
II	+	7. 43 ·16	+ n ×	0 ·038
III	+	3. 51 ·56	+ n ×	0 ·019
IV	+	0 ·05		
V	−	3. 51 ·97	− n ×	0 ·019
VI	−	7. 43 ·79	− n ×	0 ·038
VII	−	11. 34 ·71	− n ×	0 ·057

For ε Ursæ Minoris, declination = 82°. 16′ + n″.

		m s		s
I	+	5. 7 ·98	+ n ×	0 ·011
II	+	3. 25 ·10	+ n ×	0 ·007
III	+	1. 42 ·55	+ n ×	0 ·004
IV	+	0 ·02		
V	−	1. 42 ·73	− n ×	0 ·004
VI	−	3. 25 ·38	− n ×	0 ·007
VII	−	5. 7 ·56	− n ×	0 ·011

For ξ Ursæ Minoris, declination = 78°. 14′ + n″.

		m s s
I	+	3. 23 ·23 + n × 0·0047
II	+	2. 15 ·33 + n × 0·0032
III	+	1. 7 ·67 + n × 0·0014
IV	+	0·01
V	—	1. 7 ·80 — n × 0·0014
VI	—	2. 15 ·52 — n × 0·0032
VII	—	3. 22 ·94 — n × 0·0047

For γ Cephei, declination = 76°. 47′ + n″.

		m s s
I	+	3. 1 ·26 + n × 0·0038
II	+	2. 0·71 + n × 0·0025
III	+	1. 0·36 + n × 0·0013
IV	+	0·01
V	—	1. 0·46 — n × 0·0013
VI	—	2. 0·87 — n × 0·0025
VII	—	3. 1 ·01 — n × 0·0038

On October 29 a re-determination of the intervals of the wires was made, on account of some discrepancies frequently noticed in the observations of the separate wires of Polaris, which seemed to imply that the assumed intervals of the wires were not quite correct.

The observations were made as usual by means of the South Collimator, and the following Tables give the results in the usual form:—

Distance in arc of each wire from the mean of all,

		′ ″
I	+	10. 22 ·20
II	+	6. 54 ·38
III	+	3. 27 ·17
IV	+	0 ·27
V	—	3. 27 ·35
VI	—	6. 55 ·29
VII	—	10. 21 ·41

For an Equatoreal star, the intervals in time for the star's passage from any one wire to the mean of all, are,

		s
For Wire I	+	41 ·480
II	+	27 ·625
III	+	13 ·811
IV	+	0 ·018
V	—	13 ·823
VI	—	27 ·686
VII	—	41 ·427

For λ Ursæ Minoris, declination = 88°. 51′ + n''.

		m s		s
Wire I	+	34. 34 ·60	+ n ×	0 ·520
II	+	22. 58 ·64	+ n ×	0 ·344
III	+	11. 28 ·41	+ n ×	0 ·171
IV	+	0 ·89		
V	−	11. 29 ·04	− n ×	0 ·171
VI	−	23. 1 ·78	− n ×	0 ·344
VII	−	34. 31 ·91	− n ×	0 ·520

For Polaris, declination = 88° 31′. + n''.

		m s		s
Wire I	+	26. 45 ·96	+ n ×	0 ·305
II	+	17. 48 ·25	+ n ×	0 ·203
III	+	8. 53 ·66	+ n ×	0 ·101
IV	+	0 ·69		
V	−	8. 54 ·15	− n ×	0 ·101
VI	−	17. 50 ·63	− n ×	0 ·203
VII	−	26. 43 ·99	− n ×	0 ·305

For Cephei 51 (Hev.), declination = 87° 14′ + n''.

		m s		s
Wire I	+	14. 19 ·89	+ n ×	0 ·087
II	+	9. 32 ·45	+ n ×	0 ·058
III	+	4. 46 ·14	+ n ×	0 ·029
IV	+	0 ·37		
V	−	4. 46 ·40	− n ×	0 ·029
VI	−	9. 33 ·75	− n ×	0 ·058
VII	−	14. 18 ·80	− n ×	0 ·087

For δ Ursæ Minoris, declination = 86° 35′ + n''.

		m s		s
Wire I	+	11. 36 ·30	+ n ×	0 ·057
II	+	7. 43 ·60	+ n ×	0 ·038
III	+	3. 51 ·74	+ n ×	0 ·019
IV	+	0 ·30		
V	−	3. 51 ·95	− n ×	0 ·019
VI	−	7. 44 ·64	− n ×	0 ·038
VII	−	11. 35 ·41	− n ×	0 ·057

The intervals given in the Table above agree so closely with those previously determined, that no doubt could exist as to the accuracy of the determinations by the collimator. As, however, the observations of Polaris shewed the same discrepancies as before, it was thought that some error in the determination might have arisen from the circumstance that, for coincidence of the image of the collimator-wire with the extreme wires of the transit-circle, the pencil of rays must be received on a part of the object-glass of the transit-circle different from that for coincidence with the central wire; and therefore any defect in the shape of the large object-glass might produce an effect injurious to the accuracy of the determination by means of the collimators.

For the purpose of determining whether any such defect existed, a paper case was fitted to the object-glass of the transit-circle, having a circular aperture of $4^{in}\cdot 2.$, and observations were made of the coincidence of the direct and reflected images of the zenith-distance micrometer wire when the aperture was North and when it was South of the meridian, it being in each case under the extreme edge of the object-glass. The results were as follows, each being the mean of 12 readings:—

			r
With aperture North, Micrometer Reading for coincidence	- -	=	20·702.
,, South, Micrometer Reading ,,	- -	=	20·668.
,, North, Micrometer Reading ,,	- -	=	20·699.
,, South, Micrometer Reading ,,	- -	=	20·667.
Cap away, Micrometer Reading	- - - -	=	20·672.

These results exhibit a trifling difference in the readings for the North and South positions, but it is plainly quite insignificant, and therefore no sensible error could arise from error of figure in the surface of the large object-glass of the transit-circle. It is therefore presumable that the differences in the results for Polaris given by different wires were either accidental, or due to some unexplained habit of the observers, or to the change of figure of the star as seen at the side wires.

The intervals determined on October 29 were used from November 8 to the end of the year.

The signs in the preceding table must be changed when the star is below the pole.

The correction to the imperfect transit of a star can be found by adding together the equatoreal numbers from one of the tables above, for the wires observed; then dividing by the number of wires, and multiplying by the secant of the star's declination. During the year 1853, however, it has been the practice, in reducing imperfect transits, to reduce each separate wire to the mean of wires by means of an extensive table computed for the purpose.

For a planet, the number obtained as above is to be multiplied by

$$1 + \frac{\text{daily increase of R.A. in seconds of time}}{24 \times 60 \times 60};$$

$$\text{or by } 1 + \frac{\text{hourly increase of R.A. in seconds of time}}{60 \times 60}:$$

the computation being facilitated by a small table, of which the argument is the hourly increase of Right Ascension of the planet, taken from the Nautical Almanac; but it has been found easier during the year 1853 to proceed as with stars, by reducing each wire separately to the mean of wires, adding simply to the numbers given in the table the amount of the planet's increase of Right Ascension for each corresponding interval, which is very readily determined from the numbers given in the Nautical Almanac.

For the Moon, the whole factor is computed by the formula

$$\frac{3600 + I}{3600} \times \frac{\text{sin Moon's geocentric } Z.D.}{\text{sin Moon's apparent } Z.D.} \times \text{secant of Moon's geocentric declination,}$$

where I is the increase (in seconds of time) of the Moon's R.A., for the transit over a meridian upon the Earth distant by 1^h of terrestrial longitude, as given in the section *Moon-culminating Stars* in the Nautical Almanac.

For the easy computation of this formula, the following small table (including the limits of the values of I) of the natural numbers and logarithms of $\frac{3600 \times I}{3600}$, is used :—

I = Var. in R. A. for 1^h of Longitude.	$\frac{3600 + I}{3600}$ Nat. Number.	$\frac{3600 + I}{3600}$ Log.	I = Var. in R. A. for 1^h of Longitude.	$\frac{3600 + I}{3600}$ Nat. Number.	$\frac{3600 + I}{3600}$ Log.
s			s		
100	1·02778	0·01190	145	1·04028	0·01715
101	·02806	·01202	146	·04056	·01727
102	·02834	·01213	147	·04083	·01738
103	·02861	·01225	148	·04111	·01750
104	·02889	·01237	149	·04139	·01761
105	·02917	·01249	150	·04166	·01773
106	·02945	·01260	151	·04195	·01784
107	·02972	·01272	152	·04222	·01796
108	·03000	·01284	153	·04250	·01808
109	·03028	·01296	154	·04278	·01819
110	·03055	·01307	155	·04306	·01831
111	·03084	·01319	156	·04333	·01842
112	·03111	·01330	157	·04361	·01854
113	·03139	·01342	158	·04389	·01866
114	·03167	·01354	159	·04417	·01877
115	·03195	·01366	160	·04444	·01888
116	·03222	·01377	161	·04472	·01900
117	·03250	·01389	162	·04500	·01912
118	·03278	·01401	163	·04528	·01923
119	·03306	·01413	164	·04556	·01935
120	·03333	·01424	165	·04583	·01946
121	·03361	·01436	166	·04611	·01958
122	·03389	·01447	167	·04639	·01969
123	·03417	·01459	168	·04667	·01981
124	·03444	·01471	169	·04694	·01992
125	·03472	·01482	170	·04722	·02004
126	·03500	·01494	171	·04750	·02015
127	·03528	·01506	172	·04778	·02027
128	·03556	·01518	173	·04806	·02039
129	·03583	·01529	174	·04833	·02050
130	·03611	·01541	175	·04861	·02061
131	·03639	·01552	176	·04889	·02073
132	·03667	·01564	177	·04916	·02084
133	·03694	·01575	178	·04944	·02096
134	·03722	·01587	179	·04972	·02107
135	·03750	·01599	180	·05000	·02119
136	·03778	·01611	181	·05028	·02130
137	·03806	·01622	182	·05056	·02142
138	·03833	·01634	183	·05083	·02153
139	·03861	·01645	184	·05111	·02165
140	·03889	·01657	185	·05139	·02176
141	·03917	·01669	186	·05167	·02188
142	·03945	·01680	187	·05194	·02199
143	·03972	·01692	188	·05222	·02211
144	·04000	·01703	189	·05250	·02222
145	1·04028	0·01715	190	·05278	·02234

The *thirteenth* column contains the numerical values, in seconds of arc, of the errors of collimation, level, and azimuth; the two last being distinguished from the first by a round and a square bracket respectively. These errors I will treat of separately.

Error of Collimation.

The value of this error is given in seconds of space. The sign of the error is considered positive when it implies an additive correction to the observed transits of stars above the pole.

The method of determining the position of the line of collimation by means of the north and south collimators has been so fully explained in the description of the instrument above, that it is unnecessary to repeat the explanation here. It is only necessary to state that once in every week the reading of the micrometer of the south collimator, for coincidence of its nearly vertical wire with the image of that of the north collimator, is ascertained (the results of which will be found on page [82]), and that the micrometer wire of the south collimator is then left in the position so ascertained. And that every day the reading of the transit-telescope micrometer, for coincidence with the image of the wire of each collimator, is found (the results of which are given in pages [83] to [85]); that the mean of these gives the line of collimation for that day; and that the mean of these determinations, usually for a week, is adopted as the true reading for the geometrical line of collimation of the transit-telescope.

During the year 1851, the observations of the collimators with the transit-telescope were usually made twice in every day. Upon examination of the results it did not appear that there was any discoverable difference at different hours of the day, and therefore generally since that time the observations have been made only once in every day, usually at the commencement of the evening's observations.

The micrometer of the transit-telescope is left at some convenient reading, near to that of the geometrical collimation, but not necessarily coinciding with it. This reading is given at the bottom of every page of transits. The algebraical excess of the reading for geometrical collimation above this is the error of collimation, with the sign as explained above. This excess is converted into arc at the rate of $14''\cdot78$ for one revolution of the micrometer; then $-0''\cdot19$ is applied for diurnal aberration; and the result is the Error of Collimation which is given in column 13 of the *Transits*, and which is adopted for correction of the observed transits. The corrected line of collimation always lies so close to the mean of wires as to make the correction due to this cause generally insignificant.

The numerical correction in seconds of time to the observed transit is,

$$\text{Error of Collimation} \times \frac{1}{15 \sin \text{N.P.D.}}$$

Error of Level.

The error of level of the axis of revolution is considered positive when the western end of the axis is too high.

The process of determining the error of level, by taking the reading of the transit-micrometer which makes the image of the wire as seen by reflexion from the surface of quicksilver to coincide with the wire as seen directly, and comparing this reading with the reading for the geometrical line of collimation, has been sufficiently explained in the description of the instrument above. The excess of the reading for the line of collimation above the reading for coincidence of direct and reflected images gives the Error of Level, with the sign mentioned above. It is converted into arc at the rate of 14″·78 for one revolution of the micrometer. The mean of the results is adopted sometimes for a week, sometimes for a shorter time, as the instrument appears to have been more or less steady in level.

The details of these operations are given in pages [86] to [88].

The result adopted for the error of level is given in column 13 of the *Transits*.

The observations for the error of level are usually made at the same time as those for the line of collimation. During the year 1851 they were usually made twice every day; but on examination there appeared to be no discoverable difference between the results for different hours of the day; and since that time the observation has been made only once each day.

The numerical correction in seconds of time to the observed transit is,

$$\text{Error of Level} \times \frac{\cos \text{zenith distance.}}{15 \sin \text{N.P.D.}}$$

Error of Azimuth.

This error is considered positive when the Eastern pivot is too far North. It is generally determined from observations of Polaris or of δ Ursæ Minoris, at consecutive passages above and below the pole; or from one observation of Polaris combined with one observation of another star; or occasionally, from observations of δ Ursæ Minoris combined with those of other stars. The stars Cephei 51 (Hev.) and λ Ursæ Minoris have also frequently been employed. The stars used are, however, always mentioned in the Notes; the method of using them is as follows:—

If two consecutive passages of Polaris have been observed, the first transit (as corrected for the error of collimation and level error) is altered by the change of the star's R.A. and by the estimated clock-rate for 12^h; and the difference, in seconds of time, between the altered first transit and the second transit (rejecting 12^h) is divided by 3·206 to obtain the azimuthal error in seconds of space.

If three transits have been observed, the difference between the first and second is taken (rejecting 12^h), and the difference between the second and third in like manner: and the mean between these is supposed to be independent of the change of R.A. and the clock's rate, and is then divided by 3·206.

If several transits have been observed, the same process is used for every successive set of three, and the results are used separately, or the mean of the results is taken, accordingly as there appears reason to think that the position of the instrument has or has not undergone a change.

In several instances, consecutive transits of δ Ursæ Minoris have been used instead of Polaris. The divisor used with it is 1·396.

When a single observation only can be obtained, the letter *z* being put for the azimuthal error, the clock-error is found by comparing the R.A. of the Nautical Almanac (with a small alteration hereafter mentioned) with the time of transit including a term multiplied by z. The clock-error, therefore, from Polaris or δ Ursæ Minoris, or other star near the pole, contains a term depending on z. In like manner the clock-error from some other star not near the pole contains a term depending on z. Equating these (with proper allowance for rate of the clock), z is found.

The error is positive when the transit of the northern star above the pole is too late.

The numerical correction to each transit, in seconds of time, is,

$$\text{Azimuthal error} \times \frac{\text{sin zenith distance south.}}{15 \times \text{sin N.P.D.}}$$

The azimuthal errors actually used during the year 1853 are for the most part based upon the actual determinations of the error by consecutive observations of Polaris above and below the pole, in combination with the observations of the wires of the North Collimator made in determining the error of collimation, in the following manner:—

The azimuthal error, determined in the usual way by transits of circumpolar stars, has been applied to the measured angle of deviation between the wire of the North Collimator and the line of collimation, so as to give the azimuth of the North Collimator; and this, when well determined, has been used in connection with the ordinary observation of the North Collimator to determine the azimuth of the Instrument. For the determination of the azimuth of the Collimator throughout the year 1853, only consecutive observations of Polaris or δ Ursæ Minoris have been employed, and the results deduced from other observations of circumpolar stars, though scrupulously computed, have been used only to serve as a check upon the constancy of the position of the North Collimator, at times when Polaris or δ Ursæ Minoris could not be observed both above and below the pole at consecutive transits.

In the foot-notes to the *Transits*, those observations of circumpolar stars which have been actually employed in deducing the azimuth of the collimator are always mentioned, as well as the resulting azimuths of the Instrument. The whole of the details of the operations for deducing the azimuth of Collimator and the azimuth of Transit-Circle are given at page [89] and following pages.

The numerical values of the three factors for the errors of collimation, level, and azimuth, have been obtained throughout the year 1853 by means of sliding scales (one for each error) constructed by Mr. Simms, according to my directions. These scales give by simple inspection the numerical corrections in seconds of time for each transit; in the case of the stars in the Nautical Almanac by means of their names, which are written on cards attached to the scales—and in the case of all other stars, by the North Polar Distances engraved on the scales. The value of the error in collimation, level, or azimuth on the slider, is set to a brass pin, let into the scale, and the value of the correction to transits is then taken out very readily at sight.

The following tables of factors, however, for the three errors (the same tables which have been commonly used in preceding years) will be found convenient for verification of the computed corrections.

Star.	Collimation $\frac{1}{15 \text{ Sin N.P.D.}}$	Level. $\frac{\text{Cos Z.D.}}{15 \text{ Sin N.P.D.}}$	Azimuth. $\frac{\text{Sin Z.D.}}{15 \text{ Sin N.P.D.}}$	Star.	Collimation $\frac{1}{15 \text{ Sin N.P.D.}}$	Level. $\frac{\text{Cos Z.D.}}{15 \text{ Sin N.P.D.}}$	Azimuth. $\frac{\text{Sin Z.D.}}{15 \text{ Sin N.P.D.}}$
α Andromedæ	+0·076	+0·069	+0·030	α Cassiopeiæ S.P.	−0·118	−0·035	+0·113
γ Pegasi	+0·069	+0·055	+0·042	12 Canum Venaticûm	+0·086	+0·084	+0·018
α Cassiopeiæ	+0·118	+0·118	−0·009	Polaris S.P.	−2·575	−1·973	+1·655
β Ceti	+0·070	+0·024	+0·066	Spica	+0·068	+0·032	+0·060
Polaris	+2·575	+2·056	−1·551	η Ursæ Majoris	+0·104	+0·104	+0·002
θ Ceti	+0·067	+0·033	+0·059	η Boötis	+0·070	+0·060	+0·038
η Ursæ Majoris S.P.	−0·104	−0·021	+0·102	Arcturus	+0·071	+0·061	+0·037
α Arietis	+0·072	+0·063	+0·035	ε Boötis	+0·075	+0·069	+0·030
γ Ceti	+0·067	+0·044	+0·050	α Libræ	+0·069	+0·027	+0·064
β Ursæ Minoris S.P.	−0·254	−0·151	+0·205	β Ursæ Minoris	+0·254	+0·234	−0·101
α Ceti	+0·067	+0·045	+0·050	β Libræ	+0·067	+0·033	+0·058
α Persei	+0·102	+0·102	+0·004	α Persei S.P.	−0·102	−0·019	+0·100
η Tauri	+0·073	+0·064	+0·034	α Coronæ	+0·075	+0·069	+0·031
γ Eridani	+0·069	+0·028	+0·062	α Serpentis	+0·067	+0·048	+0·047
ζ Ursæ Minoris S.P.	−0·329	−0·210	+0·253	ζ Ursæ Minoris	+0·329	+0·293	−0·148
η Draconis S.P.	−0·141	−0·056	+0·130	β¹ Scorpii	+0·071	+0·023	+0·067
Aldebaran	+0·070	+0·057	+0·040	δ Ophiuchi	+0·067	+0·038	+0·054
ε Ursæ Minoris S.P.	−0·497	−0·344	+0·359	Antares	+0·074	+0·016	+0·072
Capella	+0·095	+0·095	+0·009	η Draconis	+0·141	+0·139	−0·026
Rigel	+0·067	+0·034	+0·058	ε Ursæ Minoris	+0·497	+0·427	−0·255
β Tauri	+0·076	+0·070	+0·030	Capella S.P.	−0·095	−0·012	+0·095
δ Orionis	+0·067	+0·041	+0·052	α Herculis	+0·069	+0·055	+0·041
α Leporis	+0·070	+0·025	+0·066	β Draconis	+0·109	+0·109	−0·002
β Draconis S.P.	−0·109	−0·026	+0·106	α Ophiuchi	+0·068	+0·053	+0·043
ε Orionis	+0·067	+0·040	+0·053	γ Draconis	+0·107	+0·107	0·000
α Columbæ	+0·080	+0·006	+0·080	μ Sagittarii	+0·071	+0·021	+0·068
α Orionis	+0·067	+0·048	+0·047	Cephei 51 (Hev.) S.P.	−1·394	−1·048	+0·920
γ Draconis S.P.	−0·107	−0·024	+0·104	δ Ursæ Minoris	+1·122	+0·918	−0·646
μ Geminorum	+0·072	+0·063	+0·035	α Lyræ	+0·086	+0·083	+0·019
Cephei 51 (Hev.)	+1·394	+1·131	−0·815	β Lyræ	+0·080	+0·076	+0·025
δ Ursæ Minoris S.P.	−1·122	−0·834	+0·750	ζ Aquilæ	+0·068	+0·054	+0·042
Sirius	+0·070	+0·026	+0·065	δ Aquilæ	+0·067	+0·044	+0·050
ε Canis Majoris	+0·076	+0·013	+0·075	γ Aquilæ	+0·068	+0·051	+0·045
δ Geminorum	+0·072	+0·063	+0·035	α Aquilæ	+0·067	+0·049	+0·046
Castor	+0·079	+0·074	+0·026	β Aquilæ	+0·067	+0·047	+0·048
Procyon	+0·067	+0·047	+0·048	α² Capricorni	+0·068	+0·029	+0·062
Pollux	+0·075	+0·070	+0·030	λ Ursæ Minoris	+3·300	+2·622	−2·002
15 Argûs	+0·073	+0·018	+0·070	α Cygni	+0·094	+0·093	+0·011
λ Ursæ Minoris S.P.	−3·300	−2·539	+2·106	ι Ursæ Majoris S.P.	−0·101	−0·018	+0·099
α Cygni S.P.	−0·094	−0·010	+0·093	61 Cygni	+0·085	+0·082	+0·020
ε Hydræ	+0·067	+0·048	+0·047	ζ Cygni	+0·077	+0·071	+0·029
ι Ursæ Majoris	+0·101	+0·101	+0·005	α Cephei	+0·141	+0·139	−0·026
α Cephei S.P.	−0·141	−0·056	+0·130	θ Ursæ Majoris S.P.	−0·109	−0·026	+0·106
α Hydræ	+0·067	+0·034	+0·058	β Aquarii	+0·067	+0·036	+0·057
θ Ursæ Majoris	+0·109	+0·109	−0·002	β Cephei	+0·193	+0·184	−0·061
β Cephei S.P.	−0·193	−0·101	+0·165	ε Pegasi	+0·067	+0·050	+0·045
ε Leonis	+0·073	+0·065	+0·033	α Aquarii	+0·067	+0·040	+0·053
Regulus	+0·068	+0·053	+0·043	ζ Pegasi	+0·068	+0·051	+0·045
α Ursæ Majoris	+0·145	+0·142	−0·028	Fomalhaut	+0·077	+0·011	+0·077
δ Leonis	+0·072	+0·062	+0·036	α Ursæ Majoris S.P.	−0·145	−0·059	+0·132
δ Crateris	+0·069	+0·029	+0·062	α Pegasi	+0·069	+0·055	+0·041
γ Cephei S.P.	−0·290	−0·179	+0·228	ι Piscium	+0·067	+0·046	+0·049
β Leonis	+0·069	+0·056	+0·041	Cephei	+0·290	+0·262	−0·124
γ Ursæ Majoris	+0·115	+0·115	−0·006	Ursæ Majoris S.P.	−0·115	−0·032	+0·111
β Corvi	+0·072	+0·020	+0·069				

N.P.D.	Collimation.	Level.	Azimuth.	N.P.D.	Collimation.	Level.	Azimuth.
	1 / 15 Sin N.P.D.	Cos Z. D. / 15 Sin N.P.D.	Sin Z. D. / 15 Sin N.P.D.		1 / 15 Sin N.P.D.	Cos Z. D. / 15 Sin N.P.D.	Sin Z. D. / 15 Sin N.P.D.
° ′				° ′			
−45. 0	−0·094	−0·011	+0·094	6. 0	+0·638	+0·538	−0·343
−44. 0	−0·096	−0·013	+0·095	6. 30	+0·589	+0·499	−0·312
−43. 0	−0·098	−0·014	+0·096	7. 0	+0·547	+0·466	−0·286
−42. 0	−0·100	−0·016	+0·098	7. 30	+0·511	+0·438	−0·263
−41. 0	−0·102	−0·018	+0·100	8. 0	+0·479	+0·413	−0·243
−40. 0	−0·104	−0·021	+0·102	8. 30	+0·451	+0·391	−0·226
−39. 0	−0·106	−0·023	+0·104	9. 0	+0·426	+0·371	−0·210
−38. 0	−0·108	−0·025	+0·105	9. 30	+0·404	+0·353	−0·196
−37. 0	−0·111	−0·027	+0·107	10. 0	+0·384	+0·337	−0·183
−36. 0	−0·113	−0·030	+0·109	10. 30	+0·366	+0·323	−0·172
−35. 0	−0·116	−0·033	+0·111	11. 0	+0·349	+0·310	−0·161
−34. 0	−0·119	−0·036	+0·114	11. 30	+0·334	+0·298	−0·152
−33. 0	−0·122	−0·039	+0·116	12. 0	+0·321	+0·287	−0·143
−32. 0	−0·126	−0·042	+0·119	12. 30	+0·308	+0.·277	−0·135
−31. 0	−0·129	−0·045	+0·121	13. 0	+0·296	+0·267	−0·128
−30. 0	−0·133	−0·049	+0·124	13. 30	+0·286	+0·259	−0·122
−29. 0	−0·138	−0·053	+0·127	14. 0	+0·276	+0·251	−0·116
−28. 0	−0·142	−0·057	+0·130	14. 30	+0·266	+0·244	−0·111
−27. 0	−0·147	−0·061	+0·133	15. 0	+0·257	+0·236	−0·105
−26. 0	−0·152	−0·065	+0·137	15. 30	+0·249	+0·230	−0·099
−25. 0	−0·158	−0·070	+0·141	16. 0	+0·242	+0·224	−0·093
−24. 0	−0·164	−0·076	+0·145	16. 30	+0·235	+0·218	−0·088
−23. 0	−0·171	−0·082	+0·150	17. 0	+0·228	+0·212	−0·084
−22. 0	−0·178	−0·088	+0·155	17. 30	+0·222	+0·207	−0·080
−21. 0	−0·186	−0·094	+0·160	18. 0	+0·216	+0·202	−0·076
−20. 0	−0·195	−0·102	+0·166	18. 30	+0·210	+0·197	−0·072
−19. 30	−0·200	−0·106	+0·170	19. 0	+0·205	+0·193	−0·068
−19. 0	−0·205	−0·110	+0·173	19. 30	+0·200	+0·189	−0·065
−18. 30	−0·210	−0·114	+0·176	20. 0	+0·195	+0·185	−0·062
−18. 0	−0·216	−0·119	+0·180	21. 0	+0·186	+0·177	−0·056
−17. 30	−0·222	−0·124	+0·184	22. 0	+0·178	+0·171	−0·051
−17. 0	−0·228	−0·129	+0·188	23. 0	+0·171	+0.164	−0·046
−16. 30	−0·235	−0·134	+0·192	24. 0	+0·164	+0·159	−0·041
−16. 0	−0·242	−0·140	+0·197	25. 0	+0·158	+0·153	−0·037
−15. 30	−0·249	−0·146	+0·202	26. 0	+0·152	+0·148	−0·033
−15. 0	−0·257	−0·153	+0·207	27. 0	+0·147	+0·144	−0·029
−14. 30	−0·266	−0·160	+0·213	28. 0	+0·142	+0·140	−0·026
−14. 0	−0·276	−0·168	+0·219	29. 0	+0·138	+0·136	−0·023
−13. 30	−0·286	−0·176	+0·225	30. 0	+0·133	+0·131	−0·020
−13. 0	−0·296	−0·184	+0·232	31. 0	+0·129	+0·128	−0·017
−12. 30	−0·308	−0·194	+0·240	32. 0	+0·126	+0·125	−0·014
−12. 0	−0·321	−0·204	+0·248	33. 0	+0·122	+0·122	−0·012
−11. 30	−0·334	−0·214	+0·256	34. 0	+0·119	+0·119	−0·009
−11. 0	−0·349	−0·227	+0·266	35. 0	+0·116	+0·116	−0·007
−10. 30	−0 366	−0·240	+0·276	36. 0	+0·113	+0·113	−0·005
−10. 0	−0·384	−0·254	+0·288	37. 0	+0·111	+0·111	−0·003
− 9. 30	−0·404	−0·270	+0·300	38. 0	+0·108	+0·108	−0·001
− 9. 0	−0·426	−0·288	+0·314	39. 0	+0·106	+0·106	+0·001
− 8. 30	−0·451	−0·308	+0·330	40. 0	+0·104	+0·104	+0·003
− 8. 0	−0·479	−0·330	+0·348	41. 0	+0·102	+0·101	+0·004
− 7. 30	−0·511	−0·355	+0·368	42. 0	+0·100	+0·099	+0·006
− 7. 0	−0·547	−0·383	+0·390	43. 0	+0·098	+0·097	+0·007
− 6. 30	−0·589	−0·416	+0·417	44. 0	+0·096	+0·096	+0·009
− 6. 0	−0·638	−0·455	+0·447	45. 0	+0·094	+0·094	+0·011
				46. 0	+0·093	+0·092	+0·012

N.P.D.	Collimation. $\frac{1}{15 \text{ Sin N.P.D.}}$	Level. $\frac{\text{Cos Z.D.}}{15 \text{ Sin N.P.D.}}$	Azimuth. $\frac{\text{Sin Z.D.}}{15 \text{ Sin N.P.D.}}$	N.P.D.	Collimation. $\frac{1}{15 \text{ Sin N.P.D.}}$	Level. $\frac{\text{Cos. Z.D.}}{15 \text{ Sin N.P.D.}}$	Azimuth. $\frac{\text{Sin Z.D.}}{15 \text{ Sin N.P.D.}}$
° ′				° ′			
46. 0	+0·093	+0·092	+0·012	86. 0	+0·067	+0·045	+0·049
47. 0	+0·091	+0·090	+0·013	87. 0	+0·067	+0·044	+0·050
48. 0	+0·090	+0·088	+0·015	88. 0	+0·067	+0·043	+0·051
49. 0	+0·088	+0·087	+0·016	89. 0	+0·067	+0·042	+0·052
50. 0	+0·087	+0·085	+0·017	90. 0	+0·067	+0·041	+0·052
51. 0	+0·086	+0·084	+0·018	91. 0	+0·067	+0·040	+0·053
52. 0	+0·085	+0·082	+0·020	92. 0	+0·067	+0·040	+0·054
53. 0	+0·083	+0·081	+0·021	93. 0	+0·067	+0·039	+0·054
54. 0	+0·082	+0·080	+0·022	94. 0	+0·067	+0·038	+0·055
55. 0	+0·081	+0·078	+0·023	95. 0	+0·067	+0·037	+0·056
56. 0	+0·080	+0·077	+0·024	96. 0	+0·067	+0·036	+0·057
57. 0	+0·080	+0·075	+0·025	97. 0	+0·067	+0·035	+0·057
58. 0	+0·079	+0·074	+0·026	98. 0	+0·067	+0·034	+0·058
59. 0	+0·078	+0·073	+0·027	99. 0	+0·067	+0·033	+0·059
60. 0	+0·077	+0·072	+0·028	100. 0	+0·068	+0·032	+0·060
61. 0	+0·076	+0·070	+0·029	101. 0	+0·068	+0·031	+0·060
62. 0	+0·076	+0·069	+0·030	102. 0	+0·068	+0·030	+0·061
63. 0	+0·075	+0·068	+0·031	103. 0	+0·068	+0·029	+0·062
64. 0	+0·074	+0·067	+0·032	104. 0	+0·069	+0·028	+0·063
65. 0	+0·073	+0·066	+0·033	105. 0	+0·069	+0·027	+0·063
66. 0	+0·073	+0·065	+0·034	106. 0	+0·069	+0·027	+0·064
67. 0	+0·072	+0·064	+0·035	107. 0	+0·070	+0·026	+0·065
68. 0	+0·072	+0·063	+0·035	108. 0	+0·070	+0·025	+0·066
69. 0	+0·071	+0·061	+0·036	109. 0	+0·071	+0·024	+0·066
70. 0	+0·071	+0·060	+0·037	110. 0	+0·071	+0·023	+0·067
71. 0	+0·071	+0·059	+0·038	111. 0	+0·072	+0·022	+0·068
72. 0	+0·070	+0·058	+0·039	112. 0	+0·072	+0·021	+0·069
73. 0	+0·070	+0·057	+0·039	113. 0	+0·073	+0·020	+0·070
74. 0	+0·069	+0·056	+0·040	114. 0	+0·073	+0·018	+0·071
75. 0	+0·069	+0·055	+0·041	115. 0	+0·074	+0·017	+0·072
76. 0	+0·069	+0·054	+0·042	116. 0	+0·075	+0·016	+0·072
77. 0	+0·068	+0·053	+0·043	117. 0	+0·075	+0·015	+0·073
78. 0	+0·068	+0·053	+0·043	118. 0	+0·076	+0·014	+0·074
79. 0	+0·068	+0·052	+0·044	119. 0	+0·076	+0·013	+0·075
80. 0	+0·068	+0·051	+0·045	120. 0	+0·077	+0·012	+0·076
81. 0	+0·067	+0·050	+0·045	121. 0	+0·078	+0·011	+0·077
82. 0	+0·067	+0·049	+0·046	122. 0	+0·079	+0·009	+0·078
83. 0	+0·067	+0·048	+0·047	123. 0	+0·080	+0·008	+0·079
84. 0	+0·067	+0·047	+0·048	124. 0	+0·080	+0·007	+0·080
85. 0	+0·067	+0·046	+0·048	125. 0	+0·081	+0·005	+0·081
86. 0	+0·067	+0·045	+0·049	126. 0	+0·082	+0·004	+0·082

The *fourteenth* column contains the seconds of every transit, as affected with the three preceding corrections; and is conceived to represent the time at which each body passed the true astronomical meridian of Greenwich. The numbers to which a bracket is annexed are those resulting from the mean of the two limbs of the Sun or a planet.

The *fifteenth* column contains the seconds of the tabular R.A, of the stars which are used for determining clock-errors. In addition to the list of stars taken from the Nautical Almanac, whose North Polar Distances exceed 50°, used exclusively in preceding years, there has been used in the year 1853, another list of stars, previously selected, and observed for this purpose chiefly in the years 1851 and 1852, and lying within the same limit of Polar Distance. The tabular R.A. of Polaris, Cephei 51 (Hev.), δ Ursæ Minoris, and λ Ursæ Minoris, are set down to enable the reader to judge of the general state of adjustment of the instrument.

For the Nautical Almanac stars, the Right Ascensions are computed by applying, to the numbers given in the Nautical Almanac, corrections fundamentally deduced from the Greenwich Twelve-Year Catalogue of 2156 stars. To bring up the Mean Right Ascensions from the epoch of the Catalogue, viz., 1845, to the year 1853, the precessions and the proper motions given in the British Association Catalogue have been used. The only exception is, that the proper motion of ι Piscium is taken from Argelander's Catalogue, that of the B. A. C. being erroneous. For the supplementary stars, the Right Ascensions, taken immediately from the Greenwich Catalogues of 1851 and 1852, and occasionally of 1850, are brought up to the year 1853 by the precessions and proper motions of the B. A. C., and are manifestly referred to the same equinox as the Nautical Almanac stars, since their observed places are also based fundamentally on the Greenwich Twelve-Year Catalogue. The corrections necessary to bring up the stars' Right Ascensions to the day of observation are computed by the formulæ $E e + F f + G g + H h + L + l - 300^{s}$, to which further allusion will be made below. For stars near the pole, the additional correction depending on the place of the Moon is also taken into account. The following table gives the Mean Right Ascensions for 1853, January 1, of all the stars which have been used in 1853 for determining clock errors, together with the constant alterations to the Right Ascensions of the Nautical Almanac stars; it gives also, in addition, the Right Ascensions of Polaris, and the other stars lying very near the pole, which have been observed throughout the year 1853.

Star's Name.	Assumed Mean R.A. 1853, Jan. 1.	Correction to N. A.	Star's Name.	Assumed Mean R.A. 1853, Jan. 1.	Correction to N. A.
	h m s	s		h m s	s
α Andromedæ	0. 0. 47·85	+ 0·06	ξ² Ceti	2. 20. 20·90	
γ Pegasi	0. 5. 40·25	+ 0·05	γ Ceti	2. 35. 41·25	+ 0·04
12 Ceti	0. 22. 32·25		α Ceti	2. 54. 35·97	+ 0·01
ε Andromedæ	0. 30. 47·80		ο Tauri	3. 16. 54·48	
β Ceti	0. 36. 12·49	+ 0·09	η Tauri	3. 38. 45·23	+ 0·02
μ Andromedæ	0. 48. 36·54		γ Eridani	3. 51. 10·36	+ 0·07
ε Piscium	0. 55. 19·06		ε Tauri	4. 20. 2·27	
β Andromedæ	1. 1. 30·84		Aldebaran	4. 27. 29·45	+ 0·07
Polaris	1. 5. 53·81	− 0·14	ι Aurigæ	4. 47. 25·65	
θ Ceti	1. 16. 40·60	+ 0·05	ε Leporis	4. 59. 14·32	
η Piscium	1. 23. 37·38		Rigel	5. 7. 28·53	+ 0·08
ν Piscium	1. 33. 47·06		β Tauri	5. 17. 0·19	+ 0·06
β Arietis	1. 46. 31·66		δ Orionis	5. 24. 29·92	− 0·01
α Arietis	1. 58. 53·78	+ 0·12	α Leporis	5. 26. 14·92	+ 0·03
67 Ceti	2. 9. 39·13		ε Orionis	5. 28. 45·38	+ 0·07

Star's Name.	Assumed Mean R. A. 1853, Jan. 1.	Correction to N.A.	Star's Name.	Assumed Mean R.A. 1853, Jan. 1.	Correction to N.A.
	h m s	s		h m s	s
α Columbæ	5. 34. 19·67	— 0·03	α Libræ	14. 42. 45·25	+ 0·07
α Orionis	5. 47. 12·89	+ 0·04	ψ Bootis	14. 58. 8·88	
η Geminorum	6. 6. 0·24		β Libræ	15. 9. 6·15	+ 0·10
μ Geminorum	6. 14. 4·06	+ 0·06	ο² Libræ	15. 14. 50·19	
γ Geminorum	6. 29. 13·19		α Coronæ	15. 28. 27·90	+ 0·08
Cephei 51 (Hev.)	6. 30. 4·27	— 1·44	α Serpentis	15. 37. 1·81	+ 0·08
Sirius	6. 38. 40·37	+ 0·10	ε Serpentis	15. 43. 29·47	
θ Canis Majoris	6. 47. 21·60		γ Serpentis	15. 49. 39·95	
ε Canis Majoris	6. 52. 51·00	+ 0·06	β¹ Scorpii	15. 56. 53·78	+ 0·08
γ Canis Majoris	6. 57. 6·50		δ Ophiuchi	16. 6. 38·76	+ 0·08
δ Geminorum	7. 11. 20·48	+ 0·04	γ Herculis	16. 15. 26·24	
β Canis Minoris	7. 19. 10·57		Antares	16. 20. 24·09	+ 0·07
Castor	7. 25. 12·85	+ 0·04	ζ Ophiuchi	16. 29. 4·14	
Procyon	7. 31. 36·28	+ 0·11	ζ Herculis	16. 35. 44·69	
Pollux	7. 36. 18·87	+ 0·03	κ Ophiuchi	16. 50. 42·78	
ξ Navis	7. 43. 6·69		η Ophiuchi	17. 1. 57·09	
6 Cancri	7. 54. 29·08		α Herculis	17. 7. 56·74	+ 0·05
15 Argûs	8. 1. 17·10	+ 0·03	θ Ophiuchi	17. 12. 59·10	
β Cancri	8. 8. 32·46		σ Ophiuchi	17. 19. 13·38	
η Cancri	8. 24. 12·10		α Ophiuchi	17. 28. 6·72	+ 0·08
γ Cancri	8. 34. 46·37		β Ophiuchi	17. 36. 12·73	
ε Hydræ	8. 38. 59·36	+ 0·03	μ Herculis	17. 40. 42·41	
α Cancri	8. 50. 26·56		72 Ophiuchi	18. 0. 22·88	
κ Cancri	8. 59. 46·88		μ Sagittarii	18. 4. 58·38	+ 0·10
83 Cancri	9. 10. 46·18		η Serpentis	18. 13. 42·22	
α Hydræ	9. 20. 21·82	+ 0·09	λ Sagittarii	18. 18. 53·86	
ο Leonis	9. 33. 18·11		δ Ursæ Minoris	18. 19. 45·69	— 0·06
ε Leonis	9. 37. 29·98	+ 0·02	α Lyræ	18. 31. 57·68	+ 0·07
μ Leonis	9. 44. 23·72		β Lyræ	18. 44. 39·16	+ 0 06
π Leonis	9. 52. 26·51		ε Aquilæ	18. 52. 57·07	
Regulus	10. 0. 32·36	+ 0·04	ζ Aquilæ	18. 58. 39·18	+ 0·04
γ¹ Leonis	10. 11. 51·73		ω Aquilæ	19. 10. 54·97	
ρ Leonis	10. 25. 4·07		δ Aquilæ	19. 18. 5·17	+ 0·10
34 Sextantis	10. 35. 1·95		α Vulpeculæ	19. 22. 35·37	
l Leonis	10. 41. 31·62		μ Aquilæ	19. 26. 54·45	
d Leonis	10. 52. 58·10		γ Aquilæ	19. 39. 16·26	+ 0·06
χ Leonis	10. 57. 25·93		α Aquilæ	19. 43. 36·58	+ 0·01
δ Leonis	11. 6. 17·10	+ 0·05	β Aquilæ	19. 48. 5·54	+ 0·07
δ Crateris	11. 11. 59·67	+ 0·08	c Sagittarii	19. 53. 36·73	
τ Leonis	11. 20. 22·60		θ Aquilæ	20. 3. 43·10	
υ Leonis	11. 29. 25·40		α² Capricorni	20. 9. 53·72	+ 0·12
β Leonis	11. 41. 33·48	+ 0·03	λ Ursæ Minoris	20. 10. 20·82	— 0·23
π Virginis	11. 53. 20·33		β Capricorni	20. 12. 44·87	
ε Corvi	12. 2. 34·25		ε Delphini	20. 26. 11·37	
η Virginis	12. 12. 23·14		α Delphini	20. 32. 48·61	
δ Corvi	12. 22. 15·82		ε Aquarii	20. 39. 42·88	
β Corvi	12. 26. 40·40	+ 0·14	32 Vulpeculæ	20. 48. 17·76	
δ Virginis	12. 48. 12·04		θ Capricorni	20. 57. 40·65	
θ Virginis	13. 2. 20·51		ζ Cygni	21. 6. 40·90	+ 0·05
Spica	13. 17. 27·26	+ 0·08	α Equulei	21. 8. 28·45	
ζ Virginis	13. 27. 12·36		ι Capricorni	21. 14. 3·31	
τ Bootis	13. 40. 16·62		β Aquarii	21. 23. 49·03	+ 0·04
η Bootis	13. 47. 41·14	+ 0·06	ξ Aquarii	21. 29. 55·38	
τ Virginis	13. 54. 10·06		ε Pegasi	21. 36. 57·97	+ 0·01
κ Virginis	14. 5. 3·56		δ Capricorni	21. 38. 55·33	
Arcturus	14. 8. 57·46	+ 0·06	16 Pegasi	21. 46. 22·54	
ρ Bootis	14. 25. 29·66		α Aquarii	21. 58. 13·92	+ 0·08
ε Bootis	14. 38. 34·03	+ 0·04	ι Pegasi	22. 0. 10·20	

Star's Name.	Assumed Mean R.A. 1853, Jan. 1.	Correction to N.A.	Star's Name.	Assumed Mean R.A. 1853, Jan. 1.	Correction to N.A.
	h m s	s		h m s	s
θ Aquarii.........	22. 9. 4 ·44		α Pegasi..........	22. 57. 26 ·48	+ 0 ·06
γ Aquarii.........	22. 14. 3 ·74		γ Piscium.........	23. 9. 32 ·72	
η Aquarii.........	22. 27. 48 ·07		κ Piscium.........	23. 19. 23 ·81	
ζ Pegasi..........	22. 34. 7 ·87	+ 0 ·03	ι Piscium.........	23. 32. 23 ·49	+ 0 ·07
μ Pegasi..........	22. 42. 54 ·68		δ Sculptoris.......	23. 41. 15 ·69	
λ Aquarii.........	22. 44. 56 ·52		ω Piscium.........	23. 51. 45 ·90	
Fomalhaut........	22. 49. 31 ·09	+ 0 ·11			

The *sixteenth* column contains the error of the clock, found by subtracting the numbers in the fourteenth column from those in the fifteenth. The error is therefore positive when the clock is slow.

The *seventeenth* column contains the adopted losing rate, and the adopted error of the clock at 0^h sidereal, as found by the following process. The observations are divided into groups, marked by bars across these columns (in all instances the same as the limits of the observations of each observer). The mean of the clock-errors given by all the clock-stars in each group is then taken, and this is held to be the clock-error corresponding to the mean of all the times of transit of those stars. The next step is to make allowance for personal equation; and it will be sufficient to explain that existing between Mr. Rogerson and Mr. Dunkin, since it has been the practice to reduce all the clock-times of observation with the Altazimuth to sidereal time by means of errors of the transit-clock referred to Mr. Dunkin as the standard, and Mr. Rogerson's personal equation compared with those of the other observers is one of the largest. It will be seen by one of the following tables in this Introduction that the clock-error given by Mr. Rogerson's observations is greater than that given by Mr. Dunkin's observations by $0^s{\cdot}55$, as deduced from the observations suitable for the determination of this quantity in the year 1853; the quantity $0^s{\cdot}55$ is therefore subtracted from Mr. Rogerson's clock-errors, and it is then considered that we have a set of clock-errors justly comparable amongst themselves. Each mean clock-error is now compared with that which precedes and with that which follows; a preceding rate and a following rate are thus found, and by these the computer is guided in adopting the clock-rate to be used through the group of observations: this adopted clock-rate is set down in the seventeenth column. For facility of calculation, the proportional part of this rate, corresponding to the mean sidereal time or mean of all the times of transit for the group, is applied with changed sign to the mean clock-error; and thus the clock-error at 0^h sidereal is found. If it happen that any observations included in the same group are made in the sidereal day preceding or following that for which the mean error has been found, the whole adopted daily rate is subtracted from or added to the error found for 0^h; and thus the error for 0^h of the preceding or the following sidereal day is obtained. These errors at 0^h are set down in the seventeenth column. It is to be remarked that, in the application of these errors, if the observations of small stars and planets have been made by the same person as the observations of the clock-stars (whether it be Mr. Dunkin or Mr. Rogerson), no further computation is necessary for obtaining the right ascensions of these objects than the application, to the time of transit, of the clock-error at 0^h, and of a proportional part of the clock-rate corresponding to the right ascension of the object: but if the clock-stars are observed by Mr. Rogerson, and the other object by Mr. Dunkin, a further correction $-0^s\cdot55$ must be applied: if the clock-stars are observed by Mr. Dunkin, and the object by Mr. Rogerson, $+0^s\cdot55$ must be applied. These quantities are *not* applied in the column of *Apparent Right Ascensions from the Observations* in this Section.

In the preceding years, observations were exhibited which give the relative personal equations of the different observers of transits, as far as means existed for determining them. In the year 1853, the following sets of observations have been found available for determining personal equations. They have been treated in the same manner as in former years, by comparing the clock-error at the same sidereal noon given by two different groups of stars observed by different persons.

OBSERVATIONS for the PERSONAL EQUATION between MR. MAIN and MR. HENRY.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by M.	Clock Slow at 0^h by H.	H—M.
		h		s	s	s
January	23	5	H M	12·30	12·39	+ 0·09
December	2	10	M H	49·76	49·81	+ 0·05

OBSERVATIONS for the PERSONAL EQUATION between MR. MAIN and MR. ROGERSON.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by M.	Clock Slow at 0^h by R.	R—M.
		h		s	s	s
March	25	3	R M	49·03	49·67	+ 0·64

OBSERVATIONS for the PERSONAL EQUATION between MR. MAIN and MR. DUNKIN.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by M.	Clock Slow at 0^h by D.	D—M.
		h		s	s	s
March	25 and 26	4	M D	49·57	49·71	+ 0·14
September	10	0	M D	10·50	10·68	+ 0·18
December	25	10	D M	57·57	57·55	— 0·02

OBSERVATIONS for the PERSONAL EQUATION between MR. MAIN and MR. HENDERSON.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by M.	Clock Slow at 0^h by J H.	J H—M.
	h		s	s	s
September 18	3	J H M	18·55	18·76	+ 0·21

OBSERVATIONS for the PERSONAL EQUATION between MR. MAIN and MR. ELLIS.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by M.	Clock Slow at 0^h by E.	E
	h		s	s	s
September 18 and 19	2	M E	18·55	18·69	+ 0·14
25 and 26	6	M E	24·14	24·46	+ 0·32

OBSERVATIONS for the PERSONAL EQUATION between MR. MAIN and MR. CRISWICK.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by M.	Clock Slow at 0^h by C.	C—M.
	h		s	s	s
December 1 and 2	10	C M	49·76	49·90	+ 0·14

OBSERVATIONS for the PERSONAL EQUATION between MR. MAIN and MR. TAYLOR.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by M.	Clock Slow at 0^h by F T.	F T—M.
	h		s	s	s
December 25	1	T M	58·10	58·10	0·00

OBSERVATIONS for the PERSONAL EQUATION between MR. MAIN and M. BOUVY.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by M.	Clock Slow at 0^h by Bo.	Bo—M.
	h		s	s	s
December 1 and 2	1	Bo M	49·76	49·91	+ 0·15

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. ROGERSON.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by H.	Clock Slow at 0^h by R.	R—H.
	h		s	s	s
January 4 and 5	8	R H	57·66	58·30	+ 0·64
12, 13, and 14	12	R H	6·62	7·44	+ 0·82
21 and 22	11	H R	11·82	12·53	+ 0·71
31, Feb. 1 and 2	11	R H	19·04	19·62	+ 0·58
February 17 and 18	12	H R	28·39	29·02	+ 0·63
March 14 and 15	7	H R	44·04	44·66	+ 0·62
27	1	R H	50·59	51·33	+ 0·74
April 8 and 9	12	H R	56·31	57·06	+ 0·75

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. DUNKIN.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by D.	D−H.
	h		s	s	s
January 4 and 5	3	D H	57·66	57·70	+ 0·04
March 29 and 30	9	D H	52·35	52·32	− 0·03
June 28, 29, and 30	11	D H	45·33	45·50	+ 0·17
Oct. 24, 25, and 26	7	D H	45·97	46·24	+ 0·27
Nov. 16, 17, and 18	8	D H	58·15	58·34	+ 0·19
20, 21, and 22	6	D H	56·58	56·56	− 0·02
December 14 and 15	11	D H	52·13	52·19	+ 0·06

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. HUGH BREEN.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by H B.	H B−H.
	h		s	s	s
July 22	8	H H B	7·29	7·71	(+ 0·42)
September 21	2	H B H	21·24	21·14	− 0·10
Nov. 17, 18, and 19	4	H H B	57·65	57·63	− 0·02

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. HENDERSON.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by J H.	J H−H.
	h		s	s	s
September 23 and 24	4	H J H	22·79	23·16	+ 0·37

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. ELLIS.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by E.	E−H.
	h		s	s	s
September 13	1	E H	14·14	14·19	+ 0·05
17	0	H E	17·86	17·88	+ 0·02
18 and 19	0	E H	19·50	19·69	+ 0·19
21 and 22	5	H E	21·24	21·14	− 0·10
October 28	9	E H	49·72	49·44	− 0·28
30 and 31	12	E H	2·38	2·58	+ 0·20
November 17 and 18	0	E H	58·15	58·09	− 0·06

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. J. W. BREEN.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by J B.	J B—H.
		h		s	s	s
July	6 and 7	11	JB H	51 ·57	51 ·80	+ 0 ·23
September	5 and 6	4	H J B	5 ·16	5 ·37	+ 0 ·21
October	31	0	H J B	2 ·38	2 ·52	+ 0 ·14
November	17 and 18	0	H J B	57 ·65	57 ·79	+ 0 ·14

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. CRISWICK.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by C.	C—H.
		h		s	s	s
September	13	4	H C	14 ·14	14 ·29	+ 0 ·15

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. TAYLOR.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by F T.	F T—H.
		h		s	s	s
June	29 and 30	10	F T H	45 ·33	45 ·22	— 0 ·11
	29 and 30	0	H F T	46 ·13	46 ·21	+ 0 ·08
July	6 and 7	2	H F T	52 ·43	52 ·28	— 0 ·15

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and M. BOUVY.

Day, 1853.		Interval of nearest Star.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by Bo.	Bo—H.
		h		s	s	s
December	1 and 2	9	Bo H	49 ·81	49 ·91	+ 0 ·10

OBSERVATIONS for the PERSONAL EQUATION between MR. ROGERSON and MR. DUNKIN.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by R.	Clock Slow at 0h by D.	D—R.
		h		s	s	s
January	4	5	R D	57 ·34	56 ·74	— 0 ·60
	25 and 26	8	D R	15 ·33	14 ·79	— 0 ·54
	30 and 31	1	D R	18 ·88	18 ·24	— 0 ·64
	30, 31, and Feb. 1	8	D R	19 ·62	19 ·02	— 0 ·60
February	17, 18, and 19	10	R D	29 ·46	29 ·00	— 0 ·46
March	10 and 11	11	R D	41 ·31	40 ·78	— 0 ·53
	25 and 26	7	R D	50 ·21	49 ·71	— 0 ·50
	28 and 29	1	D R	52 ·12	51 ·47	— 0 ·65
	28, 29, and 30	4	R D	52 ·92	52 ·32	— 0 ·60

OBSERVATIONS for the PERSONAL EQUATION between MR. ROGERSON and MR. HENDERSON.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by R.	Clock Slow at 0^h by J H.	J H—R.
	h		s	s	s
February 27 and 28	4	R J H	33 ·87	33 ·64	— 0 ·23
27, 28, and Mar. 1	6	J H R	34 ·52	34 ·23	— 0 ·29
March 23 and 24	7	R J H	49 ·50	49 ·00	— 0 ·50
31, April 1 and 2	6	JH R	54 ·76	54 ·37	— 0 ·39

OBSERVATIONS for the PERSONAL EQUATION between MR. ROGERSON and MR. CRISWICK.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by R.	Clock Slow at 0^h by C.	C—R.
	h		s	s	s
March 28 and 29	3	C R	52 ·12	51 ·51	— 0 ·61

OBSERVATIONS for the PERSONAL EQUATION between MR. DUNKIN and MR. HUGH BREEN.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by D.	Clock Slow at 0^h by H B.	H B—D.
	h		s	s	s
November 18 and 19	0	HB D	57 ·29	57 ·21	— 0 ·08

OBSERVATIONS for the PERSONAL EQUATION between MR. DUNKIN and MR. HENDERSON.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by D.	Clock Slow at 0^h by J H.	J H—D.
	h		s	s	s
April 26 and 27	5	D J H	58 ·98	59 ·25	+ 0 ·27
November 8 and 9	10	J H D	4 ·12	4 ·30	+ 0 ·18
16 and 17	7	J H D	58 ·91	59 ·04	+ 0 ·13
December 12	3	D J H	50 ·60	50 ·58	— 0 ·02

OBSERVATIONS for the PERSONAL EQUATION between MR. DUNKIN and MR. ELLIS.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by D.	Clock Slow at 0^h by E.	E—D.
	h		s	s	s
August 10 and 11	9	D E	30 ·63	30 ·43	— 0 ·20
24 and 25	6	E D	51 ·22	50 ·98	— 0 ·24
26 and 27	0	D E	53 ·79	53 ·67	— 0 ·12
29	1	E D	56 ·51	56 ·39	— 0 ·12

OBSERVATIONS for the PERSONAL EQUATION between MR. DUNKIN and MR. ELLIS—*continued.*

Day, 1853.		Interval of nearest Stars.	Order of Observations.		Clock Slow at 0^h by D.	Clock Slow at 0^h by E.	E—D.
		h			s	s	s
October	14	0	D	E	36·87	36·70	− 0·17
	16	3	D	E	39·13	39·13	0·00
	17 and 18	0	D	E	40·86	40·66	− 0·20
	20	0	E	D	42·31	42·24	− 0·07
	23 and 24	7	D	E	44·83	45·03	+ 0·20
	23, 24 and 25	4	E	D	45·78	45·79	+ 0·01
	27 and 28	7	D	E	49·60	49·44	− 0·16
November	8 and 9	0	D	E	4·12	3·95	− 0·17
	11	1	D	E	3·35	3·26	− 0·09
	13	2	E	D	2·30	2·19	− 0·11
	16 and 17	0	D	E	58·34	58·09	− 0·25
	19	7	D	E	57·29	57·21	− 0·08
December	26 and 27	5	E	D	58·22	58·27	+ 0·05
	28	6	D	E	58·41	58·28	− 0·13
	28 and 29	4	E	D	58·77	58·58	− 0·19
	30 and 31	6	D	E	59·12	59·00	− 0·12

OBSERVATIONS for the PERSONAL EQUATION between MR. DUNKIN and MR. J. W. BREEN.

Day, 1853.		Interval of nearest Stars.	Order of Observations.		Clock Slow at 0^h by D.	Clock Slow at 0^h by J B.	J B—D.
		h			s	s	s
September	5 and 6	0	J B	D	6·50	6·40	− 0·10
November	16 and 17	6	J B	D	58·34	58·25	− 0·09
	20 and 21	1	D	J B	56·56	56·58	+ 0·02
December	23	0	D	J B	56·51	56·53	+ 0·02
	24	8	D	J B	57·09	56·98	− 0·11
	24 and 25	7	J B	D	57·55	57·53	− 0·02

OBSERVATIONS for the PERSONAL EQUATION between MR. DUNKIN and MR. CRISWICK.

Day, 1853.		Interval of nearest Stars.	Order of Observations.		Clock Slow at 0^h by D.	Clock Slow at 0^h by C.	C—D.
		h			s	s	s
March	28	1	C	D	50·54	50·71	+ 0·17
May	25 and 26	1	D	C	15·90	15·94	+ 0·04
August	23 and 24	6	D	C	48·32	48·31	− 0·01
	26 and 27	6	D	C	53·79	53·84	+ 0·05
November	19	0	D	C	57·29	57·31	+ 0·02
December	13 and 14	9	C	D	52·19	52·09	− 0·10
	27	9	D	C	58·22	58·13	− 0·09
	27 and 28	9	C	D	58·41	58·43	+ 0·02

OBSERVATIONS for the PERSONAL EQUATION between MR. DUNKIN and MR. TAYLOR.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by D.	Clock Slow at 0^h by F T.	F T–D.
		h		s	s	s
June	22	0	D F T	39 ·92	39 ·76	– 0 ·16
	28 and 29	0	D F T	45 ·50	45 ·22	– 0 ·28
August	1	1	D F T	18 ·89	18 ·82	– 0 ·07
	12	0	F T D	33 ·48	33 ·26	– 0 ·22
December	12	0	D F T	50 ·60	50 ·33	– 0 ·27
	25	6	D F T	57 ·55	57 ·60	+ 0 ·05

OBSERVATIONS for the PERSONAL EQUATION between MR. DUNKIN and PROFESSOR C. PIAZZI SMYTH.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by D.	Clock Slow at 0^h by S.	S–D.
		h		s	s	s
August	26 and 27	0	D S	53 ·79	53 ·95	+ 0 ·16

OBSERVATIONS for the PERSONAL EQUATION between MR. HUGH BREEN and MR. ELLIS.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by H B.	Clock Slow at 0^h by E.	E–H B.
		h		s	s	s
June	23 and 24	8	E H B	40 ·53	40 ·67	+ 0 ·14
September	21 and 22	7	H B E	21 ·14	21 ·14	0 ·00
November	18 and 19	2	H B E	57 ·21	57 ·21	0 ·00

OBSERVATIONS for the PERSONAL EQUATION between MR. HUGH BREEN and MR. J. W. BREEN.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by H B.	Clock Slow at 0^h by J B.	J B–H B.
		h		s	s	s
November	18 and 19	5	J B H B	57 ·21	57 ·29	+ 0 ·08

OBSERVATIONS for the PERSONAL EQUATION between MR. HUGH BREEN and MR. CRISWICK.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by H B.	Clock Slow at 0^h by C.	C–H B.
		h		s	s	s
November	18 and 19	0	H B C	57 ·21	57 ·31	+ 0 ·10

OBSERVATIONS for the PERSONAL EQUATION between MR. HUGH BREEN and MR. TAYLOR.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by H B.	Clock Slow at 0^h by F T.	F T—H B.
	h		s	s	s
June 23 and 24	11	F T HB	40·53	40·35	— 0·18
23 and 24	0	HB F T	41·43	41·13	— 0·30

OBSERVATIONS for the PERSONAL EQUATION between MR. HENDERSON and MR. ELLIS.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by J H.	Clock Slow at 0^h by E.	E—J H.
	h		s	s	s
June 19	1	J H E	37·61	37·58	— 0·03
July 19	9	J H E	4·34	4·23	— 0·11
September 18 and 19	7	J H E	18·76	18·69	— 0·07
23 and 24	1	J H E	23·86	23·67	— 0·19
25 and 26	1	E J H	24·64	24·46	— 0·18

OBSERVATIONS for the PERSONAL EQUATION between MR. HENDERSON and MR. J. W. BREEN.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by J H.	Clock Slow at 0^h by J B.	J B—J H.
	h		s	s	s
November 16	0	J H J B	59·04	59·00	— 0·04
December 16	3	J B J H	53·60	53·47	— 0·13

OBSERVATIONS for the PERSONAL EQUATION between MR. HENDERSON and MR. CRISWICK.

Day, 1853.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by J H.	Clock Slow at 0^h by C.	C—J H.
	h		s	s	s
November 23	6	J H C	55·82	55·76	— 0·06
December 1 and 2	0	J H C	50·00	49·90	— 0·10
8	13	J H C	45·98	45·98	0·00
16	2	C J H	53·60	53·54	— 0·06

OBSERVATIONS for the PERSONAL EQUATION between MR. HENDERSON and MR. TAYLOR.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by J H.	Clock Slow at 0^h by F T.	F T – J H
		h		s	s	s
July	9	1	F T J H	54·58	54·26	– 0·32
September	20	0	J H F T	20·60	20·35	– 0·25
December	12	1	F T J H	50·58	50·33	– 0·25
	16	2	F T J H	53·60	53·30	– 0·30

OBSERVATIONS for the PERSONAL EQUATION between MR. HENDERSON and MR. TODD.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by J H.	Clock Slow at 0^h by T.	T – J H.
		h		s	s	s
May	18	0	J H T	9·86	9·75	– 0·11

OBSERVATIONS for the PERSONAL EQUATION between MR. HENDERSON and M. BOUVY.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by J H.	Clock Slow at 0^h by Bo.	Bo – J H.
		h		s	s	s
December	1 and 2	6	Bo J H	50·62	50·53	– 0·09

OBSERVATIONS for the PERSONAL EQUATION between MR. ELLIS and Mr. J. W. BREEN.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by E.	Clock Slow at 0^h by J B.	J B – E.
		h		s	s	s
September	30	0	E J B	26·92	26·92	0·00

OBSERVATIONS for the PERSONAL EQUATION between Mr. ELLIS and Mr. CRISWICK.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by E.	Clock Slow at 0^h by C.	C – E.
		h		s	s	s
August	23, 24 and 25	6	C E	49·56	49·71	+ 0·15
	27	7	E C	53·67	53·84	+ 0·17
November	19	5	C E	5/·21	57·31	+ 0·10
December	13	9	E C	51·32	51·25	– 0·07

OBSERVATIONS for the PERSONAL EQUATION between Mr. ELLIS and Mr. TAYLOR.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by E.	Clock Slow at 0^h by F T.	F T – E.
		h		s	s	s
June	23	1	E F T	40·67	40·35	– 0·32
July	5	0	E F T	50·97	50·79	– 0·18
	24 and 25	0	E F T	10·81	10·61	– 0·20

OBSERVATIONS for the PERSONAL EQUATION between MR. ELLIS and PROFESSOR C. PIAZZI SMYTH.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by E.	Clock Slow at 0^h by. S.	S – E.
		h		s	s	s
August	27	2	S E	53·67	53·95	+ 0·28

OBSERVATIONS for the PERSONAL EQUATION between MR. J. W. BREEN and MR. CRISWICK.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by J B.	Clock Slow at 0^h by C.	C – J B.
		h		s	s	s
December	16	1	J B C	53·47	53·54	+ 0·07

OBSERVATIONS for the PERSONAL EQUATION between MR. J. W. BREEN and MR. TAYLOR.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by J B.	Clock Slow at 0^h by F T.	F T—J B.
		h		s	s	s
December	16	2	J B F T	53·47	53·30	— 0·17

OBSERVATIONS for the PERSONAL EQUATION between MR. CRISWICK and MR. TAYLOR.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by C.	Clock Slow at 0^h by F T.	F T—C.
		h		s	s	s
December	16	0	C F T	53·54	53·30	— 0·24

OBSERVATIONS for the PERSONAL EQUATION between MR. CRISWICK and PROFESSOR C. PIAZZI SMYTH.

Day, 1853.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by C.	Clock Slow at 0^h by S.	S—C.
		h		s	s	s
August	27	9	S C	53·84	53·95	+ 0·11

OBSERVATIONS for the PERSONAL EQUATION between MR. CRISWICK and M. BOUVY.

Day, 1853.		Interval of nearest Stars.	Order of Observations.		Clock Slow at 0^h by C.	Clock Slow at 0^h by Bo.	Bo—C.
		h			s	s	s
November	27	4	Bo	C	52 ·82	53 ·12	+ 0 ·30
December	1	9	Bo	C	50 ·52	50 ·53	+ 0 ·01
	1 and 2	1	C	Bo	49 ·90	49 ·91	+ 0 ·01
	4	0	Bo	C	48 ·41	48 ·57	+ 0 ·16

From these differences, if we form equations wherein each observer's initial shall successively stand first, we obtain the following groups of equations:—

For M.

		s
2 (M − H)	=	− 0 ·14
M − R	=	− 0 ·64
3 (M − D)	=	− 0 ·30
M − J H	=	− 0 ·21
2 (M − E)	=	− 0 ·46
M − C	=	− 0 ·14
M − F T	=	0 ·00
M − Bo	=	− 0 ·15

For H.

2 (H − M)	=	+ 0 ·14
8 (H − R)	=	− 5 ·49
7 (H − D)	=	− 0 ·68
2 (H − HB)	=	+ 0 ·12
H − J H	=	− 0 ·37
7 (H − E)	=	− 0 ·02
4 (H − J B)	=	− 0 ·72
H − C	=	− 0 ·15
3 (H − F T)	=	+ 0 ·18
H − Bo	=	− 0 ·10

For R.

R − M	=	+ 0 ·64
8 (R − H)	=	+ 5 ·49
9 (R − D)	=	+ 5 ·12
4 (R − J H)	=	+ 1 ·41
R − C	=	+ 0 ·61

For D.

		s
3 (D − M)	=	+ 0 ·30
7 (D − H)	=	+ 0 ·68
9 (D − R)	=	− 5 ·12
D − HB	=	+ 0 ·08
4 (D − J H)	=	− 0 ·56
20 (D − E)	=	+ 2 ·16
6 (D − J B)	=	+ 0 ·28
8 (D − C)	=	− 0 ·10
6 (D − F T)	=	+ 0 ·95
D − S	=	− 0 ·16

For H B.

2 (HB − H)	=	− 0 ·12
HB − D	=	− 0 ·08
3 (HB − E)	=	− 0 ·14
HB − JB	=	− 0 ·08
HB − C	=	− 0 ·10
2 (HB − F T)	=	+ 0 ·48

For J H.

J H − M	=	+ 0 ·21
J H − H	=	+ 0 ·37
4 (J H − R)	=	− 1 ·41
4 (J H − D)	=	+ 0 ·56
5 (J H − E)	=	− 0 ·58
2 (J H − J B)	=	+ 0 ·17
4 (J H − C)	=	+ 0 ·22
4 (J H − F T)	=	+ 1 ·12
J H − T	=	+ 0 ·11
J H − Bo	=	+ 0 ·09

For E.

	s
2 (E − M)	= + 0·46
7 (E − H)	= + 0·02
20 (E − D)	= − 2·16
3 (E − HB)	= + 0·14
5 (E − JH)	= − 0·58
E − JB	= 0·00
4 (E − C)	= − 0·35
3 (E − FT)	= + 0·70
E − S	= − 0·28

For J B.

4 (JB − H)	= + 0·72
6 (JB − D)	= − 0·28
JB − HB	= + 0·08
2 (JB − JH)	= − 0·17
JB − E	= 0·00
JB − C	= − 0·07
JB − FT	= + 0·17

For C.

C − M	= + 0·14
C − H	= + 0·15
C − R	= − 0·61
8 (C − D)	= + 0·10
C − HB	= + 0·10
4 (C − JH)	= − 0·22
4 (C − E)	= + 0·35
C − JB	= + 0·07

For C—*continued.*

	s
C − FT	= + 0·24
C − S	= − 0·11
4 (C − Bo)	= − 0·48

For F T.

FT − M	= 0·00
3 (FT − H)	= − 0·18
6 (FT − D)	= − 0·95
2 (FT − HB)	= − 0·48
4 (FT − JH)	= − 1·12
3 (FT − E)	= − 0·70
FT − JB	= − 0·17

For S.

S − D	= + 0·16
S − E	= + 0·28
S − C	= + 0·11

For Bo.

Bo − M	= + 0·15
Bo − H	= + 0·10
Bo − JH	= − 0·09
4 (Bo − C)	= + 0·48

For T.

T − JH	= − 0·11

Now, since one of the above quantities denoted by M, H, R, &c., must evidently be indeterminate, we will refer all the rest to D as a standard; and, putting D = 0, the initials M, H, R, &c., will represent the values of "clock slow," which would be given by the observations of Mr. Main, Mr. Henry, Mr. Rogerson, &c., when that given by the observations of Mr. Dunkin = 0.

Then, adding all the equations in each group, we get the following equations, in which each observer's personal equation is succesively affected by a large co-efficient :

$$12\,M - 2\,H - R - JH - 2\,E - C - FT - Bo = -2{\cdot}04$$
$$36\,H - 2\,M - 8\,R - 2\,HB - JH - 7\,E - 4\,JB - C - 3\,FT - Bo = -7{\cdot}09$$
$$23\,R - M - 8\,H - 4\,JH - C = +13{\cdot}27$$
$$10\,HB - 2\,H - 3\,E - JB - C - 2\,FT = -0{\cdot}04$$
$$27\,JH - M - H - 4\,R - 5\,E - 2\,JB - 4\,C - 4\,FT - T - Bo = +2{\cdot}02$$
$$46\,E - 2\,M - 7\,H - 3\,HB - 5\,JH - JB - 4\,C - 3\,FT - S = -2{\cdot}05$$
$$16\,JB - 4\,H - HB - 2\,JH - E - C - FT = +0{\cdot}45$$
$$27\,C - M - H - R - HB - 4\,JH - 4\,E - JB - FT - S - 4\,Bo = -0{\cdot}27$$
$$20\,FT - M - 3\,H - 2\,HB - 4\,JH - 3\,E - JB = -3{\cdot}60$$
$$3\,S - E - C = +0{\cdot}55$$
$$7\,Bo - M - H - JH - 4\,C = +0{\cdot}64$$
$$T - JH = -0{\cdot}11$$

Solving these equations by successive aproximations, that is, by first substituting, in the equations with the largest co-efficients, the approximately known values of the personal equations belonging to all but that co-efficient, and then using successively the corrected values, we get finally the following values :—

$M = -0^s{\cdot}15$; $H = -0^s{\cdot}12$; $R = +0^s{\cdot}55$; $HB = -0{\cdot}09$; $JH = +0^s{\cdot}11$; $E = -0^s{\cdot}07$
$JB = -0^s{\cdot}01$; $C = +0^s{\cdot}01$; $FT = -0^s{\cdot}20$; $S = +0^s{\cdot}16$; $Bo = +0^s{\cdot}08$; $T = 0^s{\cdot}00$.

Or, remembering that each of these values represents the "clock-slow" for the corresponding observer when that for D = 0, we have, by restoring D

D − M	= + 0·15 s	D − JH	= − 0·11 s	D − FT	= + 0·20 s
D − H	= + 0·12	D − E	= + 0·07	D − S	= − 0·16
D − R	= − 0·55	D − JB	= + 0·01	D − Bo	= − 0·08
D − HB	= + 0·09	D − C	= − 0·01	D − T	= 0·00

These corrections have been applied whenever they were needed throughout the year 1853.

For the determination of personal equations, experimental observations have been likewise made with Mr. T. Jones' Binocular Eye-piece, of which a description is given in the Introduction to the volume for 1852, page xlvi.

The following are the results of the observations, of which however no farther use has been made :—

Day, 1853.	Name of Star.	Observers. First	Observers. Second	East Observer.	Seconds of Transit by First Observer.	Seconds of Transit by Second Observer.	Excess of First Observer.
October 14	60 Aquarii	D	E	D	53·73 s	53·64 s	+ 0·09 s
	ζ Pegasi			E	33·34	33·51	− 0·17
	λ Aquarii			D	22·22	22·27	− 0·05
	β Piscium			E	49·27	49·52	− 0·25
	A Piscium			D	34·72	34·75	− 0·03
	59 Pegasi			E	44·44	44·66	− 0·22
	Polaris			D	2·34	3·34	− 1·00
	Polaris			E	2·44	3·44	− 1·00

Day, 1853.	Name of Star.	Observers. First	Observers. Second	East Observer.	Seconds of Transit by First Observer.	Seconds of Transit by Second Observer.	Excess of First Observer.
October 20	ξ Pegasi	D	E	E	40 ·94	41 ·06	− 0 ·12
	σ Pegasi			D	17 ·00	17 ·03	− 0 ·03
	ρ Pegasi			E	9 ·66	9 ·81	− 0 ·15
	β Piscium			D	43 ·71	43 ·74	− 0 ·03
	55 Pegasi			E	55 ·85	56 ·10	− 0 ·25
	58 Pegasi			D	57 ·41	57 ·37	+ 0 ·04
November 8	42 Piscium	H	J H	H	47 ·56	47 ·86	− 0 ·30
	45 Piscium			J H	5 ·77	6 ·09	− 0 ·32
	49 Piscium			H	7 ·72	8 ·06	− 0 ·34
	B. A. C. 137			J H	32 ·14	32 ·42	− 0 ·28
	53 Piscium			H	6 ·59	6 ·78	− 0 ·19
	B. A. C. 177			J H	34 ·70	35 ·13	− 0 ·43
November 9	B. A. C. 8365	D	E	D	29 ·84	30 ·07	− 0 ·23
	34 Piscium			E	27 ·47	27 ·67	− 0 ·20
	γ Pegasi			D	38 ·71	38 ·70	+ 0 ·01
	d Piscium			E	0 ·38	0 ·69	− 0 ·31
	44 Piscium			D	50 ·44	50 ·46	− 0 ·02
	B. A. C. 113			E	33 ·69	33 ·74	− 0 ·05
November 18	B. A. C. 8365	H	J H	H	36 ·29	36 ·09	+ 0 ·20
	B. A. C. 5			J H	15 ·81	15 ·68	+ 0 ·13
	γ Pegasi			H	45 ·13	44 ·63	+ 0 ·50
	B. A. C. 42			J H	29 ·50	29 ·17	+ 0 ·33
	40 Piscium			H	25 ·53	25 ·32	+ 0 ·21
	B. A. C. 81			J H	4 ·20	3 ·63	+ 0 ·57

The *eighteenth* column contains the duration of passage of the semidiameter of a planet when both limbs have not been observed. For the Sun and Moon, the duration of passage is, for the year 1853, taken without alteration from the Nautical Almanac, as, commencing with this year, the corrections derived from the Greenwich Observations, and applied in former years to the tabular duration of passage, have been incorporated in that work. For Mercury, the duration of passage is taken without alteration from the Nautical Almanac; for Venus, the quantities given in the Nautical Almanac are increased by the correction

$$+ 0^{s}{\cdot}05 + 0{\cdot}03 \times \text{Time of passage of semidiameter.}$$

For Mars a new determination has been made from observations near the opposition of 1854. The mean of twenty transits, properly corrected for defect of illumination, gives for the observed duration of passage $1^{s}{\cdot}12$, while the corresponding mean for the tabular duration is $0^{s}{\cdot}86$. Hence the correction to be applied additively to the tabular times of duration, to represent these observations, is

$$\frac{1^{s}{\cdot}12 - 0^{s}{\cdot}86}{0{\cdot}86} \times \text{Time of passage of tabular semidiameter;}$$

$$\text{or } 0{\cdot}304 \times \text{Time of passage of tabular semidiameter.}$$

For Jupiter and Saturn, both limbs are always observed, if possible; but if, by accident or necessity, only one limb is observed, the duration of passage of the semidiameter is obtained from a few of the neighbouring observations.

The *nineteenth* column contains the right ascension of the center of the body observed: it is formed by adding the time from the fourteenth column, the clock error at 0^h next preceding from the seventeenth column, the proportional part of the rate in the same column corresponding to the right ascension, and the duration of the passage of the semidiameter from the eighteenth column. No result is set down for a clock-star, unless at least four clock-stars, distributed over several hours of Right Ascension, excluding Polaris, have been observed; and no result is set down for Polaris or δ Ursæ Minoris, or other close circumpolar stars, unless Polaris or δ Ursæ Minoris has been observed at opposite passages.

The *twentieth* column contains the correction with its proper sign, as it is to be applied for reducing the apparent right ascension at the time of observation to the mean right ascension on the 1st of January, 1853. It is computed in the following manner.

For stars in the list of the Nautical Almanac, the mean R. A. of the Nautical Almanac is subtracted from the apparent R. A. of the Nautical Almanac (corrected, in the case of Polaris, Cephei 51 (Hev.), δ Ursæ Minoris, and λ Ursæ Minoris, for the Moon's longitude): the sign of the quantity so found is changed.

For other stars the corrections are computed by the formula

$$\mathrm{E\,e + F\,f + G\,g + H\,h + L + l \quad 300^s},$$

which is derived from the well-known formula,

$$\mathrm{A}\,a + \mathrm{B}\,b + \mathrm{C}\,c + \mathrm{D}\,d,$$

or its equivalent,

$$\frac{\mathrm{A}}{15}\cos \mathrm{R.A.}\ \mathrm{cosec\ N.P.D.} + \frac{\mathrm{B}}{15}\sin \mathrm{R.A.}\ \mathrm{cosec\ N.P.D.} + \mathrm{C}\sin \mathrm{R.A.}\ \mathrm{cotan\ N.P.D.} \times \mathrm{numb.\ log.}\ 0{\cdot}1259 + \frac{\mathrm{D}}{15}\cos \mathrm{R.A.}\ \mathrm{cot\ N.P.D.} + \mathrm{C} \times \mathrm{numb.\ log.}\ 0{\cdot}4869,$$

by a process which is explained with sufficient detail in the Introduction to the Twelve-Year Catalogue appended to the volume for 1847. It will be sufficient here to state that E = A + 25, F = B + 25, G = C + 1·2, H = D + 25, e = a + 1·2, f = b + 1·2, g = c + 25, h = d + 1·2, L = 210 − 1·2 × E − 1·2 × F − 25 × G − 1·2 × H, l = 210 − 25 × e − 25 × f − 1·2 × g − 25 × h. The values of the day-constants log. E, log. F, log. G, log. H, and L, for the years from 1849 to 1860, both inclusive, and the values of the star-constants, log. e, log. f, log. g, log. h, and l, are generally contained in the "Greenwich Twelve-Year Catalogue." For stars not included in the Twelve-Year Catalogue, the values of log. e, log. f, &c., have been computed, and are given either in a table following the Introduction to the volume of 1848, or in tables following the Catalogues of Stars in the years 1849, 1850, 1851, 1852, and in the present volume. The values of log. A, log. B, log. C, log. D, for the formation of the numbers above, have been taken from the Nautical Almanac for all the published volumes, and for the other years they were obligingly supplied, at my request, by Lieut. Stratford, the late Superintendent of that work. The values of log. *a*, log. *b*, log. *c*, log. *d*, have been taken from the Catalogue of the British Association, whenever the star was found in that Catalogue.

For all stars whose N. P. D. is less than 5°, the small terms of lunar nutation, usually neglected, have been taken into account, corrections being computed corresponding to those given in the Nautical Almanac for Polaris, &c.

The sign of the computed quantity is changed before application.

§ 2. *Observations of the Collimators, and of the Reflected Image of the Central Vertical Wire of the Transit-Circle, for the Determination of the Errors of Collimation, Level, and Azimuth*, page [82] to [96].

Very little information is needed, with regard to these tables, in addition to the explanation which has been given in the description of the instruments, and in the explanation of the methods of determining the errors of collimation and level.

A few remarks under the head of each separate Table will be sufficient.

OBSERVATIONS FOR COINCIDENCE OF COLLIMATORS.

These observations are made on the Monday of every week, the Transit-Circle being raised to admit a view of the North Collimator by the South Collimator.

By means of the micrometer of the South Collimator, the nearly vertical sides of the squares formed by the intersecting wires are made to cross at their middle points, and the readings of the micrometer-head of the South Collimator are taken six times. The wire is then left at a reading corresponding to the mean of the six. These means are printed in the table, and will give a satisfactory idea of the firmness of the collimators.

OBSERVATIONS OF THE COLLIMATORS FOR DETERMINATION OF THE ERROR OF COLLIMATION.

The way in which these observations are made has been fully explained. The mean of the readings for the separate collimators, and the resulting reading for the line of collimation, are set down in consecutive columns, and the last column gives the reading which has been adopted for the period of time indicated by the bars above and below. By comparing the numbers in this column with the *Readings of Transit-Micrometer* given in the foot-notes of the section *Transits observed*, &c., and applying $-0''\cdot19$ for diurnal aberration, the Errors of Collimation actually used, which are supposed to apply with sufficient accuracy to the mean of wires, will be deduced. For determination of the sign of the Error, it must be observed that the micrometer-head is East, and that the readings of the micrometer increase as the wire moves towards the head.

DETERMINATION OF THE LEVEL ERROR OF THE TRANSIT-CIRCLE.

The method of making these observations has been described (page xxiii). A comparison of the transit-micrometer reading for coincidence of the direct and reflected images of the central wire, with the adopted reading for the line of collimation set down in the contiguous column, gives the error of level in terms of revolutions of the micrometer, and the numbers in the next column give the Errors of Level in arc. The last column gives the adopted values of the Error, and the limits of time during which they have been used. The determination of the sign of the Errors has been previously explained.

DETERMINATION OF THE AZIMUTH OF THE NORTH COLLIMATOR.

The reading of the Transit-Micrometer for coincidence of the transit-wire with the North Collimator, in connection with the reading for the line of collimation, and with the error of azimuth of the Transit-Circle deduced from observations of circumpolar stars, gives a determination of the azimuth of the wire of the collimator. The different columns of the Table give the mean readings for the collimator, the adopted reading for the line of collimation, the error of azimuth of the Transit-Circle, and the names of the circumpolar stars by means of which it has been deduced; and finally, the resulting and adopted values of the azimuth of the North Collimator, with the limits of time during which each value has been used.

The particulars of the determination of the separate values of the azimuth of the Transit-Circle are given in the foot-notes of the section *Transits observed*, &c.

DETERMINATION OF THE AZIMUTH OF THE TRANSIT-CIRCLE BY MEANS OF THE AZIMUTHS OF THE NORTH COLLIMATOR.

The values of the azimuth of the North Collimator, determined in the manner above described, are applied to determine the azimuth of the Transit-Circle for ordinary use. The advantage of the application of such a method depends on the degree of stability of the collimators and the transit-telescope. In the use of instruments of so massive a construction as the great Transit-Circle, and with collimators so firmly mounted as those under consideration, the mean errors of azimuth ultimately deduced by means of the micrometer-readings for coincidence of transit-wire with collimator, the assumed azimuth of collimator, and the known reading for the line of collimation, will be generally much more worthy of credit than the single determination deduced immediately from stars. The columns of the Table require no explanation.

§ 3. *Apparent Right Ascensions of Polaris and δ Ursæ Minoris; and Mean Right Ascensions of Stars observed in the Year* 1853, page [98] to [116].

The apparent right ascensions of Polaris and δ Ursæ Minoris are extracted without alteration from the *nineteenth* column of the *Transits observed*, &c.

The mean right ascensions of stars are found by applying to the apparent right ascensions in the *nineteenth* column the corrections in the *twentieth* column.

The resulting mean right ascensions have been increased by $0^s\cdot55$, when the object whose right ascension is determined was observed by Mr. Rogerson, and the clock-stars by Mr. Dunkin. The corrections applied in the cases of the other observers have been already mentioned.

The results for stars observed with the Binocular Eyepiece are distinguished by a bracket from the other results, to denote that they are of inferior accuracy, and that they will not be ultimately used in conjunction with the other observations for determining the right ascensions of the stars. They are deduced from the transits of that observer who used the Transit-Circle on the day of observation; and, in order to give an accurate result, would require to be combined with the simultaneous transits of the other observer, after correction for personal equation.

The rules for the nomenclature of the stars are the same as those in the section of the *Transits observed*, detailed in page xiii, but they are more rigorously followed. The stars in Weisse's Catalogue are referred to under the initials W.B., which stand for Weisse's Bessel. The stars in Oëltzen's Catalogue of Argelander's Zones are referred to under the abbreviation Oeltz. Arg.; and those in the Greenwich Twelve-Year Catalogue under the abbreviation Gr. (12 yr.).

§ 4. *Observations of Zenith Distance with the Transit-Circle*, page (2) to (96).

The arrangement of the printed observations is the same as for the last year, so as to include the whole of the reductions belonging to a single observation on one page. For this purpose, the elements for the reductions which are not frequently changed, and which do not require tabular arrangement, are given in the foot-notes: these are correction for runs, formula for computing micrometer-corrections, corrections for curvature of path and inclination of wire, and Zenith-Point.

The corrections for planets, including change of N.P.D. for reduction to the meridian, parallax, and semidiameter, and also the corrections for reducing the apparent places of stars to mean places, are exhibited in tabular arrangement at the lower part of each page opposite to the numbers corresponding to the observations in the upper part of the page.

DAY.—The day of observation always begins with the Sun's transit.

NO. FOR REFERENCE.—This column requires no explanation.

NAME OF OBJECT.—The nomenclature of stars follows the same general rule as in the section of *Transits observed*, &c., except that, as a last resource, the place of the star is defined by its right ascension, which may sometimes be in error 5^s or more. The letters N.L. and S.L. denote north and south limbs of planets, and N.C. and S.C. the north and south cusps of Venus. The words *Nadir Observation* indicate an observation of the image of the zenith-distance wire as seen by reflexion in a trough of mercury, as is described in page vi. For other objects, the letter R denotes that the object is observed by reflexion in the trough of mercury.

READINGS OF THE SIX MICROSCOPES.—The application of the letters is the same as in the Observations of preceding years from 1836: the observer, beginning with the northern horizontal microscope, and passing the upper microscopes, the southern horizontal, and the lower ones, in the direction of the circle's circumference, reads them in the order A, C, E, B, D, F. These readings in the observing books are placed in the order $\frac{A, C, E}{B, D, F}$: from which form they are easily changed into the order of printing. Each pair of adjacent readings, therefore, is the pair of readings at the opposite ends of a diameter. The number of integral revolutions is given in the fifth column only. Occasionally the number of revolutions expressed in this column does not apply unchanged to all the microscopes, on account of the difference of their readings; but, since the readings never differ by more than four or five tenths of a revolution, this will occasion no ambiguity. The reading of the pointer-microscope is omitted for the sake of economy of space, but it may be inferred from the Zenith Point given in full at the bottom of each page, and from the deduced Zenith Distance.

I will now proceed to explain how the revolutions and parts of revolutions of the microscope-micrometers are converted into arc.

I must premise that, as one revolution of each microscope-micrometer does not differ extravagantly from 1′ on the limb of the circle, we may consider each revolution as a nominal minute. Next, supposing the number of integral revolutions, as shewn by each microscope, to be the same for all, we ought, in order to obtain the mean of the fractions of a revolution, to add together the subdivisions as shewn by the different micrometer-heads, and divide the sum by 6. Thirdly, as the subdivisions are in the decimal scale, we should then multiply this mean by 60, to reduce it to seconds. It is evident thus that the number of nominal seconds to be attached to the nominal minute will be found by simply adding together the subdivisions on the micrometer-heads, and shifting the decimal point.

It will now be necessary to exhibit the observations made for the runs of the microscopes previously to the use of the instrument. On Nov. 26, 1850, Mr. Dunkin examined, for five different positions of the circle, the values of the runs, and obtained the results exhibited in the following Table, the numbers given in the columns under the six microscopes being the numbers of revolutions corresponding to 5′ on the circle, or to the difference of readings for two consecutive divisions.

Reading of N. P. D. Pointer.	NUMBER OF REVOLUTIONS CORRESPONDING TO 5′ FOR MICROSCOPES					
	A	B	C	D	E	F
° 98	r 4·893	r 4·869	r 4·883	r 4·882	r 4·880	r 4·876
100	·919	·892	·872	·872	·893	·880
102	·915	·876	·888	·884	·891	·871
104	·913	·893	·884	·876	·880	·881
105	·919	·883	·885	·880	·886	·882
Means.....	4·912	4·883	4·882	4·879	4·886	4·878

The results given above shew that the screws of the micrometers are so sensibly equal that, in the reduction of the observations, it is sufficient to take the mean of the six readings, and to apply to it the mean correction for runs. To do this, the following process is employed. The sum of the runs for the six microscopes above given is $29^{r}\cdot320$. Now, if the correction by which each revolution of a micrometer may be converted into a minute of arc were exactly $\frac{1}{50}$ part of the reading, then the sum of the runs would be $\frac{50}{51} \times 30^{r}\cdot000$, or $29^{r}\cdot4118$. It is not likely that the sum of the runs will in ordinary cases amount to this quantity; and the variable correction, after adding $\frac{1}{50}$ part to the mean of the readings of the microscopes, will therefore always be additive. To determine this quantity, let the sum of the runs be $29^{r}\cdot412 - x$. Then the true reading in seconds of space, corresponding to a nominal reading of r'' (including the value in seconds of the nominal minutes) will be

$$r'' \times \frac{30\cdot000}{29\cdot412 - x}$$

or

$$r'' \left\{1 + \frac{1}{50} + 0\cdot03468 \times x\right\}$$

Hence the correction, after adding $\frac{1}{50}$ part of the mean of readings, will be $+ r\,x \times 0''\cdot03468$. For the purpose of calculating this quantity easily by the ordinary proportional scale, it is convenient, in the first place, to compute its value when $r = 100''$. This value, which is evidently $+ 3''\cdot468 \times x$, is tabulated for different values of x. Let X be the number taken from this table; then, for any actual reading r, the correction will be $\frac{r\,X}{100}$: a quantity which can easily be taken from the ordinary sliding-rule.

The correction for runs on 100 seconds, determined by the method which has been previously explained, is given in the foot-notes.

MICROMETER-READING.—This column contains the reading of the micrometer in the eye-piece of the telescope. The instrument is furnished with two clamps, one north and the other south, for fixing the instrument, but with no slow-motion screw; the object must therefore be bisected by means of the micrometer-screw, and the micrometer must be read, for every observation. The reading of 20^{r} corresponds pretty nearly to the middle of the range of the screw, and the wire is then tolerably near the center of the field of view; observations are, therefore, generally made with a position of the wire not greatly different from this.

The assumed value of one revolution of the zenith distance micrometer $= 29''\cdot626$. This value is the result of the investigation made at the end of 1850, as explained in the description of the Transit Circle, page {22} Appendix I. of the volume for 1852.

A new investigation for verification of the value was made on October 28, 1853, and the resulting value was $29''\cdot618$.

VERTICAL WIRE AT WHICH OBSERVATION IS MADE. — The telescope contains seven vertical or transit wires, as has been previously mentioned, placed at sensibly equal intervals of about 14^{s} (Table, page xv), and the central wire is so nearly in the meridian as to prevent the necessity of any correction to the observed circle-reading when the body is observed at the passage over that wire. In that case the only corrections which are required to the mean of the microscope-readings (when converted to arc and combined with the equivalent for the telescope-micrometer reading) are those arising from errors of division of the graduated circle, and from astronomical flexure of the telescope. The errors due to these causes have been very elaborately investigated, and a full account of the investigations will be found in the detailed account of the Instrument, printed as an Appendix to the Volume for 1852. The corrections for flexure, included in the following table, which were used throughout 1853, are the means of three results, two of which were determined near the beginning of 1851, and the remaining one near the end of 1852.

DIVISION CORRECTION + FLEXURE CORRECTION.

(*Always Additive.*)

Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.	Pointer Reading.	Corr.
°	″	°	″	°	″	°	″	°	″	°	″	°	″	°	″	°	″	°	″
0	0·63	36	1·10	72	1·30	108	1·23	144	1·21	180	0·63	216	0·52	252	0·34	288	0·27	324	0·63
1	0·66	37	1·20	73	1·35	109	1·23	145	1·29	181	0·64	217	0·60	253	0·39	289	0·29	325	0·71
2	0·70	38	1·28	74	1·49	110	1·16	146	1·27	182	0·66	218	0·66	254	0·53	290	0·22	326	0·71
3	0·70	39	1·38	75	1·57	111	1·09	147	1·18	183	0·64	219	0·76	255	0·61	291	0·15	327	0·64
4	0·71	40	1·46	76	1·58	112	1·05	148	1·09	184	0·65	220	0·82	256	0·60	292	0·12	328	0·57
5	0·73	41	1·51	77	1·56	113	0·98	149	0·99	185	0·65	221	0·85	257	0·58	293	0·06	329	0·47
6	0·78	42	1·56	78	1·54	114	0·97	150	0·85	186	0·68	222	0·90	258	0·56	294	0·05	330	0·35
7	0·89	43	1·55	79	1·55	115	0·99	151	0·83	187	0·77	223	0·87	259	0·57	295	0·09	331	0·35
8	0·93	44	1·43	80	1·65	116	0·98	152	0·85	188	0·79	224	0·73	260	0·67	296	0·08	332	0·39
9	0·90	45	1·29	81	1·67	117	0·97	153	0·77	189	0·74	225	0·59	261	0·69	297	0·08	333	0·31
10	0·91	46	1·19	82	1·52	118	1·02	154	0·72	190	0·73	226	0·47	262	0·54	298	0·14	334	0·28
11	0·92	47	1·12	83	1·39	119	1·07	155	0·86	191	0·74	227	0·38	263	0·41	299	0·19	335	0·44
12	0·91	48	1·12	84	1·41	120	1·06	156	1·01	192	0·72	228	0·38	264	0·43	300	0·20	336	0·61
13	0·98	49	1·14	85	1·50	121	1·08	157	1·10	193	0·76	229	0·38	265	0·50	301	0·22	337	0·70
14	1·13	50	1·07	86	1·49	122	1·10	158	1·16	194	0·89	230	0·31	266	0·49	302	0·26	338	0·78
15	1·22	51	1·01	87	1·41	123	1·09	159	1·25	195	0·96	231	0·23	267	0·41	303	0·25	339	0·89
16	1·23	52	0·97	88	1·33	124	1·09	160	1·31	196	0·95	232	0·19	268	0·33	304	0·26	340	0·97
17	1·22	53	0·92	89	1·23	125	1·10	161	1·34	197	0·92	233	0·12	269	0·23	305	0·28	341	1·02
18	1·20	54	0·91	90	1·10	126	1·14	162	1·38	198	0·90	234	0·11	270	0·10	306	0·32	342	1·08
19	1·22	55	0·95	91	1·09	127	1·23	163	1·36	199	0·90	235	0·13	271	0·09	307	0·43	343	1·06
20	1·33	56	0·94	92	1·12	128	1·25	164	1·22	200	0·99	236	0·12	272	0·12	308	0·47	344	0·94
21	1·36	57	0·94	93	1·04	129	1·21	165	1·07	201	1·00	237	0·10	273	0·04	309	0·43	345	0·81
22	1·22	58	1·00	94	1·00	130	1·20	166	0·95	202	0·84	238	0·16	274	0·00	310	0·44	346	0·71
23	1·10	59	1·06	95	1·15	131	1·21	167	0·86	203	0·70	239	0·20	275	0·15	311	0·45	347	0·64
24	1·12	60	1·06	96	1·30	132	1·19	168	0·85	204	0·72	240	0·20	276	0·32	312	0·45	348	0·65
25	1·21	61	1·09	97	1·39	133	1·24	169	0·86	205	0·79	241	0·21	277	0·41	313	0·51	349	0·66
26	1·21	62	1·13	98	1·46	134	1·37	170	0·78	206	0·77	242	0·23	278	0·48	314	0·65	350	0·60
27	1·14	63	1·12	99	1·56	135	1·44	171	0·70	207	0·68	243	0·22	279	0·58	315	0·74	351	0·54
28	1·06	64	1·13	100	1·63	136	1·44	172	0·65	208	0·60	244	0·23	280	0·65	316	0·74	352	0·51
29	0·97	65	1·14	101	1·67	137	1·41	173	0·58	209	0·49	245	0·24	281	0·69	317	0·73	353	0·46
30	0·85	66	1·19	102	1·72	138	1·38	174	0·56	210	0·35	246	0·27	282	0·74	318	0·72	354	0·46
31	0·85	67	1·29	103	1·70	139	1·39	175	0·58	211	0·33	247	0·37	283	0·72	319	0·73	355	0·50
32	0·88	60	1·32	104	1·57	140	1·48	176	0·56	212	0·36	248	0·40	284	0·59	320	0·84	356	0·50
33	0·81	69	1·29	105	1·42	141	1·49	177	0·55	213	0·27	249	0·35	285	0·46	321	0·87	357	0·49
34	0·78	70	1·29	106	1·31	142	1·34	178	0·60	214	0·22	250	0·35	286	0·35	322	0·72	358	0·56
35	0·94	71	1·30	107	1·23	143	1·20	179	0·64	215	0·36	251	0·36	287	0·27	323	0·60	359	0·62

When the object has not been observed at the central wire, corrections are required for reduction to the meridian. These consist of three, viz.:—First, for want of horizontality of the micrometer-wire; secondly, for curvature of path of the object, or for difference between the small circle described by the body, and the great circle of which the horizontal wire forms a part; and thirdly, in the case of the Sun, Moon, and Planets, for the change of N.P.D. in the interval between the time of observation and the meridian passage. The correction due to inclination of wire was found by observations of stars made at the first and seventh wires, which are given in the foot-notes to the observations, and the assumed value of the correction for one interval of the wires, viz., $0''\cdot570$, additive before transit, and subtractive after transit, for stars above the pole, is given in the foot-notes. The formula for the correction for curvature is given also in the foot-notes; its value is easily interpolated from a table constructed for convenient intervals of N.P.D. Lastly, for motion, in the case of the Moon, the correction is computed from the formula change of declination for one hour of terrestrial longitude (from the section of Moon-culminating stars in the Nautical Almanac), $\times$ sec. declination $\times \frac{\text{Sin. Geoc. Z.D.}}{\text{Sin. App. Z.D.}} \times$ number (log. $= 7\cdot58983$). In the case of the other planets, the correction for motion is deduced immediately from the hourly motion in declination given in the Nautical Almanac.

SECONDS OF CONCLUDED MERIDIONAL CIRCLE-READING. — The numbers in this column are found by adding together the mean of the microscope-readings corrected for runs, the equivalent for micrometer-reading, and the corrections above mentioned. The degrees and minutes may be ascertained, when required, by subtracting the "Correction for Zenith Point" given in the notes from the Apparent Zenith Distance.

ZENITH-POINT CORRECTION.—The method of formation of the Zenith Point will be understood from the following explanation. The observations for this purpose were those of the reflected image of the wire (made precisely in the same way and at the same time as the observations for level of the axis previously explained) and of the direct and reflected images of stars made at the same transit. They differ in nothing from the method pursued in former years with the Mural Circle, excepting that the zenith points deduced from the reflected image of the wire have been always combined with those deduced from observations of stars. It has been the practice to observe when possible at least one star to the north and one to the south of the zenith on every evening, and, in combining them for zenith point, to allow to each star-observation three times the weight of a nadir-point observation, lest too great weight should be given to the readings of those divisions of the circle which correspond to the nadir-point observations.

If D denote the circle reading for a direct observation of a star, and R that for a reflexion observation, then the reading of the circle corresponding to the zenith, or the zenith-point, will be $\frac{R + D}{2} \pm 90^\circ$.

On account of the very small changes to which the zenith-point is found to be subject, and its sensible invariability for considerable periods of time, it has been the practice to collect in one group observations occupying intervals of time varying from two to four weeks, according to circumstances.

The adopted Correction for Zenith Point, determined by the rules explained above, is given in the foot notes.

APPARENT ZENITH DISTANCE.—The numbers in this column are found by adding the Zenith-Point Correction to the Concluded Meridional Circle Reading; the negative sign denotes that the object is North of the zenith. When the moon has been observed at several wires, the mean of all the concluded circle-readings is used to form the Zenith Distance.

When both limbs of the Moon are observed, it usually happens that one of them is slightly defective from the failure of illumination by the Sun. The necessary correction (which is not applied in this column, but which must be applied with others in order to form the numbers in the column of *Geocentric N. P. D. of Center*) is ascertained by computation in the following manner:—When the Moon is horned, let θ be the angle which the circle joining the cusps makes with the meridian; δ_s the Sun's declination, and δ_m the Moon's declination as seen at Greenwich: P the Sun's hour angle at the Moon's Transit: then

$$\text{Tan}\ \theta = \text{Cosec}\ P.\ \text{Cos}\ \delta_m.\ \text{Tan}\ \delta_s - \text{Cot}\ P.\ \text{Sin}\ \delta_m$$

and the correction required will be

$$\text{Moon's semidiameter} \times \text{vers}\ \theta.$$

If the Moon be gibbous, as is the case in the greater number of instances, draw a great circle through the centre of the Moon, at right angles to the meridian passing through the Moon, and let it meet the meridian passing through the Sun; then the intersection of this circle with the Sun's meridian will determine the place of a fictitious Sun, which would equally illuminate both limbs of the Moon when on the meridian; and the elevation or depression of the true Sun above or below the great circle joining the Moon and fictitious Sun, measured in a plane at right angles to that circle, will represent the angle by which the lowest or highest part of the illuminated hemisphere is distant from the limb, and therefore the angle whose versed sine multiplied into the moon's semi-diameter is the correction required.

Let then P be the North Pole of the heavens, M the Moon on the meridian of Greenwich, and S and S_1 the true and fictitious Suns, and imagine the triangles formed by great circles joining these. Let also δ_1 be the declination of the fictitious Sun, θ_1 the arc joining the true and fictitious Suns, and θ the perpendicular arc before mentioned.

Then $\quad \text{Tan}\ \delta_1 = \text{Tan}\ \delta_m.\ \text{Cos}\ MPS_1$

And $\quad \theta_1 = \delta_s - \delta_1$

Also
$$\text{Sin}\ \theta = \text{Sin}\ \theta_1.\ \text{Sin}\ MS_1P = \text{Sin}\ \theta_1 \frac{\text{Sin}\ MP}{\text{Sin}\ S_1P} = \text{Sin}\ \theta_1 \frac{\text{Cos}\ \delta_m}{\text{Cos}\ \delta_1}$$

Whence θ is found; and the correction required is

$$\text{Moon's semidaimeter} \times \text{vers}\ \theta.$$

In either case the North limb is fully illuminated if θ is positive, and the South limb if θ is negative.

A similar investigation will apply in the cases of Mercury and Venus for the computation of the unilluminated portions of their discs, excepting that the values of sin θ require in this case the additional multiplier $\frac{\text{Dist. of Earth from Sun.}}{\text{Dist. of Planet from Sun.}}$

BAROMETER.—This instrument is by Newman; the raising of the index by which the upper surface of the mercury is read, depresses a plunger in the cistern of mercury, for the purpose of making the elevation of its surface invariable. This barometer is not fit for any delicate purpose, but it is sufficiently accurate for computation of refraction.

EXTERIOR THERMOMETER.—This thermometer is by Troughton and Simms. It is mounted on the outside of the Transit-Circle Room, at the distance of nearly four feet from the north wall, in a tinned case, with its bulb quite free to the current of air, but protected from radiation.

INTERIOR THERMOMETER.—This is a small thermometer suspended in a free current of air in the Transit-Circle Room.

REFRACTION.—The refraction is computed by Bessel's tables in the *Tabulæ Regiomontanæ*. These tables, altered in form (but so as to give in all cases the same result) and expanded, are given in the Appendix to the volume for 1836. They are also given in a still more expanded form in an Appendix to the present volume. The exterior thermometer only is used in the computation, excepting in cases when the Zenith Distance exceeds 85°; these cases are always mentioned in the foot-notes, and the computation is made by means of the supplementary table in the *Tabulæ*.

PARALLAX.—The parallaxes of the Sun, Moon, and Planets, actually employed, are given in the lower part of the page, as previously stated; the assumed ellipticity of the Earth being $\frac{1}{300}$. For the planets the formula is, log. parallax = log. sin (zen. dist. − 11'. 12") + ar. co. log. distance + 0·9325. For the Moon, to the horizontal equatoreal parallaxes, interpolated from the Nautical Almanac, are applied the corrections given by Mr. Adams in his paper on the Moon's Parallax contained in the Appendix to the Nautical Almanac for 1856.

The formula employed for the computation of the parallax to be applied to the observed zenith distance, is

Parallax = (Hor. Equat. Par. from N.A. + Adam's Corr.) × Log. Sin Dist. from Geoc. Zenith + Corr. derived from the following table:—

Z. D.	Correction for South Limb.	Z. D.	Correction for South Limb.	Z. D.	Correction for North Limb.	Z. D.	Correction for North Limb.
°	"	°	"	°	"	°	"
30	− 0·01	60	+ 0·10	30	− 0·08	60	− 0·10
35	0·00	65	+ 0·11	35	− 0·09	65	− 0·10
40	+ 0·02	70	+ 0·13	40	− 0·09	70	− 0·10
45	+ 0·03	75	+ 0·15	45	− 0·10	75	− 0·10
50	+ 0·05	80	+ 0·16	50	− 0·10	80	− 0·09
55	+ 0·07			55	− 0·10		

The correction tabulated above is the sum of two corrections, viz.: of one peculiar to the Moon's limbs, for which the numbers may be inferred from the Table of Corrections given in a subsequent part of this Introduction for the Moon's parallax in Occultations, by supposing V (the angle for the Moon's limb from the vertical) = 0° or 180°; and of another due to the employment of the arc of equatoreal parallax instead of its sine, for which the formula is,

$$-\frac{(\text{Seconds of hor. parallax})^3}{6} \times \text{Cos}^2\ \text{Z. D.} \times \text{Sin Z. D.} \times \text{Sin}^2\ 1''.$$

For the computation of the parallaxes for the small planets recently discovered, the distances of Flora, Victoria, Iris, Metis, Hebe, Astræa, Irene, and Hygeia, were taken from the Ephemerides given in the Supplement of the Nautical Almanac for 1856.

For Thetis the distances are taken from Schönfeld's Ephemeris in the *Astronomische Nachrichten*, No. 848; for Thalia from Oëltzen's Ephemeris, printed in a pamphlet, giving a discussion concerning the orbit of the planet; for Calliope from Hornstein's Ephemeris in *Astronomische Nachrichten*, No. 858; and for Euterpe from an Ephemeris by Professor Chevallier, privately printed.

For Neptune the distances are taken from the approximate Ephemeris given in the Supplement to the Nautical Almanac for 1856.

SEMIDIAMETER.—The semidiameters of the Sun, Moon, and Planets are given in the lower part of the page. For the Sun and Moon the semidiameters are taken unchanged from the Nautical Almanac; the corrections derived from the Greenwich Observations, and formerly applied to the semidiameters taken from the Nautical Almanac, having been for the year 1853 incorporated in that work. For Venus, Mars, Jupiter, and Saturn they are also taken unchanged from the Nautical Almanac, except in cases where only one limb is observed, when a correction is applied derived from neighbouring observations. Such cases are always specified in the notes.

GEOCENTRIC N. P. D. OF CENTER.—The numbers in this column are found by combining the Apparent Zenith Distance with the Refraction, Parallax, Semidiameter, and assumed Co-latitude 38°. 31′. 21″·80.

CORRECTION TO MEAN N. P. D.—The corrections for the reduction of the Mean North Polar Distances of the stars to the beginning of 1853, are given at the lower part of the page. For the stars in the list of the Nautical Almanac, the correction is found by subtracting the mean declination of the Nautical Almanac from the apparent declination of the same. For stars not in the Nautical Almanac the corrections are computed by the formula,

$$\text{E}\,e' + \text{F}\,f' + \text{G}\,g' + \text{H}\,h' + \text{L} + l' - 300''$$

which is derived from the well-known formula

$$\text{A}\,a' + \text{B}\,b' + \text{C}\,c' + \text{D}\,d'$$

or its equivalent

$$\text{A}.\sin \text{N.P.D.} - (\text{numb. log} = 9{\cdot}6375) - \text{A}.\sin \text{R. A.} \cos. \text{N.P.D.} + \text{B}.\cos \text{R. A.} \cos \text{N. P. D.} + \text{C}.\cos \text{R. A.} \times \text{numb. (log} = 1{\cdot}3020) - \text{D}.\sin \text{R. A.}$$

by a process which is explained with sufficient detail in the Introduction to the Greenwich

Twelve-Year Catalogue appended to the volume for 1847. The formulæ for E, F, G, H, L, have been already given: $e' = a' + 1{\cdot}2, f' = b' + 1{\cdot}2, g' = c' + 25, h' = d' + 1{\cdot}2, l' = 210 - 25 \times e' - 25 \times f' - 1{\cdot}2 \times g' - 25 \times h'$. The values of the day-constants log. E, log. F, log. G, log. H, and L, for the years from 1849 to 1860, inclusive, and the values of the star-constants log. e′, log f′, log. g′, log. h′, and l′, for all the stars in the "Greenwich Twelve-Year Catalogue" are given in that Catalogue. For other stars the star-constants will be found in a table either following the Introduction to the volume for 1848, or following the Catalogues of Stars for the years 1849, 1850, 1851, and 1852, or following the Catalogue in the present volume.

The sign of the computed quantity is changed before application.

§ 5. *Runs of each Microscope of the Transit-Circle; and Zenith Points of the Transit-Circle, in the Year* 1853, page (98) to (106).

These Tables require but little explanation.

With regard to the *Runs of the Microscopes*, the columns under A, B, C, D, E, F, contain respectively the number of revolutions of each micrometer which measures an arc of 5′ on the circle; and the last column gives the sum of these numbers, and exhibits the number of revolutions which, for the mean of the microscopes, measures an arc of 30′, on the supposition that the screws of the micrometers have sensibly equal values. In the calculations for the reduction of the observations it is assumed that the space of 30′ corresponds approximately to $\frac{50}{51} \times 30^{r}{\cdot}000$, or to $29^{r}{\cdot}4118$, and, the fiftieth part of the micrometer-reading for the mean of the microscopes being added to the micrometer-reading, the remaining correction, depending on the difference between the values in the last column of the table in question and $29^{r}{\cdot}4118$, is computed in the way that has been previously explained.

With regard to the Table of *Zenith Points*, the following explanation will be sufficient.

Whenever observations of stars have been made by reflexion, the results for zenith point derived from them have been combined with those derived from the observations of the reflected image of the wire. The observations are always divided into three groups, viz.: those resulting from north stars, from south stars, and from wire-observations respectively; and, to prevent too much weight being given to those divisions of the circle which are always under the microscopes for the wire-observations, to one observation of a star there is attributed three times the weight of a wire-observation. From the pains taken to equalize the number of observations of stars North and South of the Zenith, no undue weight is, on the average, given to either of these positions; and, on the whole, it is presumed that, by this method of combination, the best possible average result is obtained. This explanation is in a great measure a recapitulation of that given in page liii, and is added for the sake of clearness.

§ 6. *Mean North Polar Distances of Stars deduced from each Day's Observations,* page (108) to (126).

The Mean North Polar Distances are found by applying to the North Polar Distances in Section 4, the corrections given for each star in the lower part of the page.

The results of direct and reflexion observations are kept separate, with a view of ascertaining whether there is discordance between them, as has been frequently observed in the results of other circles; and the results of observations above and below the pole are kept separate, in order to ascertain whether there is any sensible error in the assumed co-latitude.

With regard to the first of these points, the means of the groups of Direct-results and Reflexion-results have been taken for all the stars observed: and the algebraical excess of the Reflexion-result over the Direct-result (the result for stars below the pole being considered negative) is given in the subjoined table.

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS OF ZENITH DISTANCE WITH THE TRANSIT-CIRCLE, 1853.

Name of Star.	Approx. N. P. D.	Sec. of R.	Sec. of D.	R.—D.	Number of Obs. R.	Number of Obs. D.	Weight.
	° ′	″	″	″			
Polaris S. P.	− 1. 28	−26·50	−27·67	+ 1·17	4	54	16
λ Ursæ Minoris S. P. ...	− 1. 8	−49·68	−49·63	− 0·05	5	8	12
λ Ursæ Minoris	1. 8	+48·97	+49·18	− 0·21	4	11	12
Polaris	1. 28	27·37	26·70	+ 0·67	9	51	28
B. A. C. 1879	3. 14	27·95	27·51	+ 0·44	1	2	3
δ Ursæ Minoris	3. 24	5·40	4·45	+ 0·95	4	14	12
B. A. C. 1565	10. 57	1·96	2·93	− 0·97	1	1	2
ζ Ursæ Minoris	11. 45	19·85	20·42	− 0·57	4	5	8
γ Cephei	13. 11	17·20	16·91	+ 0·29	6	9	14
B. A. C. 6702	13. 44	4·74	4·20	+ 0·54	1	3	3
B. A. C. 7311	14. 39	37·55	37·72	− 0·17	2	7	6
B. A. C. 1706	15. 4	52·18	51·70	+ 0·48	2	3	4
β Ursæ Minoris	15. 15	37·89	37·57	+ 0·32	4	9	12
κ Draconis	19. 24	3·56	3·27	+ 0·29	6	6	12
β Cephei	20. 5	2·73	2·62	+ 0·11	6	13	16
9 Camelopardali	23. 55	53·16	52·97	+ 0·19	6	8	14
65 Draconis	25. 47	49·11	47·75	+ 1·36	3	7	8
h Ursæ Majoris	26. 18	57·80	57·53	+ 0·27	4	5	8
α Ursæ Majoris	27. 27	23·19	23·52	− 0·33	6	7	12
18 Cephei	27. 36	37·76	39·59	− 1·83	1	1	2
α Cephei	28. 2	10·24	9·70	+ 0·54	4	16	12
η Draconis	28. 9	10·19	7·44	+ 2·75	1	6	4
2 Lacertæ	44. 12	8·79	8·47	+ 0·32	1	1	2
α Lyræ	51. 21	1·98	2·24	− 0·26	2	20	8
61 Cygni	51. 58	15·85	15·55	+ 0·30	1	4	4
υ Cygni	55. 43	5·77	5·47	+ 0·30	1	4	4

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS OF ZENITH DISTANCE WITH THE TRANSIT-CIRCLE, 1853—*continued.*

Name of Star.	Approx. N. P. D.	Sec. of R.	Sec. of D.	R.—D.	Number of Obs. R.	Number of Obs. D.	Weight.
	° ′	″	″	″			
δ Bootis	56. 8	3 ·25	2 ·88	+ 0 ·37	3	3	6
ι Aurigæ	57. 4	18 ·63	18 ·00	+ 0 ·63	2	10	7
Castor	57. 48	38 ·41	38 ·66	— 0 ·25	1	6	4
ζ Herculis	58. 8	41 ·43	41 ·17	+ 0 ·26	2	15	8
ο Persei	58. 11	53 ·71	53 ·79	— 0 ·08	4	5	8
ρ Bootis	58. 59	51 ·24	52 ·48	— 1 ·24	1	6	4
ζ Cygni	60. 22	23 ·26	25 ·70	— 2 ·44	2	15	8
β Comæ	61. 23	32 ·92	31 ·20	+ 1 ·72	1	4	4
ε Andromedæ	61. 29	13 ·46	14 ·26	— 0 ·80	5	8	12
β Tauri	61. 31	18 ·12	18 ·54	— 0 ·42	2	15	8
α Andromedæ	61. 43	16 ·75	16 ·84	— 0 ·09	2	10	6
6 Cancri	61. 48	51 ·95	51 ·84	+ 0 ·11	3	9	8
μ Herculis	62. 11	25 ·48	25 ·13	+ 0 ·35	4	13	12
32 Vulpeculæ	62. 30	56 ·14	57 ·11	— 0 ·97	1	10	4
B. A. C. 4205	62. 58	33 ·25	32 ·37	+ 0 ·88	1	1	2
μ Leonis	63. 18	11 ·38	11 ·21	+ 0 ·17	1	8	4
16 Pegasi	64. 46	52 ·90	53 ·55	— 0 ·65	4	3	8
α Vulpeculæ	65. 38	46 ·82	47 ·33	— 0 ·51	1	3	3
μ Pegasi	66. 10	24 ·56	25 ·43	— 0 ·87	4	9	12
α Arietis	67. 14	7 ·49	6 ·61	+ 0 ·88	1	14	4
p Geminorum	67. 25	57 ·86	57 ·35	+ 0 ·51	1	8	4
η Geminorum	67. 27	18 ·86	20 ·10	— 1 ·24	1	3	3
δ Leonis	68. 40	17 ·07	18 ·72	— 1 ·65	1	7	4
η Cancri	69. 4	46 ·90	47 ·71	— 0 ·81	2	8	6
γ Leonis	69. 25	0 ·55	1 ·09	— 0 ·54	1	10	4
γ Herculis	70. 30	54 ·19	54 ·41	— 0 ·22	1	11	4
η Bootis	70. 52	48 ·32	49 ·03	— 0 ·71	2	18	8
m Tauri	71. 33	25 ·73	25 ·13	+ 0 ·60	1	1	2
83 Cancri	71. 40	26 ·68	27 ·75	— 1 ·07	7	13	18
τ Bootis	71. 49	31 ·61	31 ·84	— 0 ·23	7	12	18
γ Delphini	74. 24	10 ·76	10 ·56	+ 0 ·20	1	2	3
B. A. C. 7146	74. 41	32 ·25	32 ·06	+ 0 ·19	1	4	4
ε Aquilæ	75. 8	40 ·57	40 ·62	— 0 ·05	3	7	8
η Piscium	75. 25	48 ·69	49 ·24	— 0 ·55	2	5	6
α Ophiuchi	77. 20	44 ·43	45 ·50	— 1 ·07	1	16	3
ω Aquilæ	78. 40	57 ·97	58 ·67	— 0 ·70	1	10	4
l Leonis	78. 41	42 ·47	42 ·45	+ 0 ·02	3	11	10
s Tauri	79. 10	16 ·79	18 ·67	— 1 ·88	1	2	3
ε Delphini	79. 12	36 ·54	36 ·60	— 0 ·06	1	4	4
ζ Pegasi	79. 56	5 ·06	5 ·50	— 0 ·44	1	18	4

For the purpose of discovering with more accuracy the law followed by the differences given above, they have been grouped for convenient intervals of North Polar Distances, and the means of the differences corresponding to the mean of the North Polar Distances have been taken, weights being assigned proportioned to the product of the observations of R and D divided by this sum.

The results are contained in the following Table.

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS FROM GROUPS OF STARS, WITH THE TRANSIT-CIRCLE, 1853.

No. of Group.	Extent of Group.	Weight.	Mean N. P. D.	Zenith Distance.	R—D.
			° ′	° ′	″
1	Polaris S. P. to δ Ursæ Minoris..	83	0. 49	− 37. 42	+ 0·57
2	B.A.C. 1565 to β Ursæ Minoris..	49	13. 44	24. 47	+ 0·08
3	κ Draconis to η Draconis........	88	24. 20	− 14. 11	+ 0·35
4	2 Lacertæ to 61 Cygni	14	50. 30	+ 11. 59	− 0·02
5	υ Cygni to ζ Cygni.............	49	57. 57	19. 26	− 0·33
6	β Comæ to η Geminorum	94	63. 28	24. 57	− 0·19
7	δ Leonis to τ Bootis............	64	70. 58	32. 27	− 0·66
8	γ Delphini to ζ Pegasi	49	77. 12	+ 38. 41	− 0·32

By a bare inspection of the above table it is evident that there is a difference of the values of R and D depending on the Zenith Distance, of such a nature as to require a negative correction to direct observations of Stars south of the Zenith, and a positive correction to reflexion observations. By calculation it is found that the following formulæ will pretty accurately represent the corrections to be generally applied to observations of all objects.

For direct observations

$$-0''\cdot06 - 0''\cdot29 \times \text{Sin Z. D. South.}$$

For reflexion observations

$$+0''\cdot06 + 0''\cdot29 \times \text{Sin Z. D. South.}$$

And for use the formulæ have been tabulated as follows; and have been applied to all the observations of Zenith Distance made throughout the year.

N. P. D.	Correction to Results of Direct Observations.	Correction to Results of Reflexion Observations.	N. P. D.	Correction to Results of Direct Observations.	Correction to Results of Reflexion Observations.
°	″	″	°	″	″
− 40	+ 0·22	− 0·22	+ 50	− 0·12	+ 0·12
30	0·21	0·21	60	0·17	0·17
20	0·19	0·19	70	0·21	0·21
− 10	0·16	0·16	80	0·25	0·25
0	0·12	0·12	90	0·29	0·29
+ 10	0·08	0·08	100	0·31	0·31
20	+ 0·03	− 0·03	110	0·33	0·33
30	− 0·02	+ 0·02	120	0·35	0·35
40	0·07	0·07			

The observations of circumpolar stars have in this year also been favourable to the determination of the latitude; and the result, as in the two preceding years, shows a trifling increase in the co-latitude which has for many years been definitively assumed, viz. 38°. 31′. 21″·80.

In the following table the weights are approximately determined by multiplying $\frac{a\,b}{a+b}$ (where a is the number of observations above the pole, and b the number below) by the number 20 for the first star, 19 for the second, 18 for the third, &c., and assuming numbers proportional to those thence resulting.

CORRECTION TO ASSUMED LATITUDE.

Star's Name, and Mode of Observation.	No. of Obs.	N. P. D. Uncorrected.	Result Corrected for Discordance.	No. of Obs.	Concluded N. P. D. on assumed Latitude.	No. of Obs.	Algebraic Sum of Determinations.	Weight.	Product.
		° ′ ″	″		″		″		″
λ Ursæ Minoris .. D.	11	1. 7. 49·18	49·30	15	49·18	28	− 0·44	140	−61·60
R.	4	48·97	48·85						
D.	8	− 1. 7. 49·63	−49·50	13	−49·62				
R.	5	49·68	−49·81						
Polaris..........D.	51	1. 28. 26·78	26·81	60	26·88	119	− 0·60	570	−40·00
R.	9	27·10	27·26						
D.	55	− 1. 28. 27·66	−27·54	59	−27·48				
R.	4	26·50	−26·63						
Cephei 51 (Hev.). D.	5	2. 44. 44·99	45·10	5	45·10	12	− 0·85	54	−45·90
D.	7	− 2. 44. 46·08	−45·95	7	−45·95				
δ Ursæ Minoris...D.	14	3. 24. 4·45	4·56	18	4·72	25	− 0·48	85	−40·80
R.	4	5·40	5·29						
D.	7	− 3. 24. 5·33	− 5·20	7	−5·20				
γ Cephei ....D.	9	13. 11. 16·91	16·98	15	17·04	16	+ 1·09	16	+17·44
R.	6	17·20	17·13						
D.	1	−13. 11. 16·12	−15·95	1	−15·95				
β Ursæ Minoris ..D.	9	15. 14. 37·56	37·62	13	37·69	14	+ 1·34	15	+20·10
R.	4	37·89	37·84						
D.	1	−15. 14. 36·52	−36·35	1	−36·35				
β Cephei ....D.	13	20. 5. 2·62	2·65	19	2·67	20	+ 0·37	14	+ 5·18
R.	6	2·73	2·70						
D.	1	−20. 5. 2·49	− 2·30	1	− 2·30				
α Cephei ....D.	16	28. 2. 9·70	9·69	20	+ 9·80	22	− 0·61	23	−14·03
R.	4	10·24	10·25						
D.	2	−28. 2. 10·62	−10·41	2	−10·41				
α Cassiopeiæ.....D.	3	34. 16. 10·41	10·37	3	10·37	4	− 2·18	12	−26·16
D.	1	−34. 16. 12·77	−12·55	1	−12·55				
γ Draconis ......D.	8	38. 29. 31·39	31·19	8	31·19	9	− 0·76	11	− 8·36
D.	1	−38. 29. 32·17	−31·95	1	−31·95				

If z be the correction to the assumed co-latitude, $2z$ + the algebraical sum of the determinations ought to be = 0. Combining the whole with the weights above attached to them, $2z - 0''\cdot526 = 0$, or $z = +0''\cdot26$. And, as the assumed co-latitude for the year was $38^\circ.31'.21''\cdot80$, the co-latitude from this determination is $38^\circ.31'.22''\cdot06$.

The assumed co-latitude, or $38^\circ.31'.21''\cdot80$, has been used in the subsequent results.

§ 7. *Observations of Azimuth with the Altazimuth*, page [ii] to [xliii].

The first *eleven* columns, on the left-hand page, require little explanation, except that by "Horizontal Transit" is meant the resolved horizontal part of the inclined movement of the object in passing through the field of the telescope. In making the observation, the instrument is clamped in azimuth, and the moderately slow motion of the Vertical Circle is used to make the transit of the object take place over the middle of each vertical wire.

The *twelfth* column is occupied by the personal equation of each observer, referred to Mr. Dunkin as a standard; and this personal equation is applied to the mean of observed transits (without application of any correction for omitted wires, if the transit is imperfect) to form the "Concluded Clock Time" in the *thirteenth* column.

The column *following* the "Concluded Clock Time" contains the error of the clock, as deduced from comparisons with the Transit Clock, by a process which will be explained hereafter. The number of seconds by which the Transit Clock is slow, is, before application, corrected by the quantity $-0^{s}\cdot03$ for the difference of longitude between the position of the Transit-Circle and that of the Altazimuth. This difference of longitude is obtained by measurement on the plan of the Observatory, of which a reduced copy is attached to the volume for 1845.

By the application of this Clock Error to the Clock Time, the Sidereal Time in the *next* column is formed.

The last *four* columns contain the readings of the micrometers of the four microscopes of the Horizontal Circle. The designations, a, b, c, d, are so distributed among these microscopes that the observer, walking round the pier in the direction of the Sun's diurnal movement, passes them in the order a, b, c, d.

From the readings of the microscope-micrometers in the *last four* columns on the left-hand page, together with the pointer-reading (which is not inserted in the printed columns), the Concluded Reading of Horizontal Circle in the *first* column of the right-hand page is formed in this manner:—The runs of the micrometers being examined frequently; suppose it is found that an arc of 5′ requires $7^{\text{rev.}}\cdot8 - p$ of micrometer a, $7^{\text{rev.}}\cdot7 - q$ of micrometer b, $7^{\text{rev.}}\cdot9 - r$ of micrometer c, and $8^{\text{rev.}}\cdot0 - s$ of micrometer d. Then p, q, r, s, are very small quantities. Now, suppose that the micrometer-readings in any observation are w, x, y, z: these four quantities being very nearly equal. Then the Concluded Circle-Reading ought to be

$$\frac{5'}{4} \times \left\{ \frac{w}{7{\cdot}8-p} + \frac{x}{7{\cdot}7-q} + \frac{y}{7{\cdot}9-r} + \frac{z}{8{\cdot}0-s} \right\}$$

or

$$\frac{5'}{4} \times \left\{ \frac{w}{7{\cdot}8} + \frac{x}{7{\cdot}7} + \frac{y}{7{\cdot}9} + \frac{z}{8{\cdot}0} \right\} + \frac{5'}{4} \times \left\{ \frac{w}{7{\cdot}8} \cdot \frac{p}{7{\cdot}8} + \frac{x}{7{\cdot}7} \cdot \frac{q}{7{\cdot}7} + \frac{y}{7{\cdot}9} \cdot \frac{r}{7{\cdot}9} + \frac{z}{8{\cdot}0} \cdot \frac{s}{8{\cdot}0} \right\}$$

From the near equality of $\frac{w}{7{\cdot}8}$, $\frac{x}{7{\cdot}7}$, &c., and the smallness of p, q, &c., the factors of p, q, r, s, may be considered equal: and the whole expression then becomes

$$w \times \frac{5'}{4 \times 7{\cdot}8} + x \times \frac{5'}{4 \times 7{\cdot}7} + y \times \frac{5'}{4 \times 7{\cdot}9} + z \times \frac{5'}{4 \times 8{\cdot}0}$$
$$+ \frac{1}{4} \left\{ w \times \frac{5'}{4 \times 7{\cdot}8} + x \times \frac{5'}{4 \times 7{\cdot}7} + y \times \frac{5'}{4 \times 7{\cdot}9} + z \times \frac{5'}{4 \times 8{\cdot}0} \right\} \times \frac{p+q+r+s}{7{\cdot}85}$$

If the quantity $\frac{1}{4} \times \frac{100''}{7{\cdot}85} \times (p+q+r+s)$ be called *Correction for Runs for* 100″, then the expression is

$$w \times \frac{5'}{4 \times 7{\cdot}8} + x \times \frac{5'}{4 \times 7{\cdot}7} + y \times \frac{5'}{4 \times 7{\cdot}9} + z \times \frac{5'}{4 \times 8{\cdot}0}$$
$$+ \frac{1}{100} \left\{ w \times \frac{5'}{4 \times 7{\cdot}8} + x \times \frac{5'}{4 \times 7{\cdot}7} + y \times \frac{5'}{4 \times 7{\cdot}9} + z \times \frac{5'}{4 \times 8{\cdot}0} \right\} \times \text{Correction for Runs for } 100''.$$

The separate terms of the first line are taken from four separate tables, entered with the respective arguments w, x, y, z; and, when they are added together, the value of the second line is rapidly computed by a short multiplication (usually effected with the sliding rule).

Another correction is occasionally necessary. When the transit of the object has not been observed across every one of the six vertical wires, the mean of the times actually observed is retained unaltered; but a correction is applied to the circle-reading, representing the difference between the azimuth of the mean of the wires actually observed and the azimuth of the mean of the six vertical wires. This correction is equal to the angular distance between the mean of the wires observed and the mean of the six wires, multiplied by the cosecant of zenith distance. The angular distances from the several wires to the mean are the following: the signs here given suppose the Face of the Vertical Circle to be Right, and must be changed when the Face is Left.

Wire	1	—	599·22″
	2	—	362·99
	3	—	120·79
	4	+	120·68
	5	+	360·92
	6	+	601·37

These values were obtained from 53 transits, included between 1850, January 2, and 1850, March 5, by the formula,

$$\text{Distance of a wire from the mean of wires} = \text{Interval of time in seconds} \times 15 \times \sqrt{\text{Sin}^2 \text{ N. P. D.} - \cos^2 \text{lat.} \times \sin^2 \text{azimuth.}}$$

The values given above were used to 1853, March 3; after which time a new determination of the intervals was made, by placing each wire successively upon the image of the collimator mark, and reading the Horizontal Circle. This operation was repeated five times; the difference of each wire from the mean was taken; and those numbers were multiplied by cos 12°. 18′, (that being the apparent depression of the collimator mark). The results, given in the following table, were used during the remainder of the year:—

Wire 1	−	598″·63
2	−	363·15
3	−	121·03
4	+	120·73
5	+	361·13
6	+	600·98

When any number of wires (except the complete set of six wires) has been used in the transit, the corresponding corrections are taken from this table, and their mean is ultiplied by the cosecant of Zenith Distance taken from the *second* column on the right-hand page, and thus a correction is obtained whose value is stated in the Notes. By the application of this final correction the Concluded Reading in the *first* column on the right-hand page is formed.

The *second* column on the right-hand page contains the Approximate Zenith Distance taken from the section of Tabular Computations.

The *third* column contains the corrections to be applied to the Concluded Circle Reading on account of the error of collimation (the term having the same meaning as for a transit instrument) of the imaginary point in the field of view, which corresponds to the mean of the six vertical wires. The amount to be applied is, Horizontal Correction for Collimation × cosecant of Zenith Distance. The sign will change according as the Face of the Vertical Circle is Right or Left. The value of Horizontal Correction or Co-efficient of Correction for Collimation, Face Right, is given at the bottom of the page; the method by which it is obtained will be explained in a subsequent section.

The next eight columns (from the *fourth* to the *eleventh*) contain the readings of the level-scales of the four levels which are parallel to the axis of the Vertical Circle, *e* and *f* being the readings of the two ends of one of the lower levels, *g* and *h* those of the other lower level, *i*, *k*, and *l*, *m*, those of the two upper levels. As the reading of each level-scale proceeds in continuous order from the end next the Graduated Face of the Vertical Circle to the other end, it follows that the equivalents for the scale-values of both end-readings must be added; and that, when their mean is diminished by the reading corresponding to the horizontal position of the Horizontal Axis, the excess must be used (multiplied by the proper factor, viz., the cotangent of Zenith Distance) with its proper sign when the Graduated Face is Right, and with sign changed when the Graduated Face is left.

The *twelfth* column contains the Concluded Level Indication. It is assumed that each division on the four levels represents one second of arc; and the process for forming the Concluded Level Indication has been, to add together the eight numbers from the eight preceding columns, omitting 1000 from that sum, and to divide the remainder by 8.

From this Concluded Level Indication is subtracted the Level Indication for Horizontal Position of Axis of Vertical Circle given at the foot of every page (the method of obtaining which will be given in a subsequent section); and the remainder, which represents the angular elevation of that end of the Horizontal Axis which is farthest from the Graduated Face, is multiplied by the cotangent of Zenith Distance. When the Graduated Face is Left, the sign of the product is changed. The resulting number is given in the *thirteenth* column as the Correction for Level.

The *fourteenth* column contains the Corrected Reading of Horizontal Circle, as affected by all these corrections.

The *fifteenth* column contains the Concluded Azimuth, measuring from the South towards the West, which is formed by merely subtracting from the Corrected Reading of Horizontal Circle the Zero of Azimuth given at the bottom of the page. The method of determining the Zero of Azimuth will be explained in a subsequent section.

In cases wherein both limbs of the Moon have been observed, one of the limbs is usually defective through want of illumination. A correction to the azimuth (always mentioned in the foot-notes) is applied in all such cases, and this correction is computed by finding first the azimuth of a point opposite the Sun, and then multiplying by the sine of the Sun's zenith distance the difference between the azimuth of this point and that of the Moon's limb; the correction is versed sine of this difference multiplied by the Moon's azimuthal semidiameter.

§ 8. *Observations of Zenith Distance with the Altazimuth*, page [xlvi] to [lxxix].

The *first eleven* columns require no explanation, except that by "Vertical Transit" is meant the resolved vertical part of the inclined movement of the object in passing through the field of the telescope.

The *twelfth* column contains a correction which exists theoretically in all cases, but which in the Azimuths is practically insensible, although for the Zenith Distances, more especially those which are observed near the Meridian, it sometimes becomes important. The nature of it is this: In the subsequent calculations it is tacitly assumed that at the mean of the observed times of passage across the six horizontal wires (supposed free from error of observation), the body was at the point which represents the mean of all the six wires. This, however, is true only on the supposition that the vertical movement of the body is uniform. The correction is investigated in the following manner. In the spherical triangle whose sides are a, b, c, and where C is the angle opposite to c, let a and b be respectively the co-latitude of the zenith, and the north polar distance of the object; then C is the hour-angle, and c the zenith distance. Suppose these letters to correspond truly to the position of the object when it passes the mean of the six horizontal wires: then if δC be the addition (expressed in parts of the radius), or $\delta C_{,} \times 15 \sin 1''$ ($\delta C_{,}$ being expressed in seconds of time), which must be made to C in order to express the hour-angle when the object passes one wire, and if δc (expressed in parts of the radius), or $\delta c_{,,} \times \sin 1''$ ($\delta c_{,,}$ being expressed in seconds of arc), be the addition which must be made to c in order to give the zenith distance of the same wire, we have

$$C + \delta C_{,} \times 15 \sin 1'' = C + \frac{dC}{dc} \cdot \delta c + \frac{d^2 C}{dc^2} \cdot \frac{\overline{\delta c}|^2}{2}$$

Now $\cos a . \cos b + \sin a . \sin b . \cos C = \cos c$

Therefore $\sin a . \sin b . \sin C . \frac{dC}{dc} = \sin c$

And $\sin a . \sin b \left\{ \cos C . \left(\frac{dC}{dc}\right)^2 + \sin C . \frac{d^2 C}{dc^2} \right\} = \cos c$

Whence $\frac{dC}{dc} = \frac{\sin c}{\sin a . \sin b . \sin C}$

and $\frac{d^2 C}{dc} = -\frac{\cos C}{\sin C} \left(\frac{\sin c}{\sin a . \sin b . \sin C} \right)^2 + \frac{\cos c}{\sin a . \sin b . \sin C}$

In the case before us C is a small quantity, but no other quantity is small. Hence the first term of $\frac{d^2 C}{d c^2}$ is the principal term, and the second may be neglected in comparison with it. And thus the equation becomes,

$$C + \delta C_{,} \times 15 \sin 1'' = C + \frac{\sin c}{\sin a . \sin b . \sin C} \delta c - \frac{\cos C}{\sin C} \left(\frac{\sin c}{\sin a . \sin b . \sin C} \right)^2 \cdot \frac{\overline{\delta c}|^2}{2}$$

An approximate solution gives $\delta C_{,} \times 15 \sin 1'' = \frac{\sin c}{\sin a . \sin b . \sin C} \delta c$.

Substituting this in the last term we have

$$C + \delta C_{,} \times 15 \sin 1'' = C + \frac{\sin c}{\sin a . \sin b . \sin C} \delta c - \frac{\cot C}{2} . \overline{\delta C_{,}}|^2 . \overline{15 \sin 1''}|^2$$

or putting $C_{,}$ for the value of C in seconds of time,

$$C_{,} + \delta C_{,} = C_{,} + \frac{\sin c}{\sin a . \sin b . \sin . C . 15 \sin 1''} \delta c - \frac{\cot C}{2} . \overline{\delta C_{,}}|^2 . 15 \sin 1''$$

and, taking the mean of both sides, attributing successively to each the value which it obtains for each of the six wires, we have,

Mean of observed hour-angles in seconds of time =

$$C_{,} + \frac{\sin c}{6 \sin a . \sin b . \sin C . 15 \sin 1''} \Sigma . \delta c - \frac{\cot C . 15 \sin 1''}{12} . \Sigma . \overline{\delta C_{,}}|^2$$

As c refers to the point which is the mean of the six wires, $\Sigma . \delta c = 0$. For the convenient expression of the last term, let I be the interval in seconds of time from the first wire to the last. Then, for the first wire, $\delta C_{,} = -\frac{5}{10} I$; for the second, $\delta C_{,} \quad -\frac{3}{10} I$; for the third, $\delta C_{,} = -\frac{1}{10} I$; for the fourth, $\delta C_{,} = +\frac{1}{10} I$; for the fifth it is $+\frac{3}{10} I$; for the sixth, $+\frac{5}{10} I$. Hence the equation becomes,

Mean of observed hour-angles in seconds of time =

$$C_{,} - \frac{\cot C . 15 \sin 1''}{12} \cdot \frac{70}{100} \times I^2$$

$$= C_{,} - \frac{7}{8} . \sin 1 \quad \times \cot C \times I^2$$

Hence the correction to be applied to the mean of the observed hour-angles, in order to obtain the true hour-angle corresponding to the zenith distance at the mean of the wires, is:—

$$+ \frac{7}{8} . \sin 1'' \times \cot C \quad I^2$$

If the transit be imperfect, but the wires observed be consecutive, the following corrections will be applicable, being easily deduced from the preceding investigation:—

When three wires are observed, if I_3 be the interval in seconds of time from the first to the third, the correction in seconds of time will be $+ \frac{5}{4} \sin 1'' \times \cot C \times I_3^2$.

When four wires are observed, if I_5 be the interval from the first to the fourth, the correction will be $+ \frac{25}{24} \sin 1'' \times \cot C \times I_4^2$.

When five wires are observed, if $I_,$ be the interval from the first to the fifth, the correction will be $+ \frac{15}{16} \sin 1'' \times \cot C \times I_5^2$.

This correction will be subtractive from the mean of times when the hour-angle is diminishing, or before the object has passed the meridian, and additive to the mean of times when the object has passed the meridian. A small table of double entry is prepared with arguments C and I, and from this the correction is readily taken.

The *thirteenth* column is occupied by the personal equation (referred to Mr. Dunkin as standard), and this is applied to the mean of wires corrected as above mentioned to form the concluded Clock-time in the *fourteenth* column. The *two last* columns require no explanation beyond that in the section of Azimuths.

The *first four* columns on the right-hand side give the readings of the four microscopes, which are converted into arc by the aid of the numbers given at the bottom of the page, in the same manner as the similar numbers in the section of Azimuths.

When the observer views the graduated face of the vertical circle, the microscopes are seen in the position $\begin{matrix} A & D \\ B & C. \end{matrix}$

When the transit over any number of wires is omitted, the time of transit retained is the mean of the transits actually observed, corrected if necessary for personal equation; but a correction in arc is applied to the circle-reading, corresponding to the interval between the mean of the wires actually observed and the mean of the six wires. Calling the wires I, II, III, IV, V, VI, in the order in which a star on the west side of the meridian passes when the graduated face is right (and remarking that the signs are to be changed when only one of these conditions is altered), the corrections applicable for each wire singly, have been taken from the following table:—

		″
I	−	300·30
II	−	180·84
III	−	60·02
IV	+	60·46
V	+	180·09
VI	+	300·60

These numbers were obtained from 53 transits included between 1849, November 17, and 1850, March 6, by the formula,

Distance of a wire from the mean of wires
= Observed interval of time × 15 × cos lat. × sin azimuth.

The values given above were used to 1853, March 3. After this time a new determination of the intervals was made, by placing each wire upon the image of the collimator mark and reading the vertical circle. This observation was repeated five times, and the difference of each wire from the mean was taken. The results, given in the following table, were used during the remainder of the year.

		″
Wire I	−	299·97
II	−	180·74
III	−	59·47
IV	+	59·87
V	+	179·64
VI	+	300·67

The mean of these numbers corresponding to the wires observed, is applied as a correction to the Circle Reading, the value being stated in the Notes, and thus the Concluded Reading in the *fifth* column is formed.

The four columns from the *sixth* to the *ninth* give the readings of the two ends of the two levels which are parallel to the plane of the Vertical Circle, E and F being the readings of the two ends of the lower level, and G and H those at the two ends of the upper level. As, when the Graduated Face is Right, the Circle Readings increase with the increasing Zenith Distance, and as in the same case the numeration of the levels increases from the end next the object to the end next the observer, it follows that the indication of the levels is in all cases additive to the Circle Reading: and that the equivalents for the two ends of each level are to be combined additively.

The scale-readings are converted into arc by the values given at the bottom of each page (the zeros of E and G being $0^{\text{div.}}$, and those of F and H being respectively $170^{\text{div.}}$ and $190^{\text{div.}}$), and their mean is taken to form the Level Indication in the *tenth* column.

The Barometer, whose reading is contained in the *eleventh* column, is by Simms, with adjustible bag and float: it is placed in a small recess of the dome. The Thermometer, whose reading is contained in the *twelfth* column, is by Simms: it is placed on the East side of the tower carrying the dome, where its case is carried by long iron rods attached to the brickwork; it is mounted with its bulb inclosed by a double case, which is silvered by electro-plating, allowing a perfectly free passage for the air; it is read from a window of the dome-staircase.

An approximate zenith distance being obtained by the use of an approximate zenith point, the refraction in the *thirteenth* column is computed by the use of the tables printed in the Appendix to the Greenwich Observations, 1836, and reprinted as an Appendix to the present Volume, giving the same results as the tables in the *Tabulæ Regiomontanæ*. When the zenith distance exceeds 85°, Bessel's supplementary table is used. This refraction is always additive to the observed zenith distance, and therefore it is added to the Reading of the Vertical Circle when the Graduated Face is Right, and subtracted when it is Left.

By the combination of these various quantities, the Corrected Reading in the *fourteenth* column is formed. It is to be remarked that this Corrected Reading contains implicitly a constant depending on the assumed zeros of the Level-Scales, and equal to the Level-Indication when the axis of azimuthal rotation is vertical. In this respect it differs from the Corrected Reading of the Horizontal Circle, which contains no such constant.

The Zenith Point, whose value is given at the foot of each page, is obtained by a process which will be explained hereafter: it is sufficient here to state that it also contains implicitly the same constant depending on the assumed zeros of the Level-Scales. The concluded Zenith Distance therefore in the *fifteenth* column, which is formed by subtracting the Zenith Point from the Corrected Reading when the graduated face is Right, and by subtracting the Corrected Reading from the Zenith Point when the graduated face is Left, is freed from this constant. In cases wherein both the upper and the lower limb of the Moon have been observed, one limb is usually defective through defect of illumination. A correction on this account is applied, computed by a method analogous to that used for correcting the zenith distance of the defective limb of the Moon when observed on the meridian. (See page liv.) The corrections for defect of illumination are always mentioned in the Notes.

§ 9. *Comparison of Tabular Azimuths and Zenith Distances with Azimuths and Zenith Distances observed*, page [lxxxii] to [cxvii].

The *three first* columns need no explanation.

The Mean Solar Time in the *fourth* column is formed from the Sidereal Time in the two preceding sections, by the same process as in the formation of Mean Time for the observations of Planets (which will be described hereafter).

The Tabular R.A. of Center in the *fifth* column is formed: For stars, by applying to the places of the stars given in the Nautical Almanac, corrections fundamentally deduced from the Right Ascensions given in the Greenwich Twelve-Year Catalogue, for the epoch 1845 (see page xxix); and for the Moon, by interpolating with second differences between the hourly places of the Moon in the Nautical Almanac, using as argument the Mean Solar Time of the fourth-column.

The Hour Angle in the *sixth* column is the difference (without respect of sign, but taken less than 180°) between the Tabular R. A. and the Sidereal Time in the two preceding sections. The East or West side of the Meridian is indicated by the letter E or W in the *seventh* column.

The *eighth* column contains the Tabular Geocentric N.P.D. of Center. It is formed: For the stars, by applying to the places of the Nautical Almanac, corrections deduced from the N.P.D. given in the Greenwich Twelve-Year Catalogue for the epoch 1845; and for the Moon, by interpolating with second differences between the hourly places of the Nautical Almanac.

The *ninth* column contains the correction to the Moon's N.P.D., necessary for referring her place to the point of the Earth's axis at which the normal drawn from Greenwich meets the axis. It is thus investigated: Let a and b be the semi-major and semi-minor axes of the terrestrial ellipse, in the proportion of 300 to 299; x and y the co-ordinates parallel to them, their equation being $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$; then the subnormal upon the minor axis $= -x\frac{dx}{dy} = \frac{a^2}{b^2}y$, and the part of this included between the origin of co-ordinates and the foot of the normal, is $\frac{a^2-b^2}{b^2}y$. To find y, we remark that the tangent of the astronomical latitude of Greenwich, or $\tan l = -\frac{dx}{dy} = \frac{a^2}{b^2}\cdot\frac{y}{x} = \frac{a}{b}\cdot\frac{y}{\sqrt{(b^2-y^2)}}$; whence $y = \frac{b^2}{\sqrt{\{b^2+a^2\,\text{cotan}^2\,l\}}}$; and the distance from the center of the spheroid to the foot of the normal, measured along the Earth's axis, is $\frac{a^2-b^2}{\sqrt{\{b^2+a^2\,\text{cotan}^2\,l\}}}$; or, in parts of the semi-major axis, it is $\frac{a^2-b^2}{a\sqrt{\{b^2+a^2\,\text{cotan}^2\,l\}}}$. The logarithm of this quantity is 7·7174788. Now if, from the Earth's center, we draw a perpendicular to the Moon's radius vector, reaching the line drawn from the Moon to the foot of the normal, the length of that perpendicular will sensibly be, $a \times [7{\cdot}7174788] \times$ sin Moon's N.P.D.; the angle which it subtends as seen from the Moon will be $\frac{a}{\text{Moon's distance}} \times [7{\cdot}7174788] \times$ sin Moon's N.P.D. $= [7{\cdot}7174788] \times$ sin Moon's hor. equat. parallax $\times$ sin Moon's N.P.D.; and the value of this in seconds of arc will be $[3{\cdot}0319039] \times$ sin Moon's hor. eq. par. $\times$ sin Moon's N.P.D.; or $[7{\cdot}7174788] \times$ seconds of Moon's hor. eq. par. $\times$ sin Moon's N.P.D. In this manner the number in the ninth column has been computed. It is always subtractive.

The assumed co-latitude $38^{\circ}.\,31'.\,22''{\cdot}14$ is the same as that formerly deducedfrom observations with the Mural Circle, corrected by the quantity $+\,0''{\cdot}34$ for the difference of latitude of the positions of the two instruments as found by measurement on the plan of the Observatory before mentioned.

With the Hour Angle unaltered, and the N.P.D. altered (for the Moon) by the correction just described, and with the co-latitude $38^{\circ}.\,31'.\,22''{\cdot}14$; the Tabular Azimuth in the *tenth* column of the left-hand page, and the Tabular Normal-centric Zenith Distance in the *fifth* column of the right-hand page, are computed by the following formulæ:—

Log tan α=log cos hour-angle log tan Normal-centric N.P.D.

$\beta = \alpha -$ co-latitude.

Log tan zenithal angle=log sin α+log tan hour-angle−log sin β

Log cotan zen. dist.=log cotan β+log cos zenithal angle.

As a check upon the accuracy of a large part of this computation, the terms of the following equation are computed numerically:—

Log sin zenithal angle + log sin zen. dist. = log sin hour-angle + log sin N.P.D.

and if the numbers are not strictly equal, the computation is again examined.

The correction to Azimuth for Moon's Semidiameter, in the *first* column of the right-hand page, is thus computed. The semidiameter is interpolated with second differences from the Nautical Almanac without alteration, and the only correction required is for the difference between the distance of the Moon from the foot of the normal and her distance from the Earth's center. The former distance is greater than the latter by $a \times [7{\cdot}71748] \times$ cos Moon's N.P.D., and therefore her angular semidiameter is diminished in the proportion of Moon's distance to Moon's distance— $a \times [7{\cdot}71748] \times$ cos Moon's N.P.D., or 1 : 1 − sin hor. eq. par. $\times [7{\cdot}71748] \times$ cos Moon's N.P.D.: or, using the mean parallax 57′, the proportion is 1 : 1 − $[5{\cdot}93708] \times$ cos N.P.D. The correction required is taken out from a small table. The Correction to Azimuth is computed by the formula $\frac{\text{Corrected semidiameter}}{\text{Sine Normal-centric Zenith Distance}}$; the term depending on the difference between the sine of semidiameter and the arc being insensible.

By application of this correction to the Tabular Azimuth in the last column of the left-hand page, the Tabular Azimuth of Limb in the *second* column of the right-hand page is formed. This Azimuth is necessarily the same at the place of observation as at the foot of the normal, for which the computation has been made.

The seconds of Observed Azimuth in the *third* column are transcribed from the section of Azimuths: and the apparent error of Tabular Azimuth in the *fourth* column is formed by subtracting the observed azimuth from the tabular azimuth in the last column of the left-hand page (for a star), or from that in the second column of the right-hand page (for the Moon).

The computation of the *fifth* column has already been mentioned.

The Normal-centric Semidiameter for the Zenith Distances in the *sixth* column is interpolated without alteration from the Nautical Almanac, and the only correction which it requires is that for reduction to the foot of the normal. This correction is $-930'' \times [5\cdot93708] \times \cos$ Moon's N.P.D., and is readily tabulated.

For computation of the Parallax, the horizontal equatoreal parallax of the Nautical Almanac is first affected with Adams' correction to Burckhardt's parallax, tabulated in the Supplement to the Nautical Almanac for 1856. It is then necessary to reduce this to the Parallax referred to the foot of the Normal (the Moon's center having been referred to this point), and for this purpose, first, the Normal-centric Horizontal Parallax to be used, must be corrected so as to make it depend on the Normal-centric radius, and must therefore be multiplied by $\frac{\text{Normal-centric Radius of Greenwich}}{\text{Earth's semi-major axis}}$. Using the same notation as before, the factor is found to be $= \frac{1}{a \sin l} \cdot \frac{a^2}{b^2} y = \frac{a}{\sqrt{\{b^2 \sin^2 l + a^2 \cos^2 l\}}}$; the logarithm of which is 0·0008851. Secondly, it must be made to depend on the Moon's distance from the foot of the normal, and for this must therefore be multiplied by $1 - [5\cdot93708] \times \cos$ Moon's N. P. D. These two corrections are embodied in one logarithmic table with argument N. P. D., the number for 60° being 0·0008664, that for 90° being 0·0008851, and that for 120° being 0·0009037. By the addition of this logarithm to the logarithm of the seconds of parallax (corrected as above) which is interpolated from the Nautical Almanac with second differences, the logarithm in the *seventh* column is formed.

The parallax in the *eighth* column is computed by the formula, Normal-centric horizontal parallax × sine of observed zenith distance of limb + small correction. The observed zenith distance of limb is taken from the section of Zenith Distances. The small correction is the sum of two terms, namely, $-\frac{P^3}{6} \sin^2 1''$. sin zen. dist. cos² zen. dist. (which gives the correction for the error produced by using the parallax instead of its sine, P being $= 3420'' =$ number of seconds in Moon's mean parallax), and sin zen. dist. × Airy's correction as given in the section of Occultations. The table of corrections used is given in page .

By application of this parallax, the Tabular Apparent Zenith Distance of Limb in the *ninth* column is formed; the numbers in the *tenth* column are transcribed from the section of Zenith Distance; and the numbers in the *eleventh* are formed by subtracting those in the tenth from those in the ninth column.

§ 10. *Computation of Clock Errors and Instrumental Errors for the Observations with the Altazimuth, and of Errors of the Moon's Tabular R. A. and N. P. D.,* page [cxx] to [cxlv].

The comparisons of the Transit-Clock and the Clock (Graham 1) of the South Dome, used with the Altazimuth, were made by the solar chronometer, Arnold and Dent 1012. The chronometer is brought close to each of the clocks, and the time of accurate coincidence of beats is noted; the chronometer interval between the comparisons, which is sensibly Solar Time, is converted into Sidereal Time; and the sidereal time at the comparison with the transit-clock, being found by correcting the transit-clock time for error and rate of the transit-clock, and also for difference of longitude (see page lxii), the sidereal time at the comparison with the South Dome Clock is found, and thus the Error of that Clock is ascertained. From the successive Errors, rates of the Clock are deduced, and the Errors applicable to the observations, and which are given in the sections of Azimuth and Zenith Distance, are computed.

The instrumental constants of correction in Azimuth are thus investigated:—Let w be the correction to the computed tabular azimuth of a high star, depending upon the error in the star's assumed place: w will be an exceedingly small quantity, and will not sensibly vary between the observations made in reversed positions of the instrument. Let x be the constant of correction for error of collimation, taken with that sign which corresponds to the position of the instrument with Graduated Face Right; y the level-indication corresponding to horizontal position of the Horizontal Axis; and z the Zero of Azimuth. Also, let O_r and O_l be the Concluded Readings of Horizontal Circle from observations of a high star, with Face Right and Face Left; C_r and C_l the corresponding computed azimuths; L_r and L_l the level indications; D_r and D_l the zenith distances; and let o_r, o_l, c_r, c_l, l_r, l_l, d_r, d_l, be the similar quantities for a low star. Then the true azimuth of the high star deduced from observation, Face Right, is

$$O_r + x \,.\, \text{cosecant } D_r + (L_r - y) \,.\, \text{cotangent } D_r - z\,;$$

the computed azimuth corrected is $C_r + w$; hence this observation gives the equation,

$$O_r + L_r \,.\, \text{cotan } D_r - C_r = -x \,.\, \text{cosec } D_r + y \,.\, \text{cotan } D_r + z + w.$$

The true azimuth determined from observation, Face Left, is

$$O_l - x \,.\, \text{cosecant } D_l - (L_l - y) \,.\, \text{cotangent } D_l - z\,;$$

and this observation therefore gives the equation,

$$O_l - L_l \,.\, \text{cotan } D_l - C_l = + x \,.\, \text{cosec } D_l - y \,.\, \text{cotan } D_l + z + w.$$

Subtracting the first equation from the second,

$$(O_l - L_l \, . \, \text{cotan} \, D_l - C_l) - (O_r + L_r \, . \, \text{cotan} \, D_r - C_r) =$$
$$x \, . \, (\text{cosec} \, D_l + \text{cosec} \, D_r) - y \, . \, (\text{cotan} \, D_l + \text{cotan} \, D_r)$$

Or $\dfrac{(O_l - L_l \, . \, \text{cotan} \, D_l - C_l) - (O_r + L_r \, . \, \text{cotan} \, D_r + C_r)}{\text{cotan} \, D_l + \text{cotan} \, D_r} = x \times \dfrac{\text{cosec} \, D_l + \text{cosec} \, D_r}{\text{cotan} \, D_l + \text{cotan} \, D_r} - y.$

A similar treatment of the observations of the low star gives

$$\frac{(o_l - l_l \, . \, \text{cotan} \, d_l - c_l) - (o_r + l_r \, . \, \text{cotan} \, d_r \dot{-} c_r)}{\text{cotan} \, d_l + \text{cotan} \, d_r} = x \times \frac{\text{cosec} \, d_r + \text{cosec} \, d_r}{\text{cotan} \, d_l + \text{cotan} \, d_r} - y.$$

Subtracting the former from the latter, x is given by a simple equation.

It has been already stated that in the month of February, 1850, a Collimator was mounted admitting of accurate observation with the telescope of the Altazimuth, and requiring for its observation that the telescope be directed at an angle of 12°.18′ below the horizon. It is evident that, for the instrumental adjustments, the Collimator may be considered as an immoveable star, and that, considered as the low star in the preceding investigation, its position is exceedingly favourable. The preceding formulæ apply with no other changes than the following: for d_r and d_l put 102°.18′, and for c_r and c_l put the same symbol c. It is by this use of the Collimator in combination with a high star that the error of collimation has been found throughout the year 1853.

The construction of the instrument gives us reason to believe that the error of collimation is probably less variable than any other instrumental constant; it is usual, however, to make a new determination of the value of this element at the end of every lunation, founded on the observations of that lunation.

It is plain now that every set of four azimuths like those above will give a value of y: implying that, for that determination, the varying or slightly erroneous value of x, deduced from that individual combination, has been employed in the preliminary correction for collimation. But, as it appears better to use a mean value of x, a fresh investigation of y is made from every pair of observations. Thus, let O'_r, O'_l, be the concluded reading of horizontal circle corrected for the error of collimation. Then the first equations are,

$$O'_r + L_r \, . \, \text{cotan} \, D_r - C_r = + y \, . \, \text{cotan} \, D_r + z + w$$
$$O'_l - L_l \, . \, \text{cotan} \, D_l - C_l = - y \, . \, \text{cotan} \, D_l + z + w$$

Whence $\dfrac{(O'_r + L_r \, . \, \text{cotan} \, D_r - C_r) - (O'_l - L_l \, . \, \text{cotan} \, D_l - C_l)}{\text{cotan} \, D_r + \text{cotan} \, D_l} = y.$

Any one star, or the collimator, suffices for this determination; a high star, however, is best.

The number y, it is to be observed, corresponds strictly with the horizontal position of the Horizontal Axis of the Vertical Circle, and has no relation whatever to the Level-Zero corresponding to a vertical position of the Vertical Axis of Azimuthal Rotation: except that, supposing the workmanship of the vertical pivots to be perfectly good, and the position of the horizontal axis in its Y's to be invariable, there ought to be a constant difference between them. The latter Level-Zero would be the mean of the level-indications in opposite positions of the instrument: and it would be found with sufficient accuracy for this purpose by taking the mean of the level-indications for positions used in successive observations of the same object (though the instrument was not exactly reversed). The comparison of these Level-Zeros with those relating to the Horizontal Axis, would give a set of differences; and the mean of these differences might then be applied to the individual Level-Zeros of the Vertical Axis; and thus another value of the quantity y would be obtained, which might be combined with that found from the azimuthal transits. This process has not been used at all in the year 1853, but the results of the comparison are given in a subsequent section.

The comparison of the Observed Circle Reading for a star, corrected for Collimation and Level, with the computed Azimuth for the same star, gives the Zero of Azimuth. It has been the practice during the year 1853 to use, for the whole extent of each lunation, the mean of the separate values deduced solely from the star observations of that lunation; without reference to the observations of the Collimator, or to the individual results deduced from stars. The correctness of this principle had been proved by investigations based on the Theory of Probabilities respecting the relative stability of the Azimuthal Circle and of the Collimator, and of the Error due to the transmission of time from the Transit Instrument. From this investigation, for which the reader is referred to the Introduction to the Volume for 1850, it appeared that the Azimuthal Circle was the most stable part of the instrument; that the fluctuations in the position of the Collimator were somewhat greater; but that the principal source of errors was in the comparison of the circle-reading with the azimuth computed from the time-observation (those errors arising from errors in the actual observation, errors in the transmission of time from the transit-clock, errors in the transit-observation, and errors in the position of the transit-instrument). Undoubtedly, the last source of error mentioned, viz.: the uncertainty in the position of the transit-instrument, has been almost entirely got rid of by the use of the Transit-Circle; yet an inspection of the observations does not shew any considerable improvement in the consistency of the Azimuthal Zeros. It has been thought best, therefore, to rely solely on the stability of the Azimuthal Circle; but, as we cannot rely on its perpetual immobility, to limit the time during which the same Zero of Azimuth should be employed: and, for that time, the Zero of Azimuth must be found from the mean of all the separate determinations from star-observations during that time, but must be employed on every day, without reference to the star-observations of that day. The time through which I have thought proper to use the same Azimuthal Zero is, as has been already stated, one lunation.

In the Zenith Distances, the only instrumental constant deduced from observation is the Zenith Point (including so much of the level-indication as corresponds to a vertical position of the axis of azimuthal rotation). In two successive observations of the same star, Face Right and Face Left, let O_r and O_l be the observed circle-readings of the vertical circle corrected for level; C_r and C_l the computed zenith distances; e the possible error, which will be sensibly the same for both; Z the zenith point. Then we have

$$O_r - Z = \text{true zenith distance with Face Right} = C_r + e$$
$$Z - O_l = \text{true zenith distance with Face Left} = C_l + e$$

Subtracting the first from the second,

$$2\,Z - (O_r + O_l) = C_l - C_r$$
$$\text{or } Z = \frac{(O_r + O_l) - (C_r - C_l)}{2}.$$

When, instead of a star, the Collimator is used, C_r and C_l are necessarily equal, and the formula is simply,

$$Z = \frac{O_r + O}{2}$$

The only point which it is now necessary to explain is the method of investigating the Errors of the Moon's Tabular Place in Right Ascension and North Polar Distance. The following method is based upon the assumption that, although the Moon's positions in respect of the meridian and horizon of Greenwich are very different at the different observations made in the same evening, and although the Errors of Tabular Azimuth and the Errors of Tabular Zenith Distance will vary much in the course of an evening, yet the Moon's North Polar Distance will not have varied much, and the Errors of Tabular Right Ascension and Tabular North Polar Distance may be assumed to be invariable. It is also necessary to take into account, in arranging the form of calculation, that the Error of Tabular Azimuth and the Error of Tabular Zenith Distance are never observed at the same time.

Let $\delta.\,R.\,A.$, $\delta.\,N.\,P.\,D.$, $\delta.\,A.$, $\delta.\,Z$, be the Errors of Tabular Right Ascension, North Polar Distance, Azimuth, and Zenith Distance, in any observation: and (supposing the Moon to be west of the meridian) let S be the angle at the Moon made by the great circles drawn to the Pole and to the Zenith. Then we have,

$$\delta.Z = -\sin S.\ \sin N.P.D. \times \delta.\ R.A. + \cos S \times \delta.\ N.P.D.$$
$$\delta.A = -\frac{\cos S}{\sin Z} \sin N.P.D. \times \delta.\ R.A. - \frac{\sin S}{\sin Z} \times \delta.\ N.P.D.$$

$$\text{Let } \sin S = p,\ \cos S = q,\ \frac{\cos S}{\sin Z} = r,\ \frac{\sin S}{\sin Z} = s;\ \text{then}$$

$$\delta.\ Z = -p\ .\ \sin N.P.D. \times \delta.\ R.A. + q \times \delta.\ N.P.D.$$
$$\delta.\ A = -r\ .\ \sin N.P.D. \times \delta.\ R.A. - s \times \delta.\ N.P.D.$$

and, taking the sum of a series of equations in each element, and observing that p, q, r, s, will vary considerably during the observations.

$$\Sigma\,(\delta.Z) = -\delta.\ R.A. \times \sin N.P.D. \times \Sigma\,(p) + \delta.\ N.P.D. \times \Sigma\,(q)$$
$$\Sigma\,(\delta.A) = -\delta.\ R.A. \times \sin N.P.D. \times \Sigma\,(r) - \delta.\ N.P.D. \times \Sigma\,(s)$$

By solution of these equations,

$$\delta.R.A. = \frac{\Sigma\,(s).\Sigma\,(\delta.Z) + \Sigma\,(q).\Sigma\,(\delta.A)}{-\sin N.P.D.\ \{\Sigma\,(p).\Sigma\,(s) + \Sigma\,(q).\Sigma\,(r)\}}$$

$$\delta.N.P.D. = \frac{\Sigma\,(r).\Sigma\,(\delta.Z) - \Sigma\,(p).\Sigma\,(\delta.A)}{\Sigma\,(p).\Sigma\,(s) + \Sigma\,(q).\Sigma\,(r)}$$

A Table of double entry is prepared from which the values of p, q, r, s, are taken out at sight, with arguments Hour Angle and North Polar Distance of the Moon: and then the calculation is made by means of these formulæ.

§ 11. *Catalogue of the Mean Places of Stars observed in the Year* 1853*; and New Constants for Stars included in the Catalogue, not observed in preceding Years*, page 1 to 16.

The right ascensions in the catalogue are the means of all the separate determinations of the mean right ascension of each star, excluding only those which are contained in brackets. The annual variations for the Nautical Almanac Stars are taken from the Nautical Almanac. The geometrical precessions for all other stars are either taken from the Catalogue of the British Association, or are computed independently, with the elements given in the Nautical Almanac, 1834, 2nd edition, page xiii; which are taken from the *Tabulæ Regiomontanæ*, and which have been used for all the later volumes of the Nautical Almanac. The annual variations set down are the precessions thus computed, affected with the proper motions that are given in the British Association Catalogue, for stars contained in that catalogue.

The north polar distances in the catalogue are the means of the daily results, affected with the corrections for flexure and errors of division of Transit-Circle, and for discordance of direct and reflexion results, as has been previously explained. The adopted seconds of N. P. D. are found by taking the means of the groups of direct and reflexion observations, giving to each a weight proportional to its number of observations.

With regard to circumpolar stars, the following rules have been followed:—For stars whose N. P. D. does not exceed 15°, the observations above and below the pole are considered equally good; from N. P. D. 15° to N. P. D. 36°, those below have the weight $\frac{2}{3}$ for each observation; from N. P. D. 36° to N. P. D. 41°, those below have the weigh $\frac{1}{2}$: beyond 41° N. P. D., the observations are not combined. The annual variations are taken from the Nautical Almanac, as far as its list extends: for other stars they are either taken from the British Association Catalogue, with the additions of the proper motions given in the B. A. C.; or are computed with the elements given in the Nautical Almanac, 1834, 2nd edition, page xiii.

The nomenclature of the stars is identical with that in the second section.

The new star-constants require no further explanation than what is given at pages xlvi and lvi. They are computed to enable any person, using the Greenwich Observations, to employ the same method of reduction for all the stars found in those volumes.

§ 12. *Horizontal and Vertical Diameters, Right Ascensions, and North Polar Distances, of the Sun, Moon, and Planets; deduced from the Observations, and compared with the Tables*, page 18 to 41.

The duration of the passage of the Sun's diameter is found by subtracting the clock-time of transit of the first limb from that of the second limb in the *Transits observed, &c.*, without any further correction. The tabular duration is found by doubling the time of passage of the semidiameter given in the Nautical Almanac. The excess of the latter over the former is set down as the apparent error of the Nautical Almanac. The mean of all the values of this error is $0^{s}\cdot00$, thus shewing that the value of the diameter assumed in the Nautical Almanac for 1853, which is derived from the Greenwich Observations made with Troughton's Transit Instrument, precisely satisfies the observations made with the Transit-Circle.

The Sun's vertical diameter is found by subtracting the zenith distance of the north limb, corrected for refraction and parallax, from that of the south limb similarly corrected. The tabular diameter is found by doubling the semidiameter of the Nautical Almanac. The excess of the latter above the former is set down as the Apparent Error of the Nautical Almanac, and the mean of all the values of this error is $+ 0''\cdot58$.

For the duration of the passage of the Moon's diameter, a correction is applied (negative to the time of passage of the first limb, or positive to that of the second limb, accordingly as the Moon had passed or had not passed the opposition in right ascension), thus investigated:—The excess or defect of the difference of R.A. of the Sun and Moon from 12^{h}, at the time of the Moon's transit, being found, and expressed in arc, this quantity is multiplied by the cosine of the Sun's declination, and thus an arc θ is obtained which represents the angle, upon the Moon's surface, of the unenlightened part of the disc (with respect to right ascension); the correction required is, semidiameter × versed sine θ. The mean of four values of the error is $- 0^{s}\cdot22$.

The Moon's vertical diameter is found in the same manner as the Sun's (the correction for defective illumination having been already applied, see page liv.) The mean of seventeen values of the error is $- 0''\cdot04$.

The vertical diameters of Venus are found by subtracting the N. P. D. of the north limb from that of the south limb, after the correction for defective illumination has been applied, as explained at page lv. The vertical diameters of the other planets are obtained in a similar way, excepting that there is no correction for defective illumination.

The Mean Solar Time is found, in all cases, from the Right Ascension or Sidereal Time, by adding together the Mean Solar Time at the transit of the first point of Aries next preceding, and the equivalents in Mean Solar Time for the hours, minutes, and seconds of Sidereal Time: the whole of these numbers being taken from the Nautical Almanac. In practice, this operation is made a little easier by putting the addition in the following form:—

1. Sidereal Time.
2. Mean Solar Time of Transit of first point of Aries diminished by 4^{m}.
3. 3^{m}. $47^{s}\cdot00$ — hours of Sid. Time + solar equiv. for hours.
4. $10^{s}\cdot00$ — minutes of Sid. Time + solar equiv. for minutes.
5. $3^{s}\cdot00$ — seconds of Sid. Time + solar equiv. for seconds.

Small tables of the 3rd, 4th, and 5th quantities are prepared (see Appendix to Observations, 1837, Table No. IV.), and the operation is then very simple, consisting entirely of addition, with few figures, and no interpolation.

In the year 1853 there are very few instances in which only one element of a planet has been observed. In any case where the North Polar Distance has been observed without the corresponding Right Ascension (chiefly occurring in the case of the Sun), the Right Ascension at Transit (for the calculation of the Mean Solar Time) is taken from the Nautical Almanac.

The Right Ascensions of the Sun are transcribed from those in the *Transits observed, &c.*, with no alteration except that, when necessary, the personal equation is applied, as mentioned in a former part of this Introduction (page xliv).

The North Polar Distances of the Sun's center are generally the means of those deduced from the observations of the two limbs in the last column in the section *Observations of Zenith Distance*. In the case where only one limb has been observed, the N. P. D. of the center is deduced from that of the limb by application of the diameter given in the Nautical Almanac.

The Right Ascensions of the Moon are taken from the *Transits observed*, corrected, if necessary, for personal equation.

When both limbs of the Moon are observed, the correction for defective illumination (page lxxviii) is first applied to the proper limb, and the mean of the two is then taken without further alteration.

The corrections to the Moon's diameter, applied in former years to the numbers given in the Nautical Almanac, having, for the year 1853, been incorporated in that work, it will be sufficient to have shewn with what degree of accuracy they now represent the observed values. The mean values of the Tabular Errors in Right Ascension and Zenith Distance, previously given at page lxxviii, are $-0^{s}\cdot22$ and $-0''\cdot04$. This would seem to imply that the corrections already applied do not satisfy equally well the time of transit of the diameter, and the diameter in the direction of Zenith Distance, as observed with the Transit-Circle, and that the tabular values of the former element still require a sensible correction. The number of observations is as yet, however, too small to make the determination satisfactory, and no correction has been applied throughout the year 1853.

The Tabular North Polar Distances of the Moon are taken from the seventh column in the section *Moon-culminating Stars* of the Nautical Almanac.

It has been already mentioned (page xlv) that, for the Right Ascensions of Venus, a correction has been applied to the time of tabular semidiameter amounting to

$$+ 0^{s}\cdot 05 + 0^{s}\cdot 03 \times \text{tabular time of passage of semidiameter.}$$

This correction is derived from an investigation given in the Introduction to the Greenwich Observations for 1838.

It has also been mentioned (page xlv) that a correction represented by

$$0^{s}\cdot 304 \times \text{tabular time of passage of semidiameter,}$$

derived from the observations of the year 1854, has been applied to the tabular time of passage of the semidiameter of Mars.

For all the planets, the Right Ascensions are extracted from the *nineteenth* column of

Transits observed, &c., with no alteration, except for personal equation when necessary: the North Polar Distances are taken from the last column in the upper part of the page of the *Zenith Distances observed, &c.*, corrected for the values of R − D, and for Flexure of Telescope and Errors of Division of the Circle, as has been previously explained. The tabular places are taken chiefly from the Nautical Almanac; those of the ancient planets from the volume for the year 1853; and those for several of the recently discovered planets, viz., for Flora, Victoria, Iris, Metis, and Hebe, from the supplement to the volume for 1856. For Astræa, Calliope, and Hygeia, the tabular places are taken from the Ephemerides by Zech, Hornstein, and Chevallier, in Nos. 866, 858, and 840 of the *Astronomische Nachrichten* respectively; and for Thalia from the Ephemeris in Oeltzen's pamphlet before referred to. Finally for Neptune, the tabular places are interpolated from the Ephemeris in the Supplement to the American Nautical Almanac for 1855.

The investigation of the position of the Ecliptic is conducted in the same manner as the investigations from observations at the Cambridge Observatory, given in the Astronomical Society's Memoirs, vols. viii., ix., and x. The mean of all the errors in each month, for R. A. and for N. P. D., is supposed to be the error for the day which is nearest to the mean of all the days of observation. When the same day is not found for R. A. and for N. P. D., an alteration of a unit or more has sometimes been made. From these, the error in the Ecliptic Polar distance is obtained by means of the factors R and S in the tables forming the second part of the Appendix to the Greenwich Observations, 1836. Supposing these errors to arise from an erroneous position of the ecliptic assumed in the Nautical Almanac, they may be expressed by the formula $x \times \cos \odot$ longitude $+ y \times \sin \odot$ longitude $+ z$. For convenience, the weight attributed to each monthly equation is so altered, that the sums of those in opposite quarters are equal. The rest of the process needs no explanation.

In the Observations of 1853, the clock-error has been obtained fundamentally by means of the Right Ascensions given for 1845 in the Greenwich Twelve-Year Catalogue of 2156 Stars. The Apparent Errors of R. A. are found by comparing the observed R. A. as formed by the use of this clock-error, (no other alteration being applied) with the Tabular R.A. The Errors in longitude and E. P. D. are formed by the use of the numbers P, Q, R, S, in the Appendix to the Greenwich Observations, 1836. For any of the older small planets, whose latitude exceeds the limits of the Tables, the longitude and E. P. D. are computed, 1st from the R. A. and N. P. D., of the Nautical Almanac; 2nd, from these quantities affected with the Errors in R.A. and N.P.D.; and the difference between these results gives the Errors in Longitude and E. P. D.

For the *Errors in the Tabular Heliocentric Places of the Planets*, the following formulæ are used.

For the four small planets,

Let R = radius vector of planet,	L = planet's heliocentric longitude,
Δ = planet's distance from Earth,	λ = planet's geocentric longitude,
r = Earth's radius vector,	l = Earth's heliocentric longitude.

Then,

$$\text{Error of geoc. long.} = \frac{R \times \cos \text{hel. lat.} \times \cos(\lambda - L)}{\Delta \times \cos \text{geoc. lat.}} \times \text{error of hel. long.}$$

$$- \frac{\sin(\lambda - L)}{\Delta \times \cos \text{geoc. lat.} \times \sin 1''} \times \text{error of projection of planet's radius vector.}$$

$$\text{Error of Hel. E.P.D.} = \frac{\Delta \times \cos \text{hel. lat.}}{R \times \cos \text{geoc. lat.}} \times \text{error of geocent. E.P.D.}$$

$$- \sin \text{hel. lat.} \times \cos \text{hel. lat.} \times \tan(\lambda - L) \times \text{error of geocent. long.}$$

$$- \frac{r \times \tan \text{geoc. lat.} \times \cos(L - l)}{R^2 \times \cos(\lambda - L) \times \sin 1''} \times \text{error of projection of planet's radius vector.}$$

For other planets, the following are used:—

$$\text{Error of geocent. long.} = \frac{R \times \cos(\lambda - L)}{\Delta} \times \text{error of planet's heliocentric longitude}$$

$$- \frac{\sin(\lambda - L)}{\Delta \times \sin 1''} \times \text{error of projection of planet's radius vector}$$

$$- \frac{r \times \cos(\lambda - l)}{\Delta} \times \text{error of Earth's heliocentric longitude.}$$

$$+ \frac{\sin(\lambda - l)}{\Delta \times \sin 1''} \times \text{error of Earth's radius vector.}$$

$$\text{Error of Hel. E.P.D.} = \frac{\Delta}{R} \times \text{error of geocen. E.P.D.}$$

In the expressions above, different quantities are neglected for the small planets and for the other planets. For the small planets, it is not allowed to neglect the latitude in any part of the expressions; while, at the same time, their errors in general are so large that, in comparison with them, the Earth may be supposed to move exactly in the orbit assigned by the tables. For the other planets, the latitude may be neglected in the formula; but it appears proper to retain the errors of the Earth's place, as probably comparable in magnitude to those of the planets.

It is to be remarked, that in the column of *Extent of Group* the day is given which answers to that under which the observations may be found in the sections of *Transits Observed*, and *Observations of Zenith Distance:* but in the column of *Mean Day* the day is given whose noon is nearest to the time of observation, or to the mean of times of observation.

The errors of Tabular Longitude and Ecliptic Polar Distance of the Moon are deduced from the Errors of Tabular Right Ascension and North Polar Distance by the use of the numbers, P, Q, R, S, for all the meridian observations, as well as for the observations made with the Altazimuth. For the Altazimuth, the Errors of Tabular R.A. and N.P.D. are extracted from the last section of computations of the observations made with that instrument.

§ 13. *Observations of γ Draconis, with the Reflex Zenith Tube*, page 44 to 45.

The details of the general construction of this instrument, and of the processes by which the value of a revolution of each of its micrometers was found, will be explained in the Appendix to a subsequent volume. For the understanding of the tabular arrangement giving the successive steps of the reduction of the observations, the following explanation will suffice.

The micrometer frame is furnished with about thirty wires, and, by bringing each of these successively on the acute wire cross of an adjustment-eyepiece which was rendered capable of being brought opposite to different wires in succession, the values of the intervals of the wires were very accurately determined, in terms of revolutions both of micrometer A and micrometer B. These intervals were afterwards measured by observing the time of transit of γ Draconis over each of the wires; and eight series of observations, tolerably complete, were obtained between 1851, July 18, and August 15. By comparing then the number of revolutions of each micrometer corresponding to the intervals between each pair of consecutive wires, with the time occupied by γ Draconis in passing from one wire to the other, the value of one revolution of each is obtained in terms of time; and this is readily reduced to arc by multiplying by 15 times the sine of star's N. P. D. To ensure, however, the utmost accuracy, the hour-angle of the extreme observed wires on each side of wire 15 was found by successive addition, assuming this wire to represent the meridian with sufficient accuracy; and the angular distance of wire 15 from each of the extreme wires was computed. By this means it was found that, on one side of the wire, 156·017 revolutions of micrometer B corresponded to an arc of 43′. 38″·48; and on the other side, 181·936 revolutions corresponded to an arc of 50′. 51″·71.

Hence, in the first case, the value of a revolution was

$$\frac{\tan 43'.38''\cdot 48}{156{\cdot}017 \times \sin 1''} = 16''{\cdot}784\,;$$

and in the other case the value was

$$\frac{\tan 50'.51''\cdot 71}{181{\cdot}936 \times \sin 1''} = 16''{\cdot}775.$$

The mean of these, or 16″·78, has been used.

By obtaining the values of the intervals of several of the wires in terms of revolutions of micrometer A in a manner analogous to that explained above, and comparing them with the intervals obtained in terms of revolutions of micrometer B, it was found that 142·957 revolutions of B were equal to 142·986 revolutions of A. Hence the screws of A and B are assumed to have equal values, and one revolution of each is equal to 16″·78, as stated in the foot-notes to the Observations.

The correction due to the readings of the level-scale is determined from the following considerations:—When micrometer A is to the left—that is, south of the zenith—the micrometer readings increase as the wire moves to the left—that is, as the north zenith distance of the star increases; and, in this position, the readings of the level-scale increase from left to right, or as the right or northern edge of the object-glass is raised.

Supposing this to be the case, the central ray of light for a zenithal star, descending through the focal center and reflected up through the focal center, meets the wire-frame (which is above the focal center) not at its zenithal point, but at a point which is north, or to the right of the zenithal point.

Therefore the wire, when in that position it is laid upon the star, is more to the north or right than it ought to be; and therefore its micrometer-reading is smaller than it ought to be, and a positive correction is required: that is, for increasing readings of the level-scale the correction is positive.

The linear amount of the correction (omitting a constant depending on the zero of the level-scale) is {dist. from focal center to wire-frame} × {$\frac{1}{2}$ sum of readings of level-scale} × {value of one division of level-scale}.

The angular amount of this correction is, the above quantity divided by the focal length of the object-glass.

From statements made by Mr. Simms, it is assumed that the focal center coincides sensibly with the surface of the object-glass, and therefore that the distance of plane of wires from focal center = $0^{\text{in.}}25$; and that the value of one division of the level-scale = $6''$ nearly. Also, the focal length of the object-glass, which is that of Troughton's transit instrument recently dismounted, is 116 inches.

From these data the correction to zenith distance due to the readings of the level-scale is found to be $0''\cdot00646$ × sum of readings of the level-scale.

From these numbers the numerical value of the sums of equivalents for micrometer-readings and for level-readings is computed by the formula given in the foot-notes to the Observations; and thus is obtained the zenithal distance of the star, as measured towards micrometer B, increased by an instrumental constant, which it is necessary to determine from the observations. It is usually determined by taking for the whole of the observations the arithmetical mean of the sums of equivalents for the two reversed positions of the instrument determined on different evenings. By subtracting this constant from the sum of equivalents when B is north, or by subtracting the sum of equivalents from this constant when B is south, the star's apparent north zenith distance is obtained: and by applying to this with reversed sign the correction for the reduction of apparent N. P. D. to mean N. P. D., the mean zenith distances north given in the last column of the tabular arrangement are found.

§ 14. *Eclipse of Jupiter's First Satellite, compared with the Nautical Almanac; and Occultations of Stars by the Moon, with the Equations deduced from the Occultations*, page 48 to 54.

The observed times of observation of occultations of stars, and that of the eclipse of Jupiter's Satellite, need no explanation. The clock used is compared with the Transit-Clock near the time of the observation, and the mean solar time is computed in the usual way.

For the computation of the Occultations, the star's place is taken from the "Elements for facilitating the Computation of Occultations" in the Nautical Almanac.

The Moon's geocentric place, semidiameter, and horizontal equatoreal parallax, are interpolated with second differences from the Nautical Almanac, for the observed instant of the occultation. The correction to be applied to the parallax of the Moon's center, in order to obtain that for the point of the limb at which the occultation takes place, is derived from the following table, for the principles of the formation of which I refer to preceding volumes, from 1843 to 1849:—

Correction to the Moon's Horizontal Parallax, to be used when the Parallax is applied to the Limb.

Angle from the Vertical as seen in an inverting Telescope.		ZENITH DISTANCE.									
		0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
°	°	"	"	"	"	"	"	"	"	"	"
0	360	+0·04	+0·06	+0·08	+0·10	+0·12	+0·13	+0·15	+0·16	+0·16	+0·16
10	350	+0·04	+0·06	+0·08	+0·10	+0·12	+0·13	+0·15	+0·15	+0·16	+0·16
20	340	+0·04	+0·06	+0·08	+0·10	+0·11	+0·13	+0·14	+0·15	+0·15	+0·16
30	330	+0·04	+0·05	+0·07	+0·09	+0·11	+0·12	+0·13	+0·14	+0·15	+0·15
40	320	+0·04	+0·05	+0·07	+0·08	+0·10	+0·11	+0·12	+0·13	+0·13	+0·13
50	310	+0·04	+0·05	+0·06	+0·08	+0·09	+0·10	+0·11	+0·11	+0·12	+0·12
60	300	+0·04	+0·05	+0·06	+0·07	+0·08	+0·08	+0·09	+0·10	+0·10	+0·10
70	290	+0·04	+0·04	+0·05	+0·06	+0·06	+0·07	+0·07	+0·08	+0·08	+0·08
80	280	+0·04	+0·04	+0·04	+0·05	+0·05	+0·05	+0·05	+0·06	+0·06	+0·06
90	270	+0·04	+0·04	+0·04	+0·04	+0·04	+0·04	+0·04	+0·04	+0·04	+0·04
100	260	+0·04	+0·03	+0·03	+0·02	+0·02	+0·02	+0·02	+0·01	+0·01	+0·01
110	250	+0·04	+0·03	+0·02	+0·01	+0·01	0·00	0·00	−0·01	−0·01	−0·01
120	240	+0·04	+0·02	+0·01	0·00	−0·01	−0·01	−0·02	−0·03	−0·03	−0·03
130	230	+0·04	+0·02	+0·01	−0·01	−0·02	−0·03	−0·04	−0·04	−0·05	−0·05
140	220	+0·04	+0·02	0·00	−0·01	−0·03	−0·04	−0·05	−0·06	−0·06	−0·06
150	210	+0·04	+0·02	0·00	−0·02	−0·04	−0·05	−0·06	−0·07	−0·08	−0·08
160	200	+0·04	+0·01	−0·01	−0·03	−0·04	−0·06	−0·07	−0·08	−0·08	−0·09
170	190	+0·04	+0·01	−0·01	−0·03	−0·05	−0·06	−0·08	−0·08	−0·09	−0·09
180	180	+0·04	+0·01	−0·01	−0·03	−0·05	−0·06	−0·08	−0·09	−0·09	−0·09

Let now now δ and θ be the N. P. D. and hour-angle of the star, which are the same as the apparent N. P. D. and hour-angle of the point of the Moon's limb; δ' and θ' those of the corresponding point of the limb as seen from the Earth's center; l the geocentric latitude of the place; and P' the corrected horizontal parallax; then, by an investigation similar to that given in the Introductions to preceding volumes, from 1843 to 1849, it may be shewn that

$$\sin(\theta - \theta') = \frac{\text{Radius of parallel for Greenwich}}{\text{Moon's distance from the Earth's axis}} \times \sin\theta$$

$$\sin(\delta - \delta') = \frac{\sin l \,.\, \sin\delta \,.\, \sin\theta \,.\, \sin P'}{\sin\frac{1}{2}(\theta + \theta') \,.\, \cos\frac{1}{2}(\theta - \theta')} - \cot\tfrac{1}{2}(\theta + \theta') \,.\, \tan\tfrac{1}{2}(\theta - \theta') \,.\, \sin(\delta + \delta')$$

For the first step of computation the following quantities are formed:—

F = log. sin star's hour-angle + log. seconds of corrected eq. hor. parallax + 9·4942224

G = log. sin star's N. P. D. + log. sin star's hour-angle + log. seconds of corrected eq. hor. parallax + 9·8913935.

(The former constant is the logarithm of half the distance of Greenwich from the Earth's axis, and the latter is the logarithm of the distance of Greenwich from the plane of the equator; supposing the Earth's ellipticity $= \frac{1}{300}$).

The preceding formulæ are then adapted to logarithmic computation, and the equations are solved by successive trials, assuming a value for δ', in the following manner:—

$$\text{log. } \tfrac{1}{2}\,(\theta - \theta') \text{ in seconds} = F - \text{log. sin } \delta' + \text{log. } \frac{\text{sine}}{\text{arc}} \text{ for hor. parallax} + \text{log. } \frac{\text{arc}}{\text{sine}} \text{ for } (\theta - \theta')$$

$$\text{log. 1}^{\text{st}} \text{ number} = G + \text{log. secant } \tfrac{1}{2}\,(\theta - \theta') + \text{log. } \frac{\text{sine}}{\text{arc}} \text{ for hor. parallax} + \text{log. } \frac{\text{arc}}{\text{sine}} \text{ for } (\delta - \delta') - \text{log. sine } \tfrac{1}{2}\,(\theta + \theta')$$

$$\text{log. 2}^{\text{nd}} \text{ number} = \text{log. } \tfrac{1}{2}\,(\theta - \theta') \text{ in seconds} + \text{log. } \frac{\text{tan}}{\text{arc}} \text{ for } \tfrac{1}{2}\,(\theta - \theta') + \text{log. sin } (\delta + \delta' - 180^\circ) + \text{log. cot } \tfrac{1}{2}\,(\theta + \theta') + \text{log. } \frac{\text{arc}}{\text{sine}} \text{ for } (\delta - \delta')$$

$$\delta - \delta' = 1^{\text{st}} \text{ number} + 2^{\text{nd}} \text{ number.}$$

In the first trials the log. $\frac{\text{arc}}{\text{sine}}$, &c., are omitted. The convergence of these approximations is extremely rapid.

When δ' and θ' are found accurately, the distance of the corresponding point from tho Moon's center is thus found, by means of a subsidiary angle ψ.

If log. tan ψ = log. diff. R.A. of Moon's center and corresponding point + $\frac{1}{2}$ log. sin N. P. D. of Moon's center + $\frac{1}{2}$ log. sin δ' − log. diff. N. P. D. of Moon's center and corresponding point.

Then log. dist. = log. diff. N. P. D. log. cos ψ.
or = log. diff. R. A. + $\frac{1}{2}$ log. sin N. P. D. of center + $\frac{1}{2}$ log. sin δ' − log. sin ψ.

The coefficients of small variations of the North Polar Distances and of the Difference of Right Ascension (in the expression for distance), are computed by the formulæ,

log. 1st number = 2 log. diff. R. A. + log. sine (sum of N. P. D.) − log. dist. + 4·0835.
log. 2nd number = log. diff. N. P. D. − log. distance.
Coefficient of variation of greater N. P. D. = 1st number + 2nd number.
Coefficient of variation of smaller N. P. D. = 1st number − 2nd number.
Log. coefficient of variation of diff. R. A. =
log. diff. R. A. + log. sin δ' + log. sin Moon's N. P. D. − log. distance.

The variation of the R. A. of the corresponding point contains the following terms:—

1st. The alteration of the R. A. of the star by the quantity e'' will alter the R. A. of the corresponding point by very nearly the same quantity e''.

2nd. The alteration of the horizontal equatoreal parallax in the proportion of $1 : 1 + \frac{m}{1000}$ will alter all the deduced parallaxes (in R. A. and in N. P. D.) in nearly the same proportion: and therefore the R. A. of the corresponding point will be altered by $\frac{m}{1000} \times$ correction for parallax in R. A.

3rd. The alteration in the position of the Moon with regard to the meridian, depending on the alteration of time t^s, will introduce an alteration in the correction for parallax. It is computed by the following formula:—

Alteration in correction of R. A. of corresponding point for parallax, depending on the alteration of time =

$$15'' \times t \times \left\{ \begin{array}{l} \sin P \,.\, \cos l \,.\, \text{cosec N. P. D. cos hour-angle.} \\ + \sin^2 P \,.\, \cos^2 l \,.\, \text{cosec}^2 \text{ N. P. D. cos 2 hour-angle.} \end{array} \right\}$$

This supposes that the star's place is correct. If the Moon's place were supposed correct, the factor, instead of $15'' \times t$, would be $(15'' -$ Moon's change of R. A$) \times t$.

The variation of the R. A. of the Moon's center is $x'' + t \times$ change of R. A. in 1^s.

The variation of the N. P. D. of the corresponding point contains three terms analogous to those for R. A.: namely—

1st. The alteration of the star's N. P. D. by the quantity f'' will alter the N. P. D. of the corresponding point by f'' nearly.

2nd. The correction for parallax in N. P. D will be altered by $\frac{m}{1000} \times$ correction for parallax in N. P. D.

3rd. The increase of hour-angle (considered positive when the Moon is west of the meridian), depending on the alteration of time t^s, will alter the correction for parallax in N. P. D. by the following quantity:—

$$15'' \times t \times \left\{ \begin{array}{l} (-\sin P \,.\, \cos l \,.\, \cos \text{N. P. D.} - \sin^2 P \,.\, \sin l \,.\, \cos l \,.\, \cos 2 \text{ N.P.D.}) \times \\ \quad \text{sin hour-angle.} \\ (-\tfrac{3}{2} \sin^2 P \,.\, \cos^2 l \,.\, \cot \text{N. P. D.} + \sin^2 P \,.\, \cos^2 l \,.\, \cot \text{N. P. D.} \\ \quad \cos^2 \text{N. P. D.}) \times \text{sin 2 hour-angle.} \end{array} \right.$$

The variation of the N. P. D. of the Moon's center is $y'' + t \times$ change of N. P. D. in 1^s.

The computed distance, altered by the sum of the products of the preceding variations by their proper coefficients, is made equal to the semidiameter increased by the term, semidiameter $\times \frac{n}{1000}$: and thus the final equation is formed.

The following table contains the values of log. $\left(\frac{\text{arc}}{\text{sin}}\right)$, log. $\left(\frac{\text{sin}}{\text{arc}}\right)$, and log. $\left(\frac{\text{tan}}{\text{arc}}\right)$ to the extent to which they are needed for these computations.

′	Log. $\left(\frac{\text{Arc.}}{\text{Sin.}}\right)$	Log. $\left(\frac{\text{Sin.}}{\text{Arc.}}\right)$	′	Log. $\left(\frac{\text{Arc.}}{\text{Sin.}}\right)$	Log. $\left(\frac{\text{Sin.}}{\text{Arc.}}\right)$
1	0·0000000	0·0000000	31	0·0000058	9·9999942
2	0·0000000	0·0000000	32	0·0000062	9·9999938
3	0·0000000	0·0000000	33	0·0000066	9·9999934
4	0·0000000	9·9999999	34	0·0000070	9·9999930
5	0·0000001	9·9999999	35	0·0000074	9·9999926
6	0·0000002	9·9999998	36	0·0000078	9·9999922
7	0·0000003	9·9999997	37	0·0000083	9·9999917
8	0·0000004	9·9999996	38	0·0000088	9 9999912
9	0·0000005	9·9999995	39	0·0000093	9·9999907
10	0·0000006	9·9999994	40	0·0000098	9·9999902
11	0·0000007	9·9999993	41	0·0000103	9·9999897
12	0·0000008	9·9999992	42	0·0000108	9·9999892
13	0·0000010	9·9999990	43	0·0000113	9·9999887
14	0·0000012	9·9999988	44	0·0000118	9·9999882
15	0·0000014	9·9999986	45	0·0000124	9·9999876
16	0·0000016	9·9999984	46	0·0000129	9·9999871
17	0·0000018	9·9999982	47	0·0000135	9·9999865
18	0·0000020	9·9999980	48	0·0000141	9·9999859
19	0·0000022	9·9999978	49	0·0000147	9·9999853
20	0·0000024	9·9999976	50	0·0000153	9·9999847
21	0·0000026	9 9999974	51	0·0000159	9·9999841
22	0·0000029	9·9999971	52	0·0000165	9·9999835
23	0·0000032	9·9999968	53	0·0000171	9·9999829
24	0·0000035	9·9999965	54	0·0000178	9·9999822
25	0·0000038	9·9999962	55	0·0000185	9·9999815
26	0·0000041	9·9999959	56	0·0000192	9·9999808
27	0·0000044	9·9999956	57	0·0000199	9·9999801
28	0·0000047	9·9999953	58	0·0000206	9·9999794
29	0·0000051	9·9999949	59	0·0000213	9·9999787
30	0·0000055	9·9999945	60	0·0000221	9·9999779

′	Log. $\left(\frac{\text{Tan.}}{\text{Arc.}}\right)$	′	Log. $\left(\frac{\text{Tan.}}{\text{Arc.}}\right)$
2	0·0000000	14	0·0000024
3	0·0000001	15	0·0000027
4	0·0000002	16	0·0000031
5	0·0000003	17	0·0000035
6	0·0000004	18	0·0000039
7	0·0000006	19	0·0000044
8	0·0000008	20	0·0000049
9	0·0000010	21	0·0000054
10	0·0000012	22	0·0000059
11	0·0000015	23	0·0000065
12	0·0000018	24	0·0000071
13	0·0000021	25	0·0000077

§ 15. *Measures of Distance and Angle of Position of γ Virginis, made with a Double-Image Micrometer upon the Telescope of the East Equatoreal;* page 56.

The general construction of the double-image eyepiece, together with the mode of use, and the advantages and disadvantages attending the use of it, are described fully in the preceding volumes, from 1840 to 1849, to which it is sufficient in this place to refer.

The construction of the double-image eyepiece with which these observations were made is described in vol. xv. of the *Memoirs of the Royal Astronomical Society.* The principal improvement in the construction is, that the colour produced by the prismatic dispersion, which is occasioned by the passage of the rays through each half of the divided lens where the images are separated, is corrected by a new arrangement of the lenses. In this construction the focal length of the first lens, or that nearest to the the object-glass, is arbitrary; so that the power is changed by change of this first lens instead of the fourth, as in the original construction. The eyepiece used is the same as that which was used in 1851, and was made on the principles above explained, adopting (among the various admissible relations of the focal lengths and intervals of lenses) one which was suggested by Mr. B. Valz, of Marseilles. The principal difference between this eyepiece and that used in 1850 consists in the circumstance that the divided lens is concave, instead of being convex, as in the former case. By this means much less light is lost from the central portions of the pencil in its passage past the divided surfaces of the lenses, and the construction is undoubtedly preferable to that used before.

The value of one revolution of the screw of the micrometer is 7″·229. This value is derived from observations made in the year 1851, of which the particulars are given in the Introduction to the volume for 1851.

By observations of γ Virginis on May 20 and 21, the values of the zero of position were found to be 0°. 35′ and 0°. 45′, and these values have been used for the observations of angles of position made on those days.

As a general remark, applying to every class of observation above mentioned, I may state that the original entries of observations are in all cases preserved. The greater part of the regular observations are entered in small memorandum books, in which the entries are written with a metallic pencil whose marks are not easily effaced: but some observations are written down at once with ink in the skeleton forms in which the calculations are to be made, or in the copy which is sent to the press. All, however, are preserved. The proof sheets are read with the first skeleton form in which the observations are entered; and in which, in fact, the examination for accidental errors, &c., is made.

G. B. AIRY.

Royal Observatory, Greenwich,
1854. *December* 11.