GREENWICH

ASTRONOMICAL OBSERVATIONS,

1882.

INTRODUCTION.

I. *Personal Establishment and Arrangements.*

During the year 1882 the establishment of Assistants in the Astronomical Department of the Observatory consisted of the following persons:—

Chief Assistant,—Edwin Dunkin, F.R.S.

First Class Assistants,—George Stickland Criswick; Arthur Matthew Weld Downing, M.A.

Second Class Assistants,—Edward Walter Maunder; William Grasett Thackeray; Thomas Lewis; Henry Park Hollis, B.A. (Cantab.)

In addition to these established Assistants eight or nine computers were employed in the Astronomical Department.

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

The Chief Assistant, 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, the Chief Assistant superintends the calculations generally; and observes occasionally with any of the instruments. The Chief Assistant is always charged with the duty of making the examination of observations, as entered in the Books of First Calculations, in order to ascertain that no error has crept into the records of individual wire-transits or individual microscope-readings; and with the adoption of clock-rates, instrumental zeros, and instrumental errors.

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In the year 1882 Mr. Criswick superintended the reduction of the transit-observations, and the Results of the meridian observations. Mr. Criswick was also charged with the general superintendence of the Computers of the astronomical department, by whom the great mass of calculations and of reading proof-sheets is effected.

Mr. Downing had the charge of the Altazimuth and superintended the reduction of the observations made with that instrument till the middle of September, when the charge of the Transit-Circle and the superintendence of the circle-reductions were transferred to him.

Mr. Thackeray had the care of the library, manuscripts, and publications of the Observatory, as well as of the chronograph.

The charge of the sidereal and solar clocks, the distribution of time-signals, the dropping of the time-signal ball at 1^h, the management of the galvanic apparatus and connexions, the receiving, rating, and issuing of chronometers, and all the computations relating to the time-department, as well as the money-accounts of the Observatory, were confided to Mr. Lewis.

Mr. Hollis superintended the circle-reductions till the middle of September. Since then he has been charged with the reduction of the Altazimuth observations (thenceforward confined to the semi-lunation from last quarter to first quarter), and has also been entrusted with the measurement of the Indian photographs and with the superintendence of the reductions connected with them.

The spectroscopic and photographic observations and the reductions connected with them were entrusted to Mr. Maunder, who had the special care of the South-east or Great equatoreal and of the Photoheliograph.

The course of observations and the succession of observers are arranged every Monday by the Chief Assistant and sanctioned by the Astronomer Royal. 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. In general, the Assistant who makes the observations with the Transit-Circle is charged with all the observations that may occur from 18^h mean time (6 o'clock in the morning) to the next 15^h. During the latter part of the lunation, when the Moon passes the meridian in the early morning between 15^h and 18^h, it is found necessary to appoint separate observers for the morning and the evening. The ordinary observations with the Transit-Circle and Altazimuth have been generally made by Mr. Downing, Mr. Thackeray, Mr. Lewis, and Mr. Hollis. Occasionally when the Moon passes the meridian in the early morning, or in the absence of any of the regular observers, one of the computers is charged with the observations.

The following are the signatures of those persons who have made observations in 1882:—

W. H. M. Christie	WC	W. G. Thackeray -	T	J. Power -	- JP
E. Dunkin -	- ED	T. Lewis -	- L	H. T. James	- J
G. S. Criswick	- C	H. P. Hollis	- H	J. A. J. Pead	- AP
A. M. W. Downing	AD	W. C. Nash	- N	B. Bennett -	- B
E. W. Maunder	- M	J. W. H. Pead	- HP	W. H. Cox -	- HC

For many particulars relating to the internal constitution of the Observatory, reference may be made to the "Regulations of the Royal Observatory," forming the Appendix to the volume for 1873.

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; Bradley's small Equatoreal; 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 smaller 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-foot 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 stored away in frames constructed to hold them. The object-glass was removed from the tube in 1850, 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 Transit-Circle, constructed by Messrs. Ransomes and May, as engineers, and by the late Mr. William Simms, as optician, erected in the year 1850, and brought into use at the beginning of 1851.

The room in which this instrument is mounted occupies the site of the old Circle-room, but is extended to the south, so that its entire length is 36 feet. The ridge of the roof is in the north-and-south direction. The opening in the roof, along the ridge, is 3 feet wide, and is covered by four shutters. The vertical openings, in the north and south walls, are also 3 feet wide, and each is covered by a single shutter. Any one of the shutters can be opened without disturbing the others.

A detailed description of the instrument, illustrated by plates, is given in Appendix I. of the volume for 1852: a reprint of which, with some modifications, is attached to the volume for 1867. The following particulars may be given here. The centre of the instrument is about $5\frac{1}{2}$ feet south and 19 feet east of the old transit-instrument. The length of its telescope is nearly 12 feet, and the clear aperture of the object-glass is about 8 inches. The axis of the instrument is of cast iron, in two similar pieces, the length between the extremities of the pivots being 6 feet. 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 central cube. The pivots are of "chilled" iron and their diameter is 6 inches, the bearing of each being upon two portions of a concave cylinder.

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 hole about 0·01 inch in diameter, behind which a light can be placed for illumination; at the distance of 6 inches from this hole is a lens of 1 inch focal length, producing an image of the hole about 0·002 inch diameter, which in fact is the real mark for collimation; and in the hollow of the western pivot there is fixed an object-glass at a distance from that image equal to its focal length. This combination forms a reversed telescope 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. On 1877 February 27, observations were made for the determination of the relative errors of the form of the pivots of the transit-circle. The process employed is fully explained in Appendix I. of the volume of *Greenwich Observations* for 1852. The following table contains the residual errors, which define the apparent changes of position of a certain line in the material axis of the instrument.

N. P. D. Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.	N. P. D. Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.	N. P. D. Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.	N. P. D. Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.
° ′	″	″	° ′	″	″	° ′	″	″	° ′	″	″
2. 30	−0·28	+0·07	92. 30	−0·01	+0·09	182. 30	+0·14	−0·25	272. 30	−0·04	+0·10
7. 30	−0·32	+0·18	97. 30	+0·27	+0·19	187. 30	+0·05	+0·04	277. 30	0·00	+0·27
12. 30	−0·30	−0·08	102. 30	+0·25	+0·04	192. 30	−0·22	+0·16	282. 30	+0·04	+0·15
17. 30	−0·40	−0·28	107. 30	+0·22	−0·09	197. 30	−0·12	+0·13	287. 30	−0·14	+0·14
22. 30	−0·25	+0·07	112. 30	+0·24	−0·09	202. 30	−0·13	+0·22	292. 30	−0·18	+0·04
27. 30	−0·34	−0·13	117. 30	+0·16	+0·12	207. 30	−0·08	+0·02	297. 30	+0·22	+0·04
32. 30	−0·16	+0·08	122. 30	−0·20	+0·13	212. 30	+0·06	+0·18	302. 30	+0·29	+0·20
37. 30	−0·25	+0·02	127. 30	+0·26	+0·17	217. 30	−0·02	−0·02	307. 30	+0·20	+0·11
42. 30	−0·42	+0·16	132. 30	+0·08	+0·11	222. 30	+0·30	+0·13	312. 30	+0·17	+0·39
47. 30	−0·22	−0·16	137. 30	+0·26	−0·25	227. 30	−0·04	−0·03	317. 30	+0·15	+0·48
52. 30	−0·09	−0·11	142. 30	+0·08	+0·06	232. 30	−0·17	−0·26	322. 30	+0·25	+0·18
57. 30	−0·13	−0·10	147. 30	+0·06	−0·05	237. 30	+0·12	−0·11	327. 30	−0·02	+0·28
62. 30	−0·18	−0·26	152. 30	+0·34	−0·07	242. 30	−0·03	−0·07	332. 30	−0·02	−0·01
67. 30	+0·14	−0·42	157. 30	+0·31	−0·13	247. 30	+0·01	−0·07	337. 30	+0·04	−0·14
72. 30	−0·03	−0·20	162. 30	+0·20	−0·24	252. 30	+0·14	+0·07	342. 30	−0·20	+0·12
77. 30	+0·02	−0·26	167. 30	+0·20	−0·43	257. 30	−0·10	+0·22	347. 30	−0·17	−0·14
82. 30	+0·07	−0·44	172. 30	0·00	−0·18	262. 30	−0·19	+0·09	352. 30	−0·12	−0·20
87. 30	+0·33	−0·07	177. 30	+0·15	−0·21	267. 30	+0·04	+0·21	357. 30	−0·20	−0·08

No correction has been applied on account of error in the form of the pivots.

The wire frame contained originally (besides the horizontal wire, to be noticed shortly) seven vertical wires, adapted to observations of transits by eye-and-ear; to which six were added in the spring of 1854, for more convenient use in the observations of transits by galvanic contact: the whole frame and whole system of vertical wires are moved horizontally 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. The field of view is illuminated by the light from a central gas-lamp (to be mentioned hereafter), which enters the axis and is reflected by an internal annular reflector; by inclining the reflector, the illumination is diminished and finally destroyed; and by inclining it still more, the light is thrown (by means of reflecting prisms) in such a manner as to illuminate the wires, leaving the field dark, means being provided for graduating the intensity of illumination of the wires.

For determining the error of collimation, two horizontal telescopes or collimators of about 6 feet 10 inches focal length and 7 inches aperture, with their axes in the same horizontal line through the centre of the instrument and their object-glasses turned towards it, are mounted on Y's carried by massive brick piers, one on the north and the other on the south side of the transit-circle. Each collimator is furnished with wires in its principal focus, to be used as collimating marks; and each may be used as presenting a distinct mark 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 $2\frac{3}{4}°$, and 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). For adjustment of the collimators accurately on each other, the plates carrying the wires are moveable by micrometer-screws: that of the south collimator in altitude only, and that of the north collimator in azimuth only. 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 by the other, it is necessary to place the transit telescope vertical, and to uncover the perforations in the opposite sides of its central cube, which permit one collimator to view the other through eight holes of sector-form. The opposite sides of the central cube were pierced with these perforations in August and September 1865. This arrangement was brought into use on 1866 December 17, when the collimators of 7 inches aperture were mounted in place of those of 4 inches aperture, used up to that time. To obtain a somewhat more perfect view of one collimator by the other, it is necessary to raise the transit-circle so far that there shall be no impediment to a direct view, by means of a mechanical apparatus provided for the purpose.

In June 1882 a new form of mounting the collimators was adopted, in order to obtain a greater range of observations of stars by reflexion. In the new arrangement the collimators are mounted on upright cast-iron arms turning about centres below, which allows them to be swung on one side when not in use, the two piers having been cut down and an alteration made in the mounting of the mercury trough, by which it is raised about a foot. It is now found practicable to observe stars by reflexion as far as Z.D. $71\frac{1}{2}°$, an increase of range of more than 30°. To test the stability of the collimators during each determination of collimation-error, it is the usual practice, since the alteration, to observe the coincidence of the corresponding wires of the two collimators immediately after as well as before the observation of the two collimators with the transit-circle. When the two sets of micrometer-readings differ, a correction corresponding to the half-difference is always applied to the concluded reading for line of collimation.

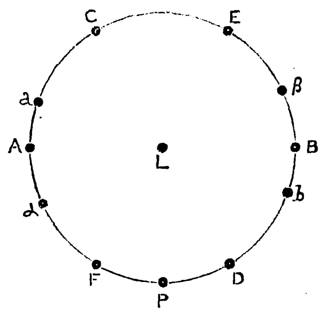
The process of adjusting the collimators, and of using them for determining the line of collimation of the transit-circle telescope, is as follows:—

The transit telescope being placed in proper position, and illumination being given to the south collimator by reflected sky-light, the eye is applied to the eyepiece of the north collimator and the systems of wires in both are distinctly seen: the nearly vertical wires of one being inclined about $5\frac{1}{2}°$ to those of the other. By means of the micrometer screw of the north collimator, the middle of one nearly vertical side of its square is made to coincide with the image of that of the south collimator, 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 daily 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 image of the nearly vertical 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-wire in the process of observation.

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 a transparent glass reflector at an angle of 45° with the axis of the eyepiece, which is placed between the lowest lens and the wires of the telescope. A beam of light being thrown horizontally upon the reflector, and a trough of quicksilver being placed below the object-glass of the telescope, the image of the central wire is seen by reflexion at the same time as the wire itself; by means of the micrometer-screw 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 shielded from the Sun's rays by the steps which are used by the observers for ascending to the upper part of the pier. It is of cast iron, 6 feet in diameter, and has two sets of divisions: one set, on its western side, cut upon a band of silver, which is let into the internal surface of a very flat cone, 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 tubes of the reading microscopes are inclined perforations through the western pier (not furnished with any metallic tube), pointing to the graduations on the flat internal conical surface of the graduated circle. Their eye-pieces are all carried by one massive brass plate at the back of the pier, and are arranged in a circle, whose centre is 5 feet 2 inches above the floor, and whose diameter is about 21 inches.

Their object glasses are separately attached to the inner or eastern side of the pier, and are arranged in a circle of about 5 feet in diameter. Each of the microscope perforations through the pier is accompanied with a perforation for illumination; these illumination-perforations all diverge from one central gas light near the western face of the pier. Each is furnished with a lens, $3\frac{1}{2}$ inches in diameter, by adjustment of which the light from the lamp, after specular reflexion from the graduated surface, is thrown up through the microscope-perforations to the microscope eye-pieces. A lining of double tin plates, inserted in the central opening of the pier, screens, from the radiation of the gas flame, the stone pier, the brass plate, the micrometers, and the eye-pieces. The number of microscopes is eleven; they are arranged in the following order:—



L is the illuminating lamp. P is a microscope usually furnished with an eye-piece of low power, carrying no micrometer, and intended only for reading the integral graduations; A, C, E, B, D, F, are the six micrometer-microscopes at intervals of 60°, used in ordinary observations; a and b are supplementary micrometer-microscopes at 20° distance from A and B respectively, and α and β similar microscopes at 25° distance from A and B; these supplementary microscopes are used for ascertaining the errors of graduation of the circle.

At the end of 1875 new micrometer screws were applied by Mr. Simms to the six ordinary micrometers A, B, C, D, E, F. In March 1878, the micrometers A, C, and F were reversed (their heads being at the same time refigured to read in the opposite direction), so that any effect of wear on the micrometer screws might be eliminated for each pair of microscopes.

There are two clamps attached to the eastern pier, at the same height as the centre of the circle (one on the north side, the other on the south side), which can take hold of the clamping circle of the instrument; but they have no slow motion. The eye-piece of the telescope contains only one horizontal wire, moveable by a micrometer, with which all observations of zenith-distance are made. For reducing every observation, therefore, it is necessary to combine the value of the reading of the telescope-micrometer with that of the mean of readings of the microscope-micrometers. When the telescope points vertically upwards, the head of the telescope-micrometer is on the north side; and the telescope-micrometer-readings increase as the wire is moved towards the head. The reading $20^{rev.}$ corresponds nearly to the centre of the field of view.

In 1873 an apparatus was attached to the telescope-micrometer for mechanical registration of its readings. In this arrangement, punctures corresponding to each bisection of an object, in its passage across the field, are made on a strip of paper, fixed on a light drum immediately above the divided head of the micrometer, and turning with it. To distinguish the several bisections, the pricker by which the punctures are made is, after each puncture, moved through a definite space in the direction of the axis of the drum, by turning a screw, which carries it, through a quarter turn. After a set of bisections the punctures are successively brought up to a straight edge, $0^{r}\cdot050$ from the pricker, and the micrometer-head is read off; each is then marked with a pencil to distinguish it from any which may be made afterwards. By this arrangement several bisections of an object can be made without the observer having to move his eye from the telescope, and a permanent record is obtained, giving facilities for the correction of mistakes.

The reading (consisting of the combination of telescope-micrometer-reading and mean of microscope-readings), 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.

Other explanations necessary for the understanding of the process of reduction of the observations will be given under the proper heads. In this place it may be useful to explain briefly the methods employed in making the various classes of observations which are required.

For star-observing generally, the telescope is directed approximately towards the object by the indications of the N.P.D. pointer, and, the telescope being moved by hand till the star is brought near the horizontal micrometer-wire at or near the reading of $20^{rev.}$, the clamping circle is fastened. The transit of the star is then observed over the vertical wires in the usual way, either by galvanic touch or by eye and ear; and, during the transit, by means of the micrometer-screw which acts on the horizontal wire, that wire is made to bisect the star near the passage over one or more of the vertical wires. The telescope-micrometer, and the pointer and the six microscope-micrometers, are afterwards read, and the observation is complete. If the star be too faint to allow of illumination of the field, the wires are illuminated, and the observation is made in a field perfectly dark.

For observations of stars by reflexion, the telescope is placed, some minutes previously to the transit of the star, in the direction which is proper for viewing the reflected image of the star, and is clamped; the mercury-trough is carefully placed in the requisite position, and the microscope-micrometers are read. The observer then ascends to the eyepiece of the telescope, and, by means of the micrometer-screw which carries the horizontal wire, bisects the reflected image of the star near the passage of the first and second vertical wires (if the star has large polar-distance), or near the second and third wires (if the star is circumpolar), and reads the revolution-counter of the telescope-micrometer. He then descends rapidly into the pit, unclamps the instrument, turns the telescope to the position proper for direct view of the star, and fastens the clamping circle; bisects the star near its passage over one or more of the vertical wires by means of the micrometer-screw, and completes the direct observation in the usual way, by reading the microscope-micrometers for the second observation, and the punctures on the telescope-micrometer register for both observations.

In observing the Sun, the transits of both limbs are taken for right ascension, and observations are made both of the upper and lower limb for north polar distance, in the following manner. The observer at the telescope is aided by two assistants (usually two of the computers), who are stationed in readiness to read the microscope-micrometers. After the transit of the first limb is completed, the telescope is moved by hand till one of the limbs (upper or lower) is brought near to the horizontal wire, when near the reading $20^{rev.}$; then the instrument is clamped, and the horizontal wire is moved, by means of the micrometer-screw which carries it, to touch the limb while passing one or more of the vertical wires (the Nos. of which are registered), corresponding punctures being made on the micrometer register. The revolution-counter of the telescope-micrometer is then read by the observer, and the microscope-micrometers by the assistants, who in fact had commenced to read the micrometers as soon as the instrument was clamped. The instrument is then unclamped, the telescope is directed to the other limb (lower or upper), the instrument is clamped, the telescope-micrometer is turned to place its wire upon the limb in its passage across one or more of the vertical wires, and the micrometers are all read again. Finally, the instrument is unclamped, and the transit of the second limb over the vertical wires is taken. The punctures on the micrometer-register are then read off at the observer's leisure. This operation requires readiness and expertness in the observers; but, when the transits are made by galvanic touch, it is found perfectly easy to take those of the first and the second limb over all the nine wires, still leaving time enough for the observations of both limbs in N.P.D.

For the Moon before opposition, (that is, when the transit of the first limb is observed,) after the transit is completed, the telescope is moved till the limb (upper or lower), which is to be observed in zenith distance, is brought near to the middle of the field; the instrument is clamped; and the telescope-micrometer wire is made to touch the limb (upper or lower) at its passage over the seven original vertical wires at wide intervals, the punctures on the micrometer register being read afterwards. The microscope-micrometers are then read, and the observation is complete.

After the opposition in right ascension, the setting for the full limb (upper or lower) is accurately computed beforehand; the instrument is set with care, and is clamped; and the microscope-micrometers are read previously to the passage. The telescope-micrometer wire is brought on the limb at the passage of each of the vertical wires, as explained above; then the clamp is relaxed, and the telescope is turned by hand to a position proper for observing the transits of the second limb in right ascension, and the transits over the vertical wires are taken. The punctures on the micrometer-register are afterwards read off, and the observation is complete.

When both the upper and the lower limbs are so nearly full as to admit of observation, as also when the first and second limbs are very nearly full at the opposition of the Moon, another person is employed to read the microscope-micrometers as in the case of the Sun; and the mode of observation will be readily understood from the preceding explanations, applying to the observation of the Sun. In this case, however, the aid of one person is sufficient.

The Chronograph.—A detailed account of this apparatus, illustrated by engravings, is given in the Appendix to the Volume for 1856, and a brief description of the chief parts will be found in the *Introduction* for 1880 and preceding years.

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

This instrument is mounted in a tower (now called the South dome), which 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, the South-east dome, and the Octagon room. Its centre is about 47 feet west and 29 feet south of the transit-circle.

The diameter of each of the two circles (horizontal and vertical) is 3 feet; the length of the telescope is 4 feet 2 inches; the aperture of its object-glass 4 inches.

The instrument can be firmly clamped in azimuth and in zenith-distance, each clamp being furnished with a slow motion. For each movement there is also a moderately-slow motion, by rack and pinion.

In March 1880 the horizontal circle was redivided by Mr. James Simms, the divisions in some places having been obliterated in course of time, and at the same time new double compound object-glasses, with adjustment for focus, were applied to the microscopes of the horizontal circle. A metal cover, with circular openings under the microscopes, was also fixed to the lower part of the revolving frame to protect the divisions of the horizontal circle from dirt or injury.

For a detailed account of this instrument, illustrated by engravings, and for a description of the processes gone through in its adjustment, reference may be made to the volume of Astronomical Observations for 1847. The description, with some modifications, is reprinted, and attached to the volume for 1867.

For determining the zenith-point of the vertical circle and the collimation-error for horizontal transits, a collimator is used, having its object-glass (of 5 inches aperture and 24½ feet focal length) planted in the coping of the north wall of the South Dome. The mark is the image of a small circular hole, as formed by a lens of short focus, and is firmly mounted on a chimney, in the focus of the 24½ feet object-glass, so as to form a horizontal collimator.

From September 1880, the observations of a moderately-distant azimuth-mark have been used in combination with stars for determining the zero of azimuth. This azimuth-mark is a vertical slit 0·5 inch wide and 4 inches long, with a reflector behind it, mounted on a stout brass tube, fixed on the parapet of the Royal Naval College, at a distance of about 1,730 feet from the altazimuth. It is viewed through a hole in the north wall of the south dome, in which a cap is fixed with a vertical slit two inches wide, so as to limit the aperture of the object-glass and diminish the confusion in the image of a moderately-distant mark, which is necessarily a little out of focus.

In May 1873 the pivots of the axis of the vertical circle of the altazimuth were examined. The method employed is the same as that explained in detail in the Introduction to the *Greenwich Observations* for 1847, and in the Description of the Altazimuth attached to the volume for 1867, page 14. The residual errors, showing the movements of certain points on the ends of the two pivots, are given in the following tables:—

Pivot on the side opposite to the Graduated Face.

Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Below.	Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Below.	Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Below.	Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Below.
°	r	r	°	r	r	°	r	r	°	r	r
5	− 0·002	− 0·020	95	+ 0·026	− 0·007	185	− 0·045	+ 0·020	275	+ 0·029	+ 0·020
15	− 0·007	+ 0·006	105	+ 0·008	− 0·012	195	− 0·026	+ 0·012	285	+ 0·021	− 0·019
25	+ 0·004	+ 0·017	115	+ 0·001	+ 0·005	205	− 0·014	− 0·002	295	+ 0·022	− 0·015
35	+ 0·006	+ 0·008	125	0·000	+ 0·012	215	− 0·044	+ 0·004	305	+ 0·010	− 0·014
45	+ 0·008	+ 0·012	135	+ 0·004	− 0·007	225	− 0·015	+ 0·021	315	− 0·006	− 0·020
55	+ 0·032	+ 0·017	145	− 0·014	+ 0·012	235	+ 0·010	− 0·001	325	− 0·022	− 0·022
65	+ 0·018	+ 0·014	155	− 0·001	+ 0·010	245	+ 0·019	+ 0·028	335	− 0·034	− 0·025
75	+ 0·048	− 0·003	165	− 0·027	+ 0·003	255	+ 0·033	+ 0·002	345	− 0·032	− 0·033
85	+ 0·030	+ 0·003	175	− 0·024	+ 0·010	265	+ 0·025	− 0·013	355	− 0·040	− 0·033

Pivot on the same side as the Graduated Face.

Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.	Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.	Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.	Pointer Reading.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.
°	r	r	°	r	r	°	r	r	°	r	r
5	+ 0·061	+ 0·038	95	+ 0·002	− 0·042	185	+ 0·029	+ 0·016	275	− 0·041	− 0·009
15	+ 0·031	− 0·003	105	− 0·005	− 0·021	195	+ 0·032	+ 0·024	285	− 0·043	− 0·022
25	+ 0·051	− 0·017	115	− 0·012	− 0·001	205	+ 0·032	+ 0·043	295	− 0·044	− 0·020
35	+ 0·045	− 0·015	125	+ 0·013	+ 0·020	215	+ 0·032	+ 0·043	305	− 0·019	− 0·043
45	+ 0·045	− 0·042	135	+ 0·026	+ 0·026	225	+ 0·003	+ 0·037	315	− 0·017	− 0·016
55	+ 0·018	− 0·040	145	+ 0·011	+ 0·044	235	− 0·034	+ 0·010	325	− 0·023	− 0·011
65	+ 0·023	− 0·060	155	+ 0·021	+ 0·061	245	− 0·056	− 0·004	335	− 0·024	+ 0·002
75	− 0·019	− 0·025	165	+ 0·020	+ 0·047	255	− 0·073	− 0·010	345	− 0·015	− 0·014
85	− 0·005	− 0·023	175	+ 0·023	+ 0·053	265	− 0·059	− 0·006	355	− 0·032	− 0·022

Value of one revolution of the Micrometer = 22″·45.

The Shuckburgh Equatoreal.—This instrument was constructed by Ramsden, and is one of that class usually called the " English equatoreal." It was originally 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. The telescope is 5 feet 4 inches in length, and has an object-glass of 4·1 inches aperture. It is mounted in the North dome, the situation of which is most unfavourable, as the south-western sky is concealed by the Octagon room.

The Sheepshanks Equatoreal in the 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 late 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, 19 feet east and $1\frac{1}{2}$ feet north of the transit-circle. The mounting, particulars of which are given in the Introductions to the Greenwich Observations for former years, is similar in general form to that known as the " German equatoreal," and was constructed by the late Mr. T. Grubb, of Dublin. Besides several negative eyepieces unfurnished with wires, this telescope has a wire-micrometer, and a comet-eyepiece with thick wires.

The South-East or *Great Equatoreal*, constructed by Messrs. Ransomes and Sims as Engineers, and the late Mr. William Simms as Instrument Maker and Optician.—A complete description of this instrument, with engravings, is attached as Appendix to the volume for 1868. The form of the instrument is the "English equatoreal;" the polar-axis turning on pivots at its extreme ends, and including between its two sides the telescope and declination-circle attached to it; the frame which carries the telescope and declination-circle having its pivots at opposite extremities of the declination-axis. The clear aperture of the object-glass, made by Messrs. Merz and Son, of Munich, is 12·8 inches and its focal length is about 17 ft. 10 in.

The Spectroscope, carried by the South-east equatoreal. — The direct-vision "half-prism" spectroscope, constructed by Mr. Hilger, has been used since July 1877. In this form of spectroscope, either great dispersion or great purity of spectrum is obtained by the use of "half-prisms,"* according as the incident pencil falls first on the perpendicular or on the oblique face. Either one, two, or three "half-prisms" can be used at pleasure, according to the dispersion required, and each "half-prism" is compound, being composed of a flint "half-prism" and a crown prism cemented on the oblique face so as to form the half of a direct-vision prism, as cut by a plane perpendicular to the base. With one "half-prism" a dispersion of about 20° from A to H, equivalent to that given by four flint prisms of 60°, is obtained, with two "half-prisms" a dispersion of about 75° from A to H, equivalent to that given by fifteen flint prisms of 60°, with three "half-prisms" a dispersion of about 300°, equivalent to that given by about sixty flint prisms of 60°, the pencil in each case being incident on the perpendicular face of each "half-prism" and emerging at the oblique face. For observations of the Solar prominences, where great purity of spectrum is desired, the slit and eye-piece are interchanged, so that the pencil is incident on the oblique face and emerges at the perpendicular face of each prism. The cross section of the first prism is 2 inches in height by 2 inches in breadth, of the second prism 2 inches in height by 0·6 inch in breadth, and of the third prism 1 inch in height by 0·4 inch in breadth, the pencil being made narrower by the oblique emergence at each prism. The collimator and viewing telescopes have focal lengths of about 23·2 and 11·6 inches respectively with apertures of $2\frac{1}{4}$ inches. Different parts of the spectrum are brought into the field by turning the "half-prisms," each through the same angle, about fixed centres, by means of a micrometer screw acting on a lever. For delicate measures a micrometer eye-piece provided with Hilger's "bright line" is used.

The spectroscope is carried by two rods, which are fixed to two collar-bearings on the eye-end of the telescope, giving the means of rotation round the axis, and carrying a position-circle. The spectroscope is held by two collars with lugs on the

* A "half-prism" is the half of an isosceles prism cut by a plane perpendicular to the base, so that the rays fall perpendicularly on the face so formed. The general theory of this form of spectroscope is given in the *Proceedings of the Royal Society*, vol. xxvi., page 8.

collimator and viewing telescope, which are fixed by clamping nuts on four strong elevator-screws fixed to the two rods and passing through slots in the lugs of the two collars; and an excentricity, either radial or tangential, can be given by altering the height of the nuts or by displacing the spectroscope laterally. The slit can thus be carried round the Sun's limb radially or tangentially, as may be desired.

Occasionally for faint objects another spectroscope of smaller dispersive power is used. This spectroscope has a single prism of flint glass, with a collimator of about 20 inches focal length and a viewing telescope of about 10 inches.

For comparison with the spectrum of hydrogen or other chemical elements, an image of the vacuum tube or electrodes is formed on the slit by means of a transparent plate of glass placed at an angle of 45° with the axis of the collimator in connexion with a collimating lens, so that the cone of rays from the comparison light as well as that from the star fills the whole of the object-glass of the collimator. The light from the star passes through the glass plate without sensible diminution of brightness.

Ample provision is made of the necessary auxiliary apparatus; namely, a Sprengel air-pump, with Crookes' improvements, made by Hicks; an induction-coil, by Browning; and a battery, by Ladd. At the head of the stairs to the Equatoreal room, a water-sink is fitted up, and a glass-blower's bench is mounted.

The Double-Image Micrometer.—The general form 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 for 1840 and for 1843 to 1849. It is a four-glass erecting eyepiece, in which the lenses are so arranged that the axis of the pencil of rays from each point of an observed object passes through the centre of the second lens (as measured from the object-glass), so that in fact an image of the object-glass is formed on this lens, which is divided by a plane passing through the axis of the telescope. The two halves of this lens are moved by a micrometer-screw in opposite directions, and the whole eye-piece is made to revolve round the axis of the telescope by a toothed-wheel and pinion movement. The arrangement of the eyepiece actually adopted is described in the *Memoirs of the Royal Astronomical Society*, vol. xv., page 199.

The double-image micrometer is adapted for use either with the South-east or the Sheepshanks equatoreal.

The Reflex Zenith-Tube, constructed under the direction of Sir G. B. Airy by the late Mr. William Simms.—A detailed account of this instrument is given in Appendix I. to the volume for 1854; in this place the following account will suffice: The object-glass 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 (with its plane horizontal), revolving with the object-glass when the latter is turned. The bearing of the screw of micrometer A is on the fixed micrometer-frame. The moving frame of micrometer A carries the bearing of the screw of micrometer B. Micrometer B carries the wires by which the star's image is bisected. The eyepiece is a four-glass diagonal eyepiece bent at right angles between its third lens and its fourth lens (counting from the eye), and having a diagonal-prism-reflector at the place where it is bent; and so placed that the fourth lens can receive rays of light from the direction of the nadir, and can, by means of the diagonal prism, transmit them horizontally to the eye. The fourth lens (which looks vertically downwards), and the diagonal prism, are placed nearly over the centre of the object-glass, being carried by arms which are fixed to the large tube; the small horizontal tube which carries the remaining lenses of the eye-piece is supported by the large tube of the telescope, and does not project over any part of the object-glass. Below the object-glass, at a distance nearly 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, to ensure accuracy of result, no firmness of construction is requisite in this instrument, except in the connection between the micrometer and the object-glass. The instrument is mounted in a building erected for it in the Middle garden, in the angle between the passage behind the Astronomer Royal's Official room and the south projection of the Transit-circle-room.

Two detached telescopes, one of which is 46 inches in focal length, and the other 30 inches. 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. The 62-inch telescope mentioned in former years, and that of the transit-instrument formerly used as a collimator to Troughton's transit, are now mounted on tripod stands, for general use.

Two Newtonian reflecting telescopes, the largest being one of 10 feet, by Sir W. Herschel.

The following instruments, used in the Transit of Venus Expedition 1874, are now transferred to the Observatory:—

Six 6-inch Equatoreals complete, viz.: the "Lee," "Naylor," "Hodgson," "Corbett," and "Simms No. 1" and "No. 2;" two 4-inch portable telescopes by

Troughton and Simms; five 3-inch portable transit instruments by Troughton and Simms; a 14-inch Altazimuth and three 14-inch Vertical Circles or Altitude Instruments by Troughton and Simms; and five Photoheliographs by Dallmeyer. Several of these are, at the present time, loaned to other Institutions. The Naylor equatoreal, mounted in the South Ground, has occasionally been used for observing comets, the eclipses, &c. of Jupiter's satellites, and other phenomena. This instrument, which had been employed at Bermuda for the observation of the Transit of Venus, 1882, was lost on the return voyage in the wreck of the "City of Brussels" at the entrance of the River Mersey.

The Sidereal Standard Clock, constructed by Messrs. E. Dent and Co., is fixed to the north wall of the Magnetic Basement, as in this apartment the temperature is nearly uniform. The escapement will be found described in Vol. III. of the *Transactions of the Cambridge Philosophical Society*: it is a detached escapement, very closely analogous to the ordinary chronometer-escapement, the pendulum receiving impulse only at each alternate vibration; consequently, the escape wheel and seconds hand move only at alternate seconds (the even seconds). The pendulum is compensated in the following way. A central steel rod is encircled by a zinc tube, which rests on the rating nut on the steel rod; the zinc tube is in its turn encircled by another steel tube, which rests at its upper end on the zinc tube, and carries at its lower end the cylindrical leaden pendulum bob attached at its centre. Slots are cut in the outer steel tube, and holes made in the intermediate zinc tube, with the object of exposing equally all parts of the compound pendulum rod to the action of temperature. For final adjustment of the rate there is placed on the crutch rod a sliding weight, which can be raised or lowered by a nut at the level of the crutch-axis without disturbing the pendulum. The rate of the clock is so steady that, when first mounted, the barometric inequality was indicated with the greatest regularity, the daily losing rate of the clock being increased by $0^{s}\cdot3$ for an increase of 1 inch of barometer reading.

In the autumn of 1873 an apparatus for correction of this inequality was applied to the clock by Messrs. E. Dent & Co., and has been in action regularly since that time. This new compensating apparatus of the Sidereal Standard is founded on the magnetic principle, long previously in use for daily adjustment of the Mean Solar Standard clock. Two bar magnets, each about six inches long, are fixed vertically to the bob of the clock pendulum, one in front, the other at the back, their lower ends being nearly level with the bottom of the pendulum bob. The lower pole of the front magnet is a north pole and the lower pole of the back magnet a south pole. Below these a horseshoe magnet, having its poles precisely under those of the pendulum magnets, is carried transversely at the end of a lever, the opposite arm of which is attached by a connecting rod to a float in the lower leg of a syphon barometer, placed in one corner of the clock case. The area of the cistern in which the float rests is four times as great as that of the upper tube. For change of one inch of barometer reading the horseshoe magnet is thus shifted two-tenths of an inch; and as the average distance between its poles and those of the pendulum-magnets is about $3\frac{3}{4}$ inches, the change of rate produced by increase or decrease of the magnetic action is sensibly uniform. As the clock gained with low barometer reading, it was necessary to place the horseshoe magnet so that there should be attraction between its poles and the adjacent poles of the pendulum-magnets. The action of this apparatus is found to be quite successful.

Galvanic contact for registration of the clock-beats is made by a wheel of 30 teeth on the escape-wheel arbor, a tooth of which at every beat of the clock presses together two light springs. Another pair of springs is also pressed together at the beginning of each minute by an arm on the same arbor, and a supplementary signal is thus sent through a galvanometer as a check on the numeration of seconds. This arrangement was substituted in the latter part of 1881 for that formerly employed (in which a pin on the pendulum was used to press together the contact springs) in order to avoid any effect on the pendulum, contact being made in the part of the beat when the pendulum is quite detached from the clock-train, after the impulse has been given. It had been intended to obtain seconds' signals on the chronograph by the use of an auxiliary clock regulated on Jones's principle, but after various experiments the method was not found satisfactory on account of the shortness of the contact. The currents obtained from the Sidereal Standard at every alternate second are used to drive a relay, from which three independent circuits are derived. One of these is appropriated to the seconds-magnet of the chronograph; in another the current regulates a half-seconds chronometer fixed to the eye-end of the telescope of the South-east equatoreal; that of the remaining circuit regulates the pendulum of a half-seconds clock placed on the foundation frame upon the south pier of the South-east equatoreal, drives a tapper in the South-east equatoreal room for making audible the beats of the clock, and drives also a galvanic chronometer placed, in the Computing Room, on the desk of the Superintendent of the Time Department. No practical difficulty is found in subdividing the interval of two seconds between the clock-beats on the chronograph. The numeration of seconds on the chronograph is readily obtained from the comparisons with the clock Hardy, as explained on page xxiv.

The clock Hardy, in the Transit-Circle-Room, was originally furnished with Hardy's escapement, for which a dead-beat escapement was substituted by Dent in the year 1829. The jewelled holes were removed by Dent in 1836, and the pivots now turn in brass holes. The clock is provided with contact-springs for the purpose of occasional registration of its seconds on the chronograph. Upon the escape-wheel-arbor a wheel having 59 teeth is mounted (that is, 60 teeth with one cut away), and at each second the start of a tooth of this wheel presses together two springs during a very small portion of a second. The omitted tooth in the wheel corresponds to the 1^s of each minute.

There is also a clock in the North dome, marked "Arnold 1," having contact apparatus similar to that in the clock Hardy, in order that the clock may, if required, be temporarily used either in place of Hardy or of the Sidereal Standard clock; one in the East dome, marked "Earnshaw;" one in the South dome (the place of the Altazimuth), marked "Graham 1;" one in the Reflex-Zenith-Tube room, marked "Mudge and Dutton," which was presented in the year 1846 to the Observatory by the Rev. Charles Turnor; one marked "Arnold 2," and one marked "Graham 2," used for occasional purposes, which have been supplied with new zinc and steel pendulums (similar to that of the Sidereal Standard), and were also used in the expeditions for observing the Transit of Venus in 1874; and one marked "Graham 3," formerly used for the daily dropping of the time-ball at 1^h, but now occasionally employed for facilitating the regulation of the galvanic motor-clock. There is a clock marked "Dent" placed in the Chronometer-room, and used occasionally for comparisons of chronometers in case of accidental failure of the galvanic clock placed there; also several chronometers kept in the Computing-room for occasional use. Besides these, there are some journeyman or assistant clocks, two of which, occasionally used in longitude operations, are fitted with contact springs, for the purpose of giving galvanic signals; and a watchman's clock.

There are also two sidereal clocks with zinc and steel compensation pendulums, and nine sidereal clocks with wooden pendulum rods, all made by Messrs. E. Dent and Co., and used in the Transit of Venus Expedition 1874.

The clocks Hardy and "Graham 3" are wound up every Monday and Thursday, and the other ordinary clocks in daily use, every Monday.

The Mean Solar Clock is placed in the lobby at the foot of the Octagon-room staircase, near to the trigger of the ball-apparatus. It is a clock of Shepherd's construction, in which the swing of the pendulum completes three galvanic circuits: by one of these the movement of the pendulum is maintained, independently of any train of wheels; by the other two a frame of magnets is made to oscillate, and thus to give motion to the seconds-wheel, and, through it, to the other wheels. The wire which carries the current that produces that oscillation is led through corresponding parts of six similar clocks, and the current, by relay action, drives a seventh clock, and regulates another. The movements of the whole of these clocks are therefore necessarily synchronous with those of the mean solar clock. One of the clocks has a large dial exposed to public view on the east boundary wall of the Observatory; three are in the Chronometer-room, and are used in the daily comparisons of chronometers; one is in the lower and one in the upper Computing-room; one (of the dimensions of a chronometer) is upon the desk of the Superintendent of the Time Department; and one is in the hall of the Astronomer Royal's dwelling house. A comparison of the mean time chronometer, with the chronometer on the same desk synchronous with the sidereal standard clock (as mentioned in a preceding paragraph), is, in fact, a comparison of the mean solar clock with the sidereal standard. The time shown by the sidereal standard at comparison being corrected for its error (as ascertained from star-transits), the true sidereal time at the comparison is found; and this is converted, by calculation, into true mean solar time at the comparison. The difference between this and the time shown by the mean solar clock is the error of the latter. Then, by means of a commutator on the same desk, the superintendent of clocks completes the circuit of a galvanic current, which, passing through a galvanic coil (with no iron core) in the clock case, can be made either to attract or to repel a magnet attached to the pendulum, and thus to accelerate or retard the mean solar clock as long as may be necessary for its correction. The clocks connected with the mean solar clock necessarily receive the same correction. The arrangement for giving hourly signals is as follows. The mean solar clock closes a circuit precisely at each hour: that at 1^h, by the intervention of electro-magnets, pulls automatically the ball-trigger and drops the time-ball at Greenwich. At every hour also the primary clock-current by relay-action causes galvanic currents to pass, on one line of wire to the central station of the Post Office Telegraphs, St. Martin's-le-Grand, London, and on another line to the London Bridge Station of the South Eastern Railway. The currents received in St. Martin's-le-Grand are distributed daily, by automatic action of the "Chronopher," on some of the principal lines of railway and to important provincial towns. The current at 1^h is used to fire a signal gun at North Shields. The hourly currents pass also to the clock tower of Westminster Palace for the guidance of the superintendent of the clock, which is not regulated or corrected by any direct galvanic action; and return-currents are received at definite times from the clock, which show daily at Greenwich the deviation of the clock from true time. The hourly currents which pass from Greenwich on the wire to London Bridge are there distributed at different hours in different directions, by the regulated clock before spoken of, principally to places on the South-Eastern lines of railway. At 1^h the current drops a time-ball at Deal, the property of the Admiralty; and from this ball a return galvanic current is automatically communicated to Greenwich at the instant that the ball has completed its descent.

In 1873, the Kew photoheliograph was erected, with the consent of the Royal Society and of the Kew Committee, in a new dome connected with the magnetic offices in the south ground, and for about two years photographs of the Sun were taken regularly with that instrument. One of the Dallmeyer photoheliographs for the Transit of Venus Expedition, of which there are five, was erected in place of the Kew photoheliograph in September 1875, and from that time has been used exclusively for solar photographs.

The Dallmeyer Photoheliograph has an object-glass of 4 inches aperture and 5 feet focal length, forming an image of the Sun half an inch in diameter; this image is enlarged by a secondary magnifier to 4 inches on the camera screen, where the sensitive plate is inserted, the whole length of the instrument being about 8 feet. The exposure is given by a shutter, having a slit of adjustible width, which is carried by a spring across the primary image. At the principal focus cross-wires are placed, which give facilities for determining the position-angles of spots on the photographs. The instrument is equatoreally mounted, though this is not absolutely necessary to its efficient action, as the exposure is practically instantaneous, amounting only to a few thousandths of a second in ordinary cases.

III. *Subjects of Observation in the Year* 1882.

The Sun has 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.

With regard to the planets, the following rules have been observed: The inferior planets, Mercury and Venus, have been observed on the meridian at every practicable opportunity, excepting Sundays. The superior large planets, Mars, Jupiter, Saturn, Uranus, and Neptune, have not generally been observed when their solar time of meridian passage is greater than 15^h, excepting at times when the Moon passes the meridian later than 15^h. The small planets have been observed only when the time of meridian passage is earlier than 13^h. The observations of all planets are intermitted on Sundays. Comets *a* and *b* 1882, have also been observed on the meridian.

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), together with 56 other stars which are used in connection with the Nautical Almanac stars, for determining clock-error.

The other stars observed are taken from a Working Catalogue containing all stars down to the fifth magnitude inclusive which had not been observed at Greenwich since 1860; circumpolar stars with polar distance up to 40°, both above and below the pole; about 850 stars used for determination of zenith-points; Moon-culminating stars from the list in the Nautical Almanac; stars whose occultations by the Moon are visible at Greenwich; variable stars; stars which pass near the north or south horizon; stars suspected or known to have large proper motions; stars of which observations have been requested for special purposes.

The Altazimuth was used till 1882 July 14 for observations of the Moon on every day when she could be seen, without exception; and for the observations of stars necessary for instrumental adjustments, and of the collimator and azimuth-mark for the same purpose. Since the lunation ending 1882 July 14, the observations of the Moon have been restricted to the first and last quarters of each lunation, it being considered that the intermediate semi-lunation is sufficiently provided for by the meridian observations. The telescope of the Altazimuth has also been occasionally used for observing occultations of stars by the Moon, and for the phenomena of Jupiter's satellites.

The Reflex-zenith-tube has been used throughout the year for observations of γ Draconis. The observations are made at every opportunity (Sundays excepted), except when γ Draconis passes the meridian early in the morning between 15^h and 18^h. In these cases the observation is only made when the Moon also passes in the early morning.

The Shuckburgh equatoreal, the Sheepshanks equatoreal, the South-east or Great equatoreal, and the Naylor equatoreal, have been used for observing occultations of stars by the Moon, and for the phenomena of Jupiter's satellites.

IV. *Explanation of the Printed Observations.*

§ 1. *Transits observed with the Transit-Circle, and Computations of Apparent Right Ascension.*

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 centre was observed. The centre is observed only when the planet's disk is so small and so round as to make it easier to estimate the centre than to determine with accuracy the place of the limb. With regard to the stars, 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. Flamsteed's constellation-No. and constellation, with Bayer's letter; taken from Baily's edition of Flamsteed. When the description thus found differs from that in the British Association Catalogue, the difference is mentioned in the notes.
2. The No. in Bessel's Fundamenta, &c., deduced from Bradley's Observations, referred to as "Bradley."
3. The hour and No. in Piazzi's Catalogue, edition 1814.
4. The No. in Groombridge's Catalogue.
5. The No. in Baily's edition of Flamsteed's Catalogue, referred to as "B.F."
6. The hour and No. in Weisse's two Catalogues of the Stars in Bessel's Zones, referred to as "W.B." and "W.B. (2)" respectively.
7. The No. in Lalande's Catalogue, published by the British Association, or in that edited by Fedorenko.
8. The No. in Lacaille's Catalogue of Southern Stars, published by the British Association.
9. The No. in Oeltzen's two Catalogues of Argelander's Zone Observations, referred to as "Oeltz. Arg. (N)" or "(S)" respectively.
10. The No. in the First and Second Radcliffe Catalogues.
11. The No. in Carrington's Red Hill Catalogue.
12. The No. in the Washington Catalogue of Stars (1860).
13. The Zone and No. in Argelander's Zone Observations of 110,984 Stars (Bonn Observations, 1859), referred to as "Arg. Zone."
14. The No. in the Greenwich Catalogues; or in the British Association Catalogue, referred to as B. A. C.

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

When no mark is attached to the name of the object observed, it is to be understood that the observations were made by the galvanic or chronographic method, which was generally in use throughout the year. In any exceptional case where the eye-and-ear method is employed, the observation is distinguished by having the initials (E & E) affixed to it. The letter R. denotes that the object was observed by reflexion in the trough of mercury.

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

The next *nine* columns contain the clock-times (seconds and decimals of a second only) at which the object was observed to pass each of the wires. For eye-and-ear transits, the wires used are those which were in use before the commencement of the galvanic observations, and they are denoted by the letters N, O, P, T, X, Y, Z.

Polaris and other stars very near the pole, are, however, observed by eye-and-ear over the wires intended for the galvanic transits. The wires used for galvanic transits are denoted by the letters P, Q, R, S, T, U, V, W, X; P, T, and X, being wires of the original system, and Q, R, S, U, V, W, being new wires inserted between P, T, and X. The intervals P–Q, Q–R, R–S, U–V, V–W, W–X, are nearly equal; the intervals, S–T, T–U, are nearly double of the former, for convenience of easily distinguishing the central wire.

In observing by galvanic contact, the observer merely makes contact of the galvanic spring at the instant of the object passing the wire. Occasionally, when no object is under observation, he makes contacts in any arbitrary manner (usually by a commutator which puts the contact-springs of the clock Hardy into circuit with the "observations" pricker-magnet of the chronograph) recording in his book the time by the clock Hardy; and thus the numeration of hours, minutes, and seconds, on the punctured sheets (referred to the Sidereal Standard clock) is easily established. The punctured sheets are examined the next day, the numeration of minutes and seconds is written upon them, and the transits are read into the transit-book.

In observing by eye-and-ear, 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 of the clock, and not to look again at the clock-face till the transit is completed. The fraction of the second is estimated 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.

All transits of stars observed by galvanic contact are usually referred to the Sidereal Standard clock; but for stars very near the pole observed by eye-and-ear, the clock Hardy is necessarily still used. The times printed in the columns "Seconds of Transit over the Wires" are those of the observations as made, the letters (E & E) in the third column indicating when the clock Hardy was used. The difference between the indications of the two clocks is given in the notes.

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

For stars observed by eye-and-ear by the clock Hardy, the *Concluded Transit* includes the correction for reduction of the transit as observed by Hardy to such as would have been observed by use of the Sidereal Standard clock. The correction in each instance applied is given in the foot notes.

When transits have not been observed over all the wires, a correction is applied to the mean of those actually observed, in order to give the mean of the transits as it would have resulted if each had been reduced separately to the centre wire. When transits have been observed over all the wires, the same process of correction is used, but the amount of correction for the mean is very small.

The adopted equatoreal intervals of the wires used are given in a table at the end of this Introduction.

For stars above the pole, the designations of Wires I., II., III., &c., at the heads of the columns of printed transits, correspond to P, Q, R, &c., (or to N, O, P, &c., when the object is observed by eye and ear (E & E), in all cases excepting Polaris, &c.) For stars below the pole, the designations I., II., III., &c., correspond to X, W, V, &c., or to Z, Y, X, &c.

The signs of the numbers 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 the table for the wires observed, then dividing by the number of wires, and multiplying by the secant of the star's declination.

For a planet, the correction, computed as for a star, is to be multiplied by

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

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

but it has generally been found easier to add, to the computed interval between the mean of wires and the centre wire, the amount of the planet's increase of right ascension for that interval, which is very readily determined from the numbers given in the Nautical Almanac.

For the Moon, the equatoreal numbers for the wires observed are added together; and the sum is divided by the number of wires; this quotient is then multiplied by,

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

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.

The *fifteenth* column contains the numerical values, in seconds of arc, of the errors of collimation, level, and azimuth; the last two being distinguished from the first by a round and a square bracket respectively. These errors will be treated separately, as follows:—

Error of Collimation.

The value of this error is given in seconds of arc. The sign of the error is considered positive when it implies an additive correction to the time of 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 fully explained above in the description of the instrument. The reading of the micrometer of the north telescope, for coincidence of its nearly vertical wire with the image of that of the south telescope, is ascertained every day, and the micrometer-wire of the north collimator is then left in that position. The reading of the transit telescope-micrometer, for coincidence with the image of the wire of each collimator is then found; the mean of these two readings gives the reading for the line of collimation for the day; and the mean of these determinations, usually for a week, is adopted as the reading for the geometrical line of collimation of the transit-telescope. A correction of $+0^{r}\cdot019$ has been applied to the "Adopted mean of group," to reduce the collimation-readings resulting from the observations of the collimator made through the central cube of the transit-circle to those resulting from observations made when the instrument is raised, this being the discordance found from a comparison of the two methods of observation.

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.

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 foot of every page of transits. The algebraical excess of the reading for 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. (This determination of the value of a revolution was made at the end of the year 1850, as is explained in the description of the transit circle, page {22}, Appendix I., of the Volume for 1852, or in the reprint attached to the Volume for 1867, page 25: a new investigation for verification of the value was made on 1854, June 27, the resulting value of a revolution being $14''\cdot76$, which is essentially identical with the preceding.) To the excess thus converted into are is then applied $-0''\cdot19$ for diurnal aberration; and the result is the quantity which is given in the fifteenth column of the *Transits* as the Error of collimation, and which is adopted for correction of the observed transits.

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

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

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 consists in 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, as is explained in the description of the instrument above, and comparing this reading with the reading for the geometrical line of collimation. 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 result adopted for the error of level is given in the fifteenth column of the *Transits*.

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

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

The error of level has usually been observed twice every day, and in some instances where there appeared to be a considerable change the separate results have been used for the morning and evening observations respectively.

As a check on the general system of correction for error of level, transits of stars have been occasionally observed by reflexion, and the results have been compared with those of direct observations. A table exhibiting this comparison together with the apparent correction to the error of level, deduced from each star observed, is given at the end of this Introduction.

Error of Azimuth.

This error is considered positive when the eastern pivot is too far north. It is generally determined from observations of Polaris, of δ Ursæ Minoris, of Cephei 51, or of λ Ursæ Minoris, at consecutive passages above and below the pole; or from one observation of Polaris, or occasionally of λ Ursæ Minoris, combined with one observation of another star; or from observations of δ Ursæ Minoris and Cephei 51 in combination. 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 second 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 through 12^h; and the difference, in seconds of time, between the first transit and the altered second transit (rejecting 12^h) is divided by 3·603 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 of the clock's rate, and is then divided by 3·603.

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.

When only one observation of a circumpolar star can be obtained, the following process is used:—The letter z being put for the azimuthal error; the time of true transit of any star consists of an observed time with an additional term multiplied by z; and, therefore, the clock-error as given by comparison of that transit with the star's tabular R.A., contains a term multiplied by z. The clock-error given thus by a star near the pole contains a large multiple of z. The clock-error given by a star far from the pole contains a small multiple of z. Equating these, with proper allowance for the rate of clock, z is found. The combination of two stars, both near the pole, but one above and the other below the pole, is very favourable, as both factors of z are large and have opposite signs.

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

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

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

The numerical values of the three corrections for the errors of collimation, level, and azimuth, have been obtained throughout the year by means of sliding logarithmic scales (one for each error) constructed by Mr. Simms. These scales give by simple inspection the numerical corrections in seconds of time for each transit by means of 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 which is let into the scale; and the value of the correction to transits, with its proper sign, is then taken out very readily at sight.

A table of factors for the three errors, having for argument the N.P.D. of the object, which may be found convenient for the verification of the computed corrections, is given at the end of this Introduction.

The *sixteenth* column contains the seconds of every transit, as affected with the three preceding corrections; and is conceived to represent the clock-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 *seventeenth* column contains the seconds of the tabular R.A. of the stars which are used for determining clock-errors. In addition to 155 clock-stars taken from the Nautical Almanac, whose N.P.D. exceed 50°, there has been used another list, consisting of 56 stars, selected and observed for this purpose, and lying beyond the same limit of N.P.D. The tabular right ascensions of Polaris, Cephei 51 (Hev.), δ Ursæ Minoris and λ Ursæ Minoris, are set down, whenever they have been actually used in determining the azimuthal error, to be used in conjunction with the numbers in the sixteenth column, in order to enable the reader to judge of the general state of adjustment of the instrument; but not to assist in determining clock-errors.

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 "Standard Mean Right Ascensions of Clock-Stars for 1872 January 1, based on 12-hour Groups," printed in the Introduction to the Nine-Year Catalogue of Stars for 1872, page 21 (Appendix to Greenwich Observations, 1876). To bring up the mean right ascensions from the epoch of the Catalogue, viz., 1872, to the year 1882, use has been made of the precessions of that Catalogue, and of the proper motions given by Mr. Main or by Mr. Stone. The corrections necessary to bring up the stars' right ascensions to the day of observation are computed by the formula $E\,e + F\,f + G\,g + H\,h + L + 1 - 300^s + \mu\,t$, 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. In a table at the end of this Introduction are given the Mean Right Ascensions for 1882 January 1, of all the stars which have been used for determining clock-errors, together with the constant corrections to the right ascensions of the Nautical Almanac stars; and also the right ascensions of Polaris and other stars very near the pole, which have been observed for the determination of azimuthal error.

The *eighteenth* column contains the error of the clock, found by subtracting the numbers in the sixteenth column from those in the seventeenth. The error is therefore positive when the clock is slow. The apparent clock-errors given by Polaris, Cephei 51, δ Ursæ Minoris, and λ Ursæ Minoris, as has been remarked above, are not employed in determining the clock-errors available for computations of right ascensions.

The *nineteenth* 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, defined by bars across this column (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 considered to be the clock-error corresponding to the mean of all the times of transit of those stars. The next step is to investigate the clock-rate, making allowance for personal equation between the transits of successive observers; and it will be sufficient to explain the personal equation existing between any two observers, but more especially between Mr. Downing and some other observer; for example, between Mr. Downing and Mr. Thackeray; since it has been the practice from the beginning of 1882 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. Downing as the standard. Suppose then that transits have been observed on successive days by Mr. Downing and Mr. Thackeray, and that, for the set of observations on each day, the mean is taken as described above. It will be seen by a table in the Introduction to the *Greenwich Observations*, 1881, page xcvi., that the clock-error given by Mr. Thackeray's observations is greater than that given by Mr. Downing's observations by $0^{s}\cdot14$, as deduced from observations suitable for the determination of this quantity in the year 1881; and this is the last determination of personal equation which is available for the daily reduction of observations in 1882. The quantity $0^{s}\cdot14$ is therefore subtracted from Mr. Thackeray's clock-errors, and it is then considered that we have two sets of clock-errors (namely, Mr. Downing's as unaltered, and Mr. Thackeray's as modified) justly comparable. Each mean clock-error, properly modified, 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 nineteenth 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} for all the different sidereal days are also set down in the nineteenth 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. Downing or Mr. Thackeray), no further computation is necessary for obtaining the right ascensions of those 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. Thackeray, and the other object by Mr. Downing, a further correction $-0^{s}\cdot14$ must be applied: if the clock-stars are observed by Mr. Downing, and the object by Mr. Thackeray, $+0^{s}\cdot14$ must be applied. The personal equations are *not* applied in the column of *Apparent Right Ascensions from the Observations* in this Section.

The observations which are available in the year 1882 for determining personal equations in the use of the chronographic method of recording transits are discussed in a table at the end of this Introduction. They have been treated in the same manner as in preceding years, by comparing the clock-error at the same sidereal hour given by two different groups of stars observed by different persons.

The following are the personal equations as applicable to the chronographic method of observing, deduced from the observations made in 1882 and referred to Mr. Downing as Standard Observer:—

A D − T = − $\overset{s}{0}$·14	A D − H P = − $\overset{s}{0}$·12	A D − B = + $\overset{s}{0}$·08
A D − L = + 0·04	A D − J P = + 0·12	A D − H C = − 0·06
A D − H = + 0·12	A D − A P = − 0·03	

These have been applied to the collected results of transits for the Sun, Moon, and planets, whenever they were needed throughout the year 1882.

But those used in the adoption of clock-rate as explained above, and in the reduction of altazimuth observations, referred to Mr. Downing as Standard, have been deduced from the observations in 1881. The investigation of these is given in the *Introduction to the Greenwich Astronomical Observations*, 1881, page xci.

The observations by eye and ear since 1859 are insufficient in number to give a trustworthy determination of the personal equations observed by that method.

In the standing foot-note on each page is given the duration of passage for the semidiameter of a planet when only one limb has been observed. It is found as follows:—

For the Sun, a correction of $-0^{s}\cdot04$, derived from the observations of several preceding years, is applied to the Nautical Almanac semidiameter.

For the Moon and Mercury, the duration is taken without alteration from the Nautical Almanac.

For Venus, a correction is applied to the Nautical Almanac semidiameter, determined from observations made with the transit-circle from 1851 to 1862. The investigation, by Mr. Stone, will be found in the *Monthly Notices of the Royal Astronomical Society*, Vol. XXV. No. 3. The correction which has been applied additively to the Nautical Almanac semidiameter during the year is

$$+0^{s}\cdot026 + 0\cdot027 \times \text{tabular duration of passage of semidiameter.}$$

For Jupiter and Saturn, both limbs are always observed, if possible; but if, through accident or necessity, only one limb is observed, the duration of passage of the semidiameter is obtained by applying to the value given in the Nautical Almanac a correction derived from a few of the neighbouring observations. The elements of computation are given in the notes.

The *twentieth* column contains the right ascension of the centre of the body observed: it is formed by adding the time from the sixteenth column, the clock-error at 0^h next preceding from the nineteenth 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 foot-notes. No result is set down for a clock-star, unless at least four clock-stars, distributed over six hours of right ascension, have been observed; no result is set down for Polaris, δ Ursæ Minoris, Cephei 51, or λ Ursæ Minoris, unless Polaris, δ Ursæ Minoris, or Cephei 51, has been observed at opposite passages; and no result is set down for other close circumpolar stars, unless there has been a good determination of the azimuthal error on the day of observation.

Whenever the concluded result in this or other sections is obviously erroneous, it is enclosed within brackets, and is not used in subsequent computations.

The *twenty-first* column contains the correction with its proper sign, as it is to be applied for reducing the apparent right ascension of each star at the time of observation to the mean right ascension on 1882 January 1. 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: the sign of the quantity so found is changed.

For other stars, the corrections are computed by the formula

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

(where μ is the annual proper motion in R. A. taken from Mr. Main's or Mr. Stone's papers in the *Memoirs of the Royal Astronomical Society*, or from the *British Association Catalogue*, and t is the fraction of a year corresponding to the day of observation) which is derived from the well-known formula,

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

or its equivalent,

$$\begin{aligned} &\tfrac{\mathrm{A}}{15}\cos \mathrm{R.A.\ cosec\ N.P.D.} \\ +&\tfrac{\mathrm{B}}{15}\sin \mathrm{R.A.\ cosec\ N.P.D.} \\ +&\mathrm{C}\sin \mathrm{R.A.\ cot\ N.P.D.} \times \text{numb. log. } 0{\cdot}1259 \\ +&\tfrac{\mathrm{D}}{15}\cos \mathrm{R.A.\ cot\ N.P.D.} \\ +&\mathrm{C} \times \text{numb. log. } 0{\cdot}4869 \\ +&\mu\,\mathrm{t}, \end{aligned}$$

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

Nine-Year Catalogue for 1872, appended to the volume for 1876, and in the Introductions to previous Catalogues. It will be sufficient here to state that $E = A + 25$, $F = B + 25$, $G = C + 1{\cdot}2$, $H = D + 25$, $e = a + 1{\cdot}2$, $f = b + 1{\cdot}2$, $g = c + 25$, $h = d + 1{\cdot}2$, $L = 210 - 1{\cdot}2 \times E - 1{\cdot}2 \times F - 25 \times G - 1{\cdot}2 \times H$, $l = 210 - 25 \times e - 25 \times f - 1{\cdot}2 \times g - 25 \times h$. The values of the day-constants log. E, log. F, log. G, log. H, and L, are given in the Nautical Almanac. The values of the star-constants, log. e, log. f, log. g, log. h, and l, for stars contained in the Nine-Year Catalogue for 1872 are printed in that Catalogue. For other stars, the star-constants will be found in one of the annual Catalogues from 1877 to the present year.

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, and Level.*

With regard to these tables, the following remarks, in addition to the explanation which has been given, in the description of the instrument, and in the account of the methods of determining the errors of collimation and level, will be sufficient.

OBSERVATIONS FOR COINCIDENCE OF COLLIMATORS.

These observations are made on every week day. For those made on Monday, the transit-circle is raised to admit an uninterrupted view of the south collimator by the north collimator. On other days, the view is taken through the pierced cube of the transit-circle.

Immediately before the observations of the collimators with the transit-circle for determination of collimation error, six readings of the micrometer of the north collimator for coincidence of the middle of the nearly vertical side of its square with the corresponding point of the square in the south collimator are taken, and the wire is then left at a reading corresponding to the mean of the six. Since the alteration in the form of mounting of the collimators, referred to on page vi., this observation has been usually repeated immediately after the observations of the collimators with the transit-circle. The means of both sets of micrometer-readings 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 (pages vi and vii). The means of the readings for the separate collimators are set down in the second and third columns. The mean of these gives, after the application of a correction " $+0{\cdot}41 \times$ excess of first reading over second reading of North Collimator for coincidence with South Collimator," the concluded reading set down in the fourth column. The next column gives the reading which has been adopted for the period of time limited by the bars above and below; and the last column gives the adopted reading for the line of collimation after the application of a correction of $+ 0^{r}\cdot019$ to reduce the result to that which would have been obtained if the instrument had been raised when the observation for coincidence of the collimators was made. 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 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.

The method of making these observations has been described (page vii). A comparison of the transit-micrometer reading for coincidence of the direct and reflected images of the central wire (printed in the second column) with the adopted reading for the line of collimation, gives the error of level in terms of revolutions of the micrometer; and the numbers in the third column exhibit 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.

§ 3. *Observations of Zenith Distance with the Transit-Circle.*

In order to include the whole of the reductions belonging to a single observation on one page, the elements for those reductions which are not frequently changed, and which do not require tabular arrangement, are given in the foot-notes: these are;—correction for runs; formulæ used in computing micrometer-corrections, corrections for curvature of path, and inclination of wire; and zenith-point corrections.

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 reference-numbers which correspond 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 is generally accurate to 1^{s}. 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 Mercury or Venus. The words *Nadir Observation* indicate an observation of the image of the horizontal or zenith-distance wire as seen by reflexion in a trough of mercury, as is described in page ix. For other objects, the letter R. denotes that the object is observed by reflexion in the trough of mercury.

READINGS OF THE MICROSCOPE-MICROMETERS.—The application of the letters for the six ordinary microscope-micrometers 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 (see diagram, page viii). These readings in the observing books are placed in the order $\frac{\text{A, C, E,}}{\text{B, D, F}}$; 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, and the order of the more conspicuous differences is noted at the bottom of the page, this will occasion no ambiguity. On a few occasions the cross-wires have fallen on the negative side of the micrometer-zero; in such cases (which are always mentioned in the notes) the fractional part of the reading given is positive, being that taken from the micrometer-head, but the integer 9 represents −1. 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.

It is proper now to explain how the revolutions and parts of revolutions of the microscope-micrometers are converted into arc, when the six ordinary microscopes are used.

First, it may be premised 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 shown 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 shown 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 sexagesimal 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.

When the four supplementary microscopes are used, the subdivisions are added together, and the sum is multiplied by 3 and divided by 2; it is then only necessary to shift the decimal point.

From the ordinary observations of runs it is known 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 never differs materially from $29^{r}\cdot3$. Now, if the correction, by the addition of 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 ever 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 both of the nominal minutes and of the subdivisions of the nominal minute) 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 $\frac{rX}{100}$: a quantity which can easily be taken from the ordinary sliding-rule.

For the four supplementary microscopes the constant for the sum of the runs would be $\frac{50}{51} \times 20^{r}\cdot000 = 19^{r}\cdot608$. Hence the true reading in seconds of space will be

$$r'' \times \frac{20\cdot000}{19\cdot608 - x}$$

or

$$r'' \left\{1 + \frac{1}{50} + 0\cdot05202 \times x\right\}$$

and the correction, after adding $\frac{1}{50}$th part of the mean of readings, will be $+ r x \times 0\cdot05202$.

CORRECTIONS FOR ERROR OF DIVISION AND FOR FLEXURE OF TELESCOPE.—The errors of division were elaborately investigated in 1851 and 1852, and a full account of the processes employed in the investigations will be found in the detailed accounts of the instrument, printed as Appendixes to the volume for 1852, and to the volume for 1867. At the end of the year 1856 a new investigation of the division-corrections was made. It is not necessary to give any details of the work, as the method employed is precisely the same as that adopted in the computations made in 1851 and 1852. The means of the results of these independent investigations have been adopted for use. They are given in a table at the end of this Introduction.

A re-determination of these errors, agreeing sensibly with those in the table, was made in 1871. In this determination the divisions 30°, 90°, 150°, &c. were taken as the primary divisions instead of 0°, 60°, 120°, &c. as in previous investigations.

The observations for determination of the horizontal astronomical flexure of the transit-circle telescope are given at the end of this Introduction.

The nearly horizontal wire of the south collimator, used in these observations, was brought upon the image of the corresponding wire of the north collimator, by looking through the cube of the transit-circle; and the micrometer-head was set at the mean of 20 successive readings. After each complete set of 10 observations of the collimating wires the observations for coincidence of these wires were repeated. And a correction has been applied, when required, to the mean circle-reading at bisection of the wire of south collimator, for the half-difference in the two sets of observations for coincidence.

From April 1879 no correction for flexure has been applied, the flexure correction being virtually included in the correction for discordance of direct and reflexion observations.

READINGS OF TELESCOPE-MICROMETER.—This column contains the readings of the micrometer in the eyepiece of the telescope, corresponding to the several bisections of an object during its passage across the field of view. 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 centre of the field of view; observations are, therefore, generally made with a position of the wire not greatly different from this.

A new telescope-micrometer, prepared by Mr. James Simms, has been in use since 1867 July 10.

The value of the micrometer-revolution was determined on 1867 July 12:—The telescope was directed to the nearly horizontal wire of the southern collimator, and was placed so as to give circle readings (approximately) alternately of 89°. 29′

and 89°. 34′; the microscope-micrometers were read and corrected as usual; and the reading of the telescope-micrometer was taken, which was required to produce coincidence of its wire with the image of the wire of the collimator. The observations were made under the direction of Mr. Dunkin. The mean of 42 intervals thus measured gave one revolution of telescope-micrometer = 34″·526.

On 1867 July 31, after relieving the micrometer from a very slight constraint, observations were made by Mr. Stone for ascertaining the validity of this revolution-value through several revolutions. It appeared that, with different indexes of micrometer-revolutions, the following corrections were necessary, to refer the complete results (in the form of Results of Zenith Distance Observations) to the same mean:—

Micrometer-reading		^{r} 14,	correction required	appeared to be	$-$ 0″·19
,,	,,	19,	,,	,,	0·00
,,	,,	22,	,,	,,	$-$ 0·16
,,	,,	27,	,,	,,	+ 0·35

The corrections apparently required are too small to be adopted for use.

On 1875 March 30, a redetermination of the value of one revolution was made by Mr. Downing, by observations of the reflected image of the wire in the nadir position; the mean of 10 intervals of 5^{r} each thus measured gave a value 34″·559, sensibly agreeing with the preceding.

In previous Introductions there were given observations made by Mr. Dunkin in 1868, which showed that there is no appreciable difference of results, according as the screw is turned to increase readings or to diminish readings, and that the separate portions of the screw's revolution are not sensibly different. Four sets of observations, made by Mr. Downing in October 1882, for the comparison of the values of successive half-revolutions of the telescope-micrometer gave a similar result. (Transit-Circle Tables, p. cii.)

VERTICAL WIRES IN THE TELESCOPE-FIELD, AT WHICH CIRCLE-OBSERVATIONS ARE TAKEN.— Omitting, in this Section, all reference to the wires Q, R, S, U, V, W, adapted to galvanic observation of transits, the telescope contains seven vertical or transit wires N, O, P, T, X, Y, Z, here called 1, 2, 3, 4, 5, 6, 7, placed at sensibly equal intervals of about 14^{s} for transit of an equatoreal star; and the central or 4th 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-micrometer-readings (when converted into 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.

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 bisections of stars (by the telescope-micrometer) at the first and seventh vertical wires. Its numerical value, additive before transit and subtractive after transit, for stars above the pole, is given in the foot-notes.

The general 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. In the case of stars very near the Pole, when the place of observation does not coincide with a vertical wire, the correction for curvature is computed from the formula, "correction for curvature = number (log = 6·43569) $\times$ sin 2 N. P. D. $\times$ t^2," t being the interval between the time of meridian passage and the time of transit expressed in seconds of time.

The formulæ for correction for motion are the following. In the case of the Moon, the correction for the change of N.P.D. in passing from one wire to the next 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 $\times \frac{\text{Sin. Geoc. Z.D.}}{\text{Sin. App. Z.D.}} \times \frac{14}{3600}$ (the logarithm of the last factor being 7·58983)"; this formula supposes the equatoreal interval of the wires to be 14^s. 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; or, in the case of newly discovered planets, from their peculiar Ephemerides.

SECONDS OF CONCLUDED MERIDIAN CIRCLE-READING.—The numbers in this column are found by adding together the mean of the microscope-readings corrected for runs, the equivalent for the mean of the telescope-micrometer-readings, corrected for curvature and inclination of the wire, and the correction for motion in the case of the Sun, Moon, or planets. 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 observations for this purpose are those of the reflected image of the horizontal wire, and those of the direct and reflected images of stars made at the same transit.

The details of the computation of zenith-point are given in a subsequent table. The adopted corrections for zenith-point are given in the foot-notes to this Section.

APPARENT ZENITH-DISTANCE.—The numbers in this column are found by adding the Zenith-point correction to the Concluded meridian circle-reading; when the sum exceeds 270° (denoting that the object is between the zenith and the north horizon), the complement to 360° is taken, and the negative sign is attached to it; for stars observed by reflexion, the sum is subtracted from 180°, and the remainder, with its algebraical sign, is the apparent zenith-distance. When the object 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 Centre*) is ascertained by computation in the following manner:—When the Moon is horned, let θ be the angle which the great 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

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

and the correction to be applied to the Geocentric N.P.D. will be

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

For Mercury and Venus, when horned, the investigation of the correction for defective illumination assumes the same form as for the Moon.

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

And $$\theta_1 = \delta_s - \delta_1 \,.$$

Also $$\begin{aligned}\text{Sin } \theta &= \text{Sin } \theta_1 \,.\, \text{Sin } MS_1P \\ &= \text{Sin } \theta_1 \frac{\text{Sin } MP}{\text{Sin } S_1P} \\ &= \text{Sin } \theta_1 \frac{\text{Cos } \delta_m}{\text{Cos } \delta} \,.\end{aligned}$$

From which θ is found.

The correction required to Geocentric N.P.D. is

Moon's geocentric semidiameter $\times$ versin θ.

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

In the cases of Mercury and Venus when gibbous, or of Mars and other planets sensibly gibbous, the investigation takes the following form. The angle θ being found as above, the length of the straight line drawn from the Sun perpendicular to the plane represented by the great circle above mentioned, is equal to Distance of Earth from Sun $\times$ sin θ; and therefore if ϕ be the apparent angular distance of the Sun from that plane as seen from the planet, the value of ϕ is determined by the equation

$$\text{Sin } \phi = \frac{\text{Length of perpendicular line}}{\text{Dist. of Planet from Sun}} = \frac{\text{Dist. of Earth from Sun}}{\text{Dist. of Planet from Sun}} \times \sin \theta.$$

The angle ϕ represents in this case the angle by which the lowest or highest point of the illuminated hemisphere is distant from the limb as viewed by an observer anywhere in the plane of this great circle, and the correction therefore will be

Planet's semidiameter $\times$ versin ϕ.

BAROMETER.—The barometer is by Horne and Thornthwaite, marked "No. 389," with metallic scale and graduation modified for change of mercury-surface in the cistern. Its scale is divided by vernier to 0·002 inch; but it is not usually necessary to read it to a smaller quantity than 0·01 inch for the computation of refraction. This barometer was substituted in April 1879, for the barometer by Newman, which had been in use to that date. From comparisons with the Standard Barometer made between 1879 March 19 and May 6 (allowance being made for the difference of temperature of the two barometers), it appears that the correction required to the barometer "Horne and Thornthwaite No. 389" is only −0·007 inch. No correction has been applied to the readings of the new barometer.

EXTERIOR THERMOMETER.—This thermometer is by Troughton and Simms. It is mounted on the north front of the Observatory, where it is carried by an arm projecting from the wall to a distance of 4½ feet, at a height of nearly seven feet from the ground.

The following are the results of comparisons with the Standard Thermometer made on 1881 April 13:—

Temperatures.	Excess of Reading of Exterior Thermometer.
°	°
32·0	+0·8
32·0	+0·8
56·5	+0·7
57·2	+0·8
79·6	+0·6
81·5	+0·6

INTERIOR THERMOMETER.—This thermometer is No. 12264, by Negretti and Zambra.

The following are the results of comparisons with the Standard Thermometer made on 1881 April 13:—

Temperatures.	Excess of Reading of Interior Thermometer.
°	°
32·0	+0·6
56·6	+0·6
57·2	+0·7
79·0	+0·7
81·2	+0·6

From 1879 April 3 a correction of −0°·7 has been applied to the readings of the exterior thermometer, and from 1881 April 12 of −0°·6 to the readings of the interior thermometer.

REFRACTION.—The refraction is computed as in former years fundamentally from 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 an Appendix to the Greenwich Observations, 1853. The exterior thermometer only is used in the computation, excepting in cases when the zenith distance exceeds 85°. For such cases the refraction is derived from Bessel's *Fundamenta*, the Supplementary Table being no longer used.

The mean refractions used are the mean refractions of Bessel's *Tabulæ Regiomontanæ*, or those of Bessel's *Fundamenta* increased in the proportion of 1 : 1·003282.

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—

$$\text{log. parallax} = \text{log. sin. (Z. D.} - 11'.12') + \text{ar. co. log. distance} + 0·95045.$$

For the Moon, the horizontal equatoreal parallaxes are interpolated, without alteration, from the Nautical Almanac, for the time of observation. 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. × Sin Dist. from Geoc. Zenith × Geocentric Radius (Log = 9·9991136) + 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, from the vertical, of the point of the Moon's limb under observation) = 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,

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

For the computation of the parallaxes of the small planets, the distances are taken from the Supplement to the Nautical Almanac, or from the *Berliner Jahrbuch*, for planets given in those works.

SEMIDIAMETER.—The semidiameters of the Sun, Moon, and planets are given in the lower part of the page. For the Moon, Mercury, and Uranus, they are taken unchanged from the Nautical Almanac. For the Sun, Venus, Mars, Jupiter, and Saturn, the semidiameters are also taken unchanged from the Nautical Almanac, except in cases where only one limb has been observed. In these cases, for the Sun, the correction $-$ 0''·53, derived from the observations of several preceding years, has been applied to the tabular semidiameter; for Venus, the correction $+$ 0''·392 $+$ 0·027 $\times$ tabular semidiameter, derived from an investigation mentioned at page xxxi above, has been applied to the semidiameter given in the Nautical Almanac; and, for Mars, Jupiter, and Saturn, a correction usually derived from neighbouring observations, and specified in the notes, has been similarly applied.

GEOCENTRIC N. P. D. OF CENTRE.—The numbers in this column are found by combining the Apparent Zenith Distance with the Refraction, Parallax, Semi-diameter, and Assumed Colatitude 38°. 31'. 21''·90.

CORRECTION TO MEAN N. P. D. OF STARS.—The corrections for reducing the Apparent N. P. D. of the stars to the Mean North Polar Distances for the beginning of 1882, 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 numbers required to change Mean N. P. D. to Apparent N. P. D. are computed by the formula,

$$\mathrm{E\,e'} + \mathrm{F\,f'} + \mathrm{G\,g'} + \mathrm{H\,h'} + \mathrm{L} + \mathrm{l'} - 300'' + \mu'\,\mathrm{t}$$

(where μ' is the annual proper motion in N. P. D. taken from Mr. Main's or Mr. Stone's papers in the *Memoirs of the Royal Astronomical Society*, or from the *British Association Catalogue*, and t is the fraction of a year corresponding to the day of observation) which is derived from the well-known formula

$$\mathrm{A}\,a' + \mathrm{B}\,b' + \mathrm{C}\,c' + \mathrm{D}\,d' + \mu'\,\mathrm{t}$$

or its equivalent

$$\begin{aligned} &\mathrm{A\,.\,sin\,N.P.D.} \times \mathrm{numb.\,(log.} = 9{\cdot}6376) \\ -\,&\mathrm{A\,.\,sin\,R.A.\,cos\,N.P.D.} \\ +\,&\mathrm{B\,.\,cos\,R.A.\,cos\,N.P.D.} \\ +\,&\mathrm{C\,.\,cos\,R.A.} \times \mathrm{numb.\,(log.} = 1{\cdot}3020) \\ -\,&\mathrm{D\,.\,sin\,R.A.} + \mu'\,\mathrm{t.} \end{aligned}$$

The formulæ for E, F, G, H, L, have been already given (page xxxiii): $e' = a' + 1{\cdot}2$, $f' = b' + 1{\cdot}2$, $g' = c' + 25$, $h' = d' + 1{\cdot}2$, $l' = 210 - 25 \times e' - 25 \times f' - 1{\cdot}2 \times g' - 25 \times h'$. The values of the day-constants log. E, log. F, log. G, log. H, and L, are given in the Nautical Almanac. The values of the star-constants log. e′, log. f′, log. g′, log. h′, and l′, for the stars contained in the Nine-Year Catalogue for 1872, are printed in that Catalogue. For other stars the star-constants will be found in one of the annual Catalogues from 1877 to the present year.

The sign of the computed quantity is changed before application.

§ 4. *Runs of each Microscope Micrometer of the Transit-Circle; and Zenith Points of the Transit-Circle, in the Year* 1882.

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 columns give the sums of these numbers for the six microscopes, and exhibit the number of revolutions which, for the mean of the six microscopes, measures an arc of 30′, on the supposition that the screws of the micrometers have sensibly equal values. In the first 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 columns of the tables in question and $29^{r}{\cdot}4118$, is computed in the way that has been explained (page xxxvi).

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 results are always divided into three groups, viz.: those resulting from north stars, those from south stars, and those from wire-observations, and the mean of each group is taken. In combining these a weight 2 is attributed to each of the means of the two groups of star-observations, and a weight 1 to the mean of the group of wire-observations, in order to prevent too much weight being given to those divisions of the circle which are always under the microscopes for the wire-observations. 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.

§ 5. *Ledgers of Mean Right Ascensions and Mean North Polar Distances of Stars, deduced from each day's observation in the Year* 1882.

The mean right ascensions of stars are found by applying to the apparent right ascensions in the *twentieth* column of Section 1 the corrections in the *twenty-first* column.

The corrections for personal equation have been invariably applied in this section when the observations of stars for clock-error have been made by one observer, and those of any other object requiring reduction, on the same day, by another observer.

The rules for the nomenclature of stars are the same as those in the section of the *Transits observed,* detailed in page xxiii, but they are more rigorously followed. The stars in Weisse's two Catalogues are referred to under the initials W.B., which stand for "Weisse's Bessel." The stars in Oeltzen's Catalogues of Argelander's Zones are referred to under the abbreviation Oeltz. Arg. (N) or (S).

The mean north polar distances are found by applying, to the north polar distances in Section 3, the corrections given for each star in the lower part of the page.

§ 6. *Observations of Azimuth with the Altazimuth.*

The *first eleven* columns, on the left-hand page, require little explanation, except that in observing the transit the instrument is clamped in azimuth, and the slow-motion pinion of the vertical circle is used to make the transit of the object take place over the middle of each vertical wire. The observations have in general been made by the chronographic method, excepting at times when the galvanic apparatus has been out of order. Such cases are always distinctly marked whenever they occur.

The *twelfth* column is occupied by the personal equation of each observer, referred to Mr. Downing as a standard, deduced from the observations of transits in the year 1881 (see Introduction to Greenwich Observations 1881, page xcvi), as the observations of 1882 are not available for the daily reductions of 1882.

The column "Clock slow" contains the error of the clock; that is, of the Sidereal Standard clock, when the observations are made by galvanic contact; or of Graham 1, when they are made by eye and ear. The number of seconds by which the Sidereal Standard 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 has been obtained by measurement on the plan of the Observatory, of which a reduced copy is attached to the volume for 1862.

By the application of the personal equation and clock error to the mean of observed transits the Sidereal time in the *next* column is formed.

The *next four* columns contain the readings of the micrometers of the four microscopes of the horizontal circle. Occasionally the cross-wires fall on the negative-side of the micrometer-zero; in such cases the fractional part of the reading given is positive, being taken from the micrometer-head, but the integer 9 represents -1. 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 together with the pointer reading (which is not inserted in the printed columns), the concluded reading of horizontal circle is formed in this manner:—Suppose it is found, on examining the runs, that an arc of $5'$ requires $8^{\text{rev}}\cdot 5 - p$ of micrometer a, $8^{\text{rev}}\cdot 5 - q$ of micrometer b, $8^{\text{rev}}\cdot 5 - r$ of micrometer c, and $8^{\text{rev}}\cdot 5 - s$ 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

$$\frac{5'}{4} \times \left\{ \frac{w}{8\cdot5-p} + \frac{x}{8\cdot5-q} + \frac{y}{8\cdot5-r} + \frac{z}{8\cdot5-s} \right\}$$

or

$$\frac{5'}{4 \times 8\cdot5} \left\{ (w + x + y + z) + \frac{1}{8\cdot5} (wp + xq + yr + zs) \right\}$$

From the near equality of w, x, y, z, and the smallness of p, q, r, s, the factors of p, q, r, s, may be considered equal: and the whole expression then becomes

$$\frac{5'}{4 \times 8\cdot5} (w + x + y + z)(1 + \frac{p + q + r + s}{4 \times 8\cdot5})$$

or

$$\frac{5'}{4 \times 8\cdot5} (w + x + y + z) (1 + \frac{1}{100} \times \text{correction for runs for } 100'')$$

which is readily computed by the help of a table of micrometer-equivalents.

In March 1880 the horizontal circle was redivided by Mr. James Simms, and on July 14, 15, and 16 observations were made for the determination of the errors of its divisions. In this investigation the errors of the four primary divisions 0°, 90°, 180°, 270° referred to one of them, say 0°, were first determined by taking twenty sets of readings of the four microscopes a, b, c, d, with each of these divisions successively under each of the microscopes. Secondly, two supplementary microscopes p, q were mounted at a distance of 30° from a and c respectively, and the errors of the divisions 30°, 60°, 120°, 150°, &c. referred to the four primary divisions were determined by ten sets of readings of a, p, c, q. Thirdly, the microscopes p, q were mounted at a distance of 20° from a and c respectively, and thus by steps of 20° in combination with the two preceding operations which gave the errors for every 30°, the errors for every 10° were found, ten sets of readings of a, p, c, q for each arc being taken. Fourthly, the microscopes p, q were mounted at a distance of 25° from a and c respectively, giving the means, in combination with the preceding results, of determining the division errors for every 5°. In this operation five sets of readings of a, p, c, q for each arc of 25° were taken. The errors for every degree were then deduced from those for every 5° by interpolation. The following table contains the final corrections for errors of division applicable to the circle-reading as given by the mean of the four microscopes for every degree in the first quadrant. In the three succeeding quadrants the same corrections are applicable, commencing in the table respectively with pointer readings 90°, 180°, or 270°, instead of 0°.

DIVISION CORRECTION.

Pointer Reading.	Correction.	Pointer Reading.	Correction.	Pointer Reading.	Correction.	Pointer Reading.	Correction.	Pointer Reading.	Correction.	Pointer Reading.	Correction.
°	″	°	″	°	″	°	″	°	″	°	″
0	+1·01	15	+0·02	30	+0·34	45	+0·70	60	+0·94	75	+1·10
1	1·00	16	0·02	31	0·36	46	0·74	61	0·97	76	1·06
2	1·00	17	0·01	32	0·37	47	0·78	62	1·01	77	1·03
3	0·99	18	0·01	33	0·39	48	0·82	63	1·04	78	0·99
4	0·99	19	0·00	34	0·40	49	0·86	64	1·08	79	0·96
5	0·98	20	0·00	35	0·42	50	0·90	65	1·11	80	0·92
6	0·89	21	0·04	36	0·43	51	0·90	66	1·14	81	0·92
7	0·80	22	0·07	37	0·44	52	0·90	67	1·16	82	0·92
8	0·71	23	0·11	38	0·45	53	0·90	68	1·19	83	0·92
9	0·62	24	0·14	39	0·46	54	0·90	69	1·21	84	0·92
10	0·52	25	0·18	40	0·47	55	0·90	70	1·24	85	0·92
11	0·42	26	0·21	41	0·52	56	0·91	71	1·21	86	0·94
12	0·32	27	0·24	42	0·56	57	0·92	72	1·18	87	0·96
13	0·22	28	0·28	43	0·61	58	0·92	73	1·16	88	0·97
14	+0·12	29	+0·31	44	+0·65	59	+0·93	74	+1·13	89	+0·99

From 1880 April 15, these corrections have been applied in forming the concluded reading of the horizontal circle.

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 following are the angular distances from the several wires to the mean, which have been used throughout 1882, the designations of wires being the same as in preceding years: the signs given suppose the face of the vertical circle to be to the right, and are changed when the face is left :—

For wires used in chronographic observations :

		″
Wire	s	− 120·42
	t	− 77·11
	u	− 31·19
	v	+ 31·46
	w	+ 76·41
	x	+ 120·86

For wires used in observations by eye and ear :

		″
Wire	q	− 598·77
	r	− 360·76
	s	− 121·77
	x	+ 119·81
	y	+ 361·50
	z	+ 600·01

For daily observation of the image of the collimator, which is now in the horizontal plane, it is necessary to make use of a single wire, and the wire v has generally been employed for this purpose. The correction to be made to the Circle reading in chronographic observations is $\pm$ 31″·46. This value is applicable for reduction to the mean of wires s, t, u, &c.; but, when the transits are observed by eye and ear, over the wires q, r, s, &c., the correction to be made to the Circle reading is $\pm$ 30″·26.

By the application of these corrections, when necessary, the concluded circle-reading is formed.

The *nineteenth* column contains the Approximate apparent zenith distance taken from the tabular computations.

The *last* column on the left-hand page contains the correction 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 error of collimation × cosec. Z. D. The sign will change according as the face of the vertical circle is right or left. The value of error of 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 first *eight* columns on the right-hand page 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* and *k*, *l* and *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 appropriate 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 *ninth* column contains the Concluded level indication. It is assumed from a careful determination with a level-prover in 1874, that for the mean of the four levels, each division represents one second of arc exactly; 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 explained 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 *tenth* column as the Correction for level.

The Corrected reading of horizontal circle, as affected by all these corrections, is then readily formed.

The *eleventh* column contains the Concluded azimuth, measuring from the south towards the west, which is formed by subtracting the zero of azimuth given at the bottom of the page from the Corrected reading of horizontal circle. The method of determining the zero of azimuth will be explained in a subsequent section.

In cases where 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; this correction is computed by finding first the azimuth of a point opposite the Sun, and then multiplying the distance between the azimuth of this point and that of the Moon's limb by the sine of the Sun's zenith distance; the correction is, versin of this difference multiplied by the Moon's azimuthal semidiamater.

The Hour angle in the *twelfth* column is the difference (without respect of sign, but taken less than 180°) between the Tabular R. A. and the Sidereal time. The east or west side of the meridian is indicated by the letter E or W in this column.

The Tabular R.A. is thus formed. For stars in the list of the Nautical Almanac, there are applied, to the places given in the Nautical Almanac, corrections fundamentally deduced from the "Standard Mean Right Ascensions of Clock-Stars for 1872 January 1, based on 12-hour Groups," printed in the Introduction to the Nine-Year Catalogue, page 21 (see page xxix). For the Moon, the Tabular R.A. of Centre is formed by interpolating with second differences between the hourly places of the Moon given in the Nautical Almanac, using as argument the Mean Solar Time of the *fourth* column.

The *thirteenth* 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 $y = \frac{b^2}{\sqrt{\{b^2+a^2\cot^2 l\}}}$; and the distance from the centre of the spheroid to the foot of the normal, measured along the Earth's axis, is $\frac{a^2-b^2}{\sqrt{\{b^2+a^2\cot^2 l\}}}$; or, in parts of the semi-major axis, it is $\frac{a^2-b^2}{a\sqrt{\{b^2+a^2\cot^2 l\}}}$. The logarithm of this quantity is 7·7174788. Now if, from the Earth's centre, 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 colatitude 38°. 31′. 22″·19 is deduced from that assumed for the Transit-Circle, corrected by the quantity + 0″·29 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 colatitude 38°. 31′. 22″·19; the Tabular azimuth, and the Tabular normal-centric zenith distance are computed by the following formulæ:—

Log tan α=log cos hour-angle + log tan normal-centric N.P.D.
$\beta=\alpha-$colatitude.
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.

A discussion of the observed diameters of the Moon to the end of 1879, both in azimuth and zenith distance, has shown that there is considerable personality in the observations of diameter. It has therefore been considered advisable, from the beginning of 1880, to apply to the semidiameter interpolated from the Nautical Almanac the following corrections depending on the respective observers, determined in this investigation:—

Observer.	Correction to Tabular Semidiameter.	
	Azimuth.	Zenith Distance.
	″	″
Mr. Christie............	− 0·94	− 1·54
Mr. Criswick	+ 1·18	+ 0·98
Mr. Downing...........	+ 0·05	+ 0·80
Mr. Thackeray	+ 0·32	+ 0·75
Other Observers	+ 0·24	+ 0·69

The *fourteenth* column contains the correction to tabular azimuth for Moon's semidiameter. There is then applied the correction required for the difference between the distance of the Moon from the foot of the normal and her distance from the Earth's centre. The former distance is greater than the latter by $a\times$ [7·71748] cos Moon's N.P.D., and therefore her angular semidiameter is diminished in the proportion of Moon's distance to Moon's distance $-a\times$ [7·71748] $\times$ cos Moon's N.P.D., or 1 : 1−sin hor. eq. par. $\times$ [7·71748] $\times$ cos Moon's N.P.D.: or, using the mean parallax 57′, the proportion is 1 : 1 − [5·93708] $\times$ cos Moon's N.P.D. The correction required is taken out from a small table. The Correction to azimuth is computed by the formula $\frac{\text{Corrected semidiameter}}{\text{Sine normal-centric zenith distance}}$ + small correction. The small correction $\frac{\Delta^3}{6}$ sin 1″ $\times$ cot^2 Z.D. $\times$ cosec. Z.D. (where Δ is the Moon's semidiameter) depending on the difference between the sine of semi-diameter and the arc, is insensible, except when the Moon's zenith distance is less than 35°.

By application of these corrections to the Tabular azimuth in the case of the Moon, the tabular azimuth of limb 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 apparent error of Tabular azimuth in the *last* column is formed by subtracting the Observed azimuth from the Tabular azimuth (for a star), or from the Tabular azimuth of limb (for the Moon).

§ 7. *Observations of Zenith Distance with the Altazimuth.*

The *first eleven* columns on the left-hand page require no explanation, except that in the observation the vertical circle is clamped, and the slow-motion pinion of the horizontal circle is used to make the transit of the object take place over the middle of each horizontal wire. The methods of observing and recording the times of transit are the same as for the horizontal transits.

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 geometrical mean of the six horizontal wires: then if δC be the addition (expressed in parts of the radius), or $\delta C_s \times 15 \sin 1''$ (δC_s 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

$$C + \delta C_s \times 15 \sin 1'' = C + \frac{dC}{dc} \cdot \delta c + \frac{d^2 C}{dc^2} \cdot \frac{(\delta c)^2}{2}.$$

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

Therefore $\sin a . \sin b . \sin C . \frac{d\,C}{d\,c} = \sin c$.

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

Whence $\frac{d\,C}{d\,c} = \frac{\sin c}{\sin a . \sin b . \sin C}$

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

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,

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

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

Substituting this in the last term, we have

$$C + \delta\, C_s \times 15 \sin 1'' = C + \frac{\sin c}{\sin a . \sin b . \sin C}\, \delta\, c - \frac{\cot C}{2} . (\delta\, C_s)^2 . (15 \sin 1'')^2;$$

or, putting C_s for the value of C in seconds of time,

$$C_s + \delta\, C_s = C_s + \frac{\sin c}{\sin a . \sin b . \sin C . 15 \sin 1''}\, \delta\, c - \frac{\cot C}{2} . (\delta\, C_s)^2 . 15 \sin 1'';$$

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

Mean of observed hour-angles in seconds of time =

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

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, $\delta\, C_s = -\frac{1}{2}\,\mathrm{I}$; for the second, $\delta\, C_s = -\frac{1}{3}\,\mathrm{I}$; for the third, $\delta\, C_s = -\frac{1}{6}\,\mathrm{I}$; for the fourth, $\delta\, C_s = +\frac{1}{6}\,\mathrm{I}$; for the fifth it is $+\frac{1}{3}\,\mathrm{I}$; for the sixth, $+\frac{1}{2}\,\mathrm{I}$. Hence the equation becomes,

Mean of observed hour-angles in seconds of time =

$$C_s - \frac{\cot C . 15 \sin 1''}{12} . \frac{28}{36} \times \mathrm{I}^2,$$

$$= C_s - \frac{35}{36} . \sin 1'' \times \cot C \times \mathrm{I}^2.$$

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:—

$$+\frac{35}{36}\cdot \sin 1'' \times \cot C \times I^2.$$

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 the first or last 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 the first or last four wires are observed, if I_4 be the interval from the first to the fourth, the correction will be $+\frac{525}{512}\sin 1'' \times \cot C \times (I_4)^2$.

When five consecutive wires are observed, if I_5 be the interval from the first to the fifth, the correction will be $+\frac{129}{125}\sin 1'' \times \cot C \times (I_5)^2$.

If the wires are not consecutive, the corresponding correction will be found, on the same principles, with little difficulty.

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. Downing as standard), and the *next* column by the error of the clock. By the application of the personal equation and clock-error to the mean of observed transits (corrected where necessary for inequality of motion) the Sidereal time of transit in the *fifteenth* column is formed.

The *last four* columns give the readings of the four microscope-micrometers, 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 $\begin{matrix} A & D \\ B & C \end{matrix}$.

From 1880 April 15, corrections for the errors of the divisions of the vertical circle have been applied in forming the concluded reading of vertical circle. These corrections, given in the following table for every degree in the first quadrant, have been derived from the investigation made in April 1847. (Introduction to Greenwich Observations, 1847, page xix.) The same corrections are applicable in the three succeeding quadrants, commencing in the table respectively with pointer readings 90°, 180°, or 270°, instead of 0°.

DIVISION CORRECTION.

Pointer Reading.	Correction.	Pointer Reading.	Correction.	Pointer Reading.	Correction.	Pointer Reading.	Correction.	Pointer Reading.	Correction.	Pointer Reading.	Correction.
°	"	°	"	°	"	°	"	°	"	°	"
0	+0·49	15	+0·09	30	+0·74	45	+0·30	60	+0·56	75	+0·43
1	0·52	16	0·06	31	0·78	46	0·28	61	0·64	76	0·36
2	0·56	17	0·03	32	0·82	47	0·25	62	0·73	77	0·28
3	0·59	18	0·00	33	0·86	48	0·22	63	0·81	78	0·20
4	0·56	19	0·05	34	0·82	49	0·20	64	0·83	79	0·19
5	0·54	20	0·10	35	0·78	50	0·19	65	0·85	80	0·18
6	0·51	21	0·14	36	0·74	51	0·17	66	0·86	81	0·17
7	0·49	22	0·19	37	0·70	52	0·16	67	0·88	82	0·16
8	0·46	23	0·24	38	0·66	53	0·14	68	0·90	83	0·15
9	0·40	24	0·32	39	0·60	54	0·19	69	0·84	84	0·20
10	0·34	25	0·41	40	0·54	55	0·24	70	0·78	85	0·26
11	0·27	26	0·49	41	0·48	56	0·29	71	0·71	86	0·31
12	0·21	27	0·58	42	0·42	57	0·34	72	0·65	87	0·37
13	0·15	28	0·66	43	0·36	58	0·39	73	0·59	88	0·42
14	+0·12	29	+0·70	44	+0·33	59	+0·47	74	+0·51	89	+0·45

When the transits over any number of wires are 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 whole system of wires (including both the eye-and-ear and the galvanic wires) in the order in which a star on the west side of the meridian passes them when the graduated face of the vertical circle is right, *Q*, *R*, *S*, *T*, *U*, *V*, *W*, *X*, *Y*, *Z*, then the corrections to reduce the several wires to the mean of either system of wires used throughout 1882 are:—

For wires used in chronographic observations, and in eye-and-ear observations of objects near the meridian,

Wire *S*	=	−	59″·78
T	=	−	38·56
U	=	−	19·37
V	=	+	17·30
W	=	+	39·68
X	=	+	60·75

For wires used in observations by eye and ear:

Wire *Q*	=	−	303″·73
R	=	−	177·11
S	=	−	59·40
X	=	+	61·13
Y	=	+	178·72
Z	=	+	300·39

The concluded circle-reading is readily formed, in the instances when the celestial body's transit has been observed over all the wires, by the simple mean of the equivalents for readings of microscope-micrometers (duly corrected for runs and errors of division); in the instances in which the transits over a part only of the wires are obtained, by applying to the mean of equivalents the correction (stated in the foot-notes) for the difference between the mean of all the wires and the mean of the wires observed; and in observations of the collimator, by applying to the mean of equivalents the entire correction corresponding to the single wire employed (usually U).

The *first four* columns on the right-hand page 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 of 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.

For the mean of the two levels, one division of the scale is assumed (from a careful determination with a level-prover in 1874) to be equal to $1''{\cdot}075$ (the zeros of E and G being $0^{\text{div.}}$, and those of F and H being respectively $200^{\text{div.}}$ and $250^{\text{div.}}$), and then the mean of the four readings increased by $\frac{3}{40}$ of its amount is taken to form the Level-indication in the *fifth* column.

The Barometer, "Horne and Thornthwaite No. 388," whose reading is given in the *sixth* column, has a metallic scale and graduation modified for change of mercury-surface in the cistern. From comparisons with the Standard barometer made between 1879 June 17 and September 8 (the two barometers hanging side by side), it appears that the readings of the new altazimuth barometer require a correction of $-0^{\text{in}}{\cdot}01$, which has therefore been applied to the readings of the barometer throughout the year.

The Exterior Thermometer, by Browning, whose reading is printed in the *seventh* column, 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 zinc case, allowing a perfectly free passage for the air, and is read from a window pierced in the eastern side of the altazimuth observing room. The corrections required for its errors, ascertained by comparisons with the Standard thermometer made on 1879 April 3, and verified by further comparisons on 1881 April 13, are as follows:—

CORRECTIONS TO ALTAZIMUTH EXTERIOR (PORCELAIN) THERMOMETER.

Altazimuth Thermometer.	Correction.
°	°
Below 20	− 0·4
20° to 35	− 0·5
35 to 40	− 0·6
40 to 48	− 0·5
48 to 68	− 0·6
Above 68	− 0·5

These corrections have been applied to the readings of the altazimuth thermometer throughout the year.

The Interior Thermometer, "Negretti and Zambra, No. 7981," whose reading is contained in the *eighth* column, is placed in a recess in the south-east part of the dome, near the face of the clock Graham 1, and its readings are used in the calculation of the refractions when the Moon is observed at a zenith distance greater than 85°. The correction applied to the readings of the interior thermometer, determined by comparisons with the Standard thermometer on 1879 April 3, and again on 1881 April 13, is $-1°\cdot2$.

An approximate zenith distance being obtained by the use of an approximate zenith-point, the refraction in the *ninth* column is computed by the use of the tables printed in an Appendix to the Greenwich Observations, 1853. These tables give the same results as the tables in Bessel's *Tabulæ Regiomontanæ;* the mean refractions used being those of the *Tabulæ Regiomontanæ*, which are equivalent to those of Bessel's *Fundamenta*, increased in the proportion of 1 : 1·003282. The refraction being always additive to the observed zenith distance 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 circle-reading 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 *tenth* 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 where both the upper and the lower limb of the Moon have been observed, one limb is usually defective through want of illumination. A correction for this defect 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. The correction is, Moon's augmented semidiameter $\times$ versin θ, to be applied to the observed zenith-distance. The corrections for defect of illumination are always mentioned in the notes.

The *next two* columns require no explanation beyond that given in the section of Azimuths.

The Normal-centric semidiameter for zenith distances in the *thirteenth* column is interpolated from the Nautical Almanac, corrected by the numbers in the third column of the above table; and for reduction to the foot of the Normal. The last correction is $-930'' \times [5\cdot93708] \times$ cos Moon's N.P.D., and is readily tabulated.

For computation of the Parallax; in the first place, the horizontal equatoreal parallax is interpolated from the Nautical Almanac without alteration. It is then necessary to deduce from this the parallax referred to the foot of the normal (the Moon's centre having been referred to that point): and for this purpose, first, the equatoreal horizontal parallax must be corrected so as to make the horizontal parallax 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 − [5·93708] × 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 of the normal-centric horizontal parallax is formed.

The parallax in the *fourteenth* column is computed by the formula, Normal-centric horizontal parallax × sine of observed zenith distance of limb + small correction. The small correction is the sum of two terms, namely, $-\frac{P^3}{6} \sin^2 1''. \sin \text{Z.D.} \times \cos^2 \text{Z.D.}$ (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 Z.D. × Airy's correction as given in the section of Occultations. The table of corrections used is given on page lxxvi.

By application of the semidiameter and parallax, the Tabular apparent zenith distance of limb is formed; and by subtracting from this the Observed zenith distance the Apparent error of tabular zenith distance in the *last* column is deduced.

§ 8. *Clock-Comparisons and Instrumental Errors for the Altazimuth.*

In general, the times of the transits taken with the altazimuth by means of the method of galvanic contact are those of the Sidereal Standard clock, and no comparisons of clocks are necessary. The errors of the Sidereal Standard clock are obtained for the time of each observation, and, after correction by $-0^s{\cdot}03$ for difference of longitude, and for personal equation, are applied to the registered times of transit, to form the sidereal time. When, however, through failure of the galvanic apparatus, it is necessary to observe by eye and ear, the comparisons of the clock Hardy and the clock Graham 1 of the South dome, used with the altazimuth, are usually made by means of a mean solar chronometer, whose name is mentioned. 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 expressed as an interval of mean solar time, is converted into an interval of 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, for personal equation, and also for difference of longitude, 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 quanities 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,

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

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

A similar treatment of the observations of the low star gives

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

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

The collimator is now used in a horizontal position, and the determination of collimation-error is thus made independently of the observation of a high star. In fact the collimation-error is simply half the excess of the circle reading with face right over that with face left (with 180° added), and is unaffected by the level-indication.

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.

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, on account of the steadiness of collimation, it appears better to use a mean value of x throughout, a fresh investigation of y is afterwards made from every pair of observations. Thus, let O_r', O_l', be the concluded readings of horizontal circle corrected for the adopted 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 $$\frac{(O_r' + L_r \,.\, \text{cotan}\, D_r - C_r) - (O_l' - L_l \,.\, \text{cotan}\, D_l - C_l)}{\text{cotan}\, D_r + \text{cotan}\, D_l} = y.$$

A high star for this determination is best; and high stars (at an altitude of about 45°) have been exclusively used throughout the year.

The number y, it is to be observed, corresponds strictly with the horizontal position of the axis of the vertical circle, and has no relation whatever to the level-zero corresponding to a vertical position of the 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 following are the results of comparisons of these level-zeros since the erection of the altazimuth. In March 1859 the discordance between the two level-zeros was corrected by filing away the surfaces of the Y of the pivot on the same side as the graduated face. In September 1872 the instrument was dismounted for alteration of the Y bearings, and was again erected in January 1873, but was not at first sufficiently adjusted for perpendicularity of the two axes of rotation. The discordance was reduced on 1873 April 23, by placing two pieces of paper under one of the Y's, and again on 1873 May 26, by adding another piece of paper.

EXCESS OF THE LEVEL INDICATION FOR HORIZONTAL POSITION OF THE AXIS OF THE VERTICAL CIRCLE ABOVE THE LEVEL INDICATION FOR VERTICAL POSITION OF THE AXIS OF REVOLUTION, SINCE THE ERECTION OF THE ALTAZIMUTH.

Year.	Mean Excess.	Year.	Mean Excess.
	″		″
1848	+ 1·13	1866	− 5·07
1849	+ 2·33	1867	− 4·30
1850	+ 6·67	1868	− 5·94
1851	+ 8·75	1869	− 5·06
1852	+ 10·50	1870	− 3·28
1853	+ 11·36	1871	− 3·02
1854	+ 11·71	1872	− 3·47
1855	+ 12·51	1873 Jan. 8 to Apr. 19	+ 38·52
1856	+ 13·23	1873 Apr. 29 to May 19	+ 16·45
1857	+ 13·59	1873 May 27 to Dec. 31	− 2·26
1858	+ 13·70	1874	− 1·96
1859 Jan. & Feb.	+ 13·75	1875	− 0·94
1859 Mar. to Dec.	− 4·23	1876	+ 0·25
1860	− 4·91	1877	+ 0·51
1861	− 5·48	1878	+ 2·15
1862	− 6·24	1879	+ 4·14
1863	− 5·39	1880	+ 3·68
1864	− 5·01	1881	+ 4·36
1865	− 4·56	1882	+ 4·40

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 thought best to use, for each day's observations, the zero of azimuth determined by the star-observations of that day, whenever the changes appear greater than would warrant the combination with other days.

From 1880 October 7, the Adopted zero of azimuth has been formed by combining the observations of the stars with those of the azimuth-mark fixed to the parapet of the Royal Naval College.

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). It is found by taking half the sum of the circle-readings for two successive observations of the collimator, face right and face left respectively.

§ 9. *Catalogue of Mean R.A. and N.P.D. of Stars observed in* 1882, *and New Constants for Stars in the Catalogue, not observed in preceding years since* 1876.

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. For the Nautical Almanac Stars, the annual variations in right ascension are taken from the Nautical Almanac. For all other stars, the geometrical precessions are computed independently, with the elements given by Professor C. A. F. Peters in the *Numerus Constans Nutationis:* the annual variations in right ascension set down are the precessions thus computed, affected with proper motions derived in the order of preference from Mr. Main's or Mr. Stone's papers in the *Mem. R. Ast. Soc.*, from the *British Association Catalogue*, or, for a few special stars having a large proper motion, from Vol. VII. of the *Bonn Observations.*

The north polar distances in the catalogue are the means of the daily results, affected with the corrections for errors of division of the transit-circle, for discordance of direct and reflexion results, and in the case of reflexion observations, for inclination of the verticals at the surface of the mercury and at the centre of the transit-circle. As has been previously explained, Bessel's Refractions of the *Tabulæ Regiomontanæ*, and the Assumed Colatitude 38°. 31′. 21″·90, have been used in the reductions. 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. In the case of circumpolar stars, the results above and below the pole have been kept separate.

The annual variations in north polar distance are formed in the same manner as the annual variations in right ascension, above.

The nomenclature of the stars is identical with that described at page xxiii.

The new star-constants require no further explanation than what is given at pages xxxii and xliv. They are printed for the sake of enabling any person, using the *Greenwich Observations*, to employ the same method of reduction for all the stars found in those volumes.

§ 10. *Horizontal and Vertical Diameters, Right Ascensions, and North Polar Distances of the Sun, Moon, and Planets, deduced from the Observations, and compared with the Nautical Almanac and other Ephemerides: with the inferred Position of the Ecliptic, the Geocentric Errors of the Sun, Moon, and Planets, in Longitude and Ecliptic Polar Distance, and the Equations between the Geocentric Errors of the Planets and the Heliocentric Errors of the Earth and Planets.*

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 the passage of the semidiameter given in the Nautical Almanac. The excess of the latter above the former is set down as the apparent error of the Nautical Almanac. The mean of 87 measures of the value of this error is $+0^s{\cdot}08$, agreeing nearly with the results of preceding years.

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 error of the Nautical Almanac, and the mean of 97 measures of the value of this error is $+0''{\cdot}68$.

For the duration of the passage of the Moon's diameter, the correction for defect of illumination (negative to the time of passage of the first limb, or positive to that of the second limb, according as the Moon had passed or had not passed the opposition in right ascension), is 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 disk (with respect to right ascension); the correction required is, duration of passage of semidiameter $\times$ versed sine θ. Four determinations of the error of the Moon's tabular duration of passage in 1882 give $-0^s{\cdot}03$.

The Moon's vertical diameter is found in the same manner as that of the Sun (the correction for defective illumination having been already applied, see page xl). The mean of 21 determinations of the error of the Moon's tabular vertical diameter made in 1882 is $-0''{\cdot}19$.

From a comparison of the observed vertical diameters with the tabular diameters of the Moon, made from the erection of the transit-circle, to the end of 1863 (see Introduction, 1863, page lxxxvii) it appears that Hansen's semidiameter requires to be increased by $+0''{\cdot}18$, in order to represent the observations of diameter made with the transit-circle.

For the planets, the duration of passage of diameter is found by subtracting the clock-time of transit of the first limb from that of the second limb in the section *Transits observed*, the correction for defect of illumination being applied where necessary. This correction is double the amount applicable to the mean of limbs, which is stated in the notes to that section.

The vertical diameters of Mercury, Venus and Mars 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 xli. 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 preceding 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 any case where the N.P.D. has been observed without the corresponding R.A., the R.A. at transit (for the calculation of the mean solar time) is taken from the Nautical Almanac for the Sun and for planets included in that work; and from other ephemerides, for planets not included in the Nautical Almanac; but in all cases as near an approximation as possible is made to the correct R.A., by the application of corrections derived from neighbouring observations.

The observed right ascensions of the Sun's centre are generally the means of those deduced from the observations of the two limbs; but, when one limb only has been observed, the R.A. of the centre is deduced from that of the limb, by application of the duration of transit of semidiameter given in the Nautical Almanac, corrected by $-0^{s}\cdot04$. The right ascensions are transcribed from those in the section of *Transits observed*, without alteration, except that, when necessary, the personal equation is applied, as mentioned in a former part of this Introduction (page xxxi).

The observed north polar distances of the Sun are taken from the section of *Zenith Distances*, &c., the correction for discordance of direct and reflexion results being applied. As has been previously explained, Bessel's refractions of the *Tabulæ Regiomontanæ* and assumed colatitude $38°. 31'. 21''\cdot90$ have been used throughout in the reductions. The tabular right ascensions and north polar distances are taken without correction from the Nautical Almanac.

The observed right ascensions of the Moon's centre are taken from the *Transits observed*, corrected, when necessary, for personal equation, and also for the Moon's motion in R.A. during the passage from the mean of wires to the true meridian. When both limbs of the Moon are observed, the correction for defective illumination (page lxv) is first applied to the proper limb, and the mean of the two is then taken without any further alteration.

The tabular right ascension of the Moon's centre is found by applying to the right ascension of the limb (given in the section *Moon-culminating Stars* of the Nautical Almanac) the sidereal duration of passage of semidiameter, which is given in the same section of the Nautical Almanac.

The observed north polar distances of the Moon's centre are taken from the section of *Zenith Distances observed*, &c., corrected for the values of $\frac{1}{2}$ (R—D). The motion in N.P.D. during the passage from the mean of wires to the true meridian has been applied when it amounted to $0''\cdot05$.

The tabular north polar distances of the Moon's centre are taken from the section *Moon-culminating stars* of the Nautical Almanac.

For all the planets, the right ascensions are extracted from the twentieth column of *Transits observed*, 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 $\frac{1}{2}$ (R—D). The tabular places are taken from the Nautical Almanac, for such planets as are given in that work and its appendixes. For all others the tabular places are taken from the *Berliner Jahrbuch*, 1882, or its Circulars.

The investigation of the position of the Ecliptic is conducted in the same manner as in preceding Volumes from the year 1836. 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 of the year are equal. The rest of the process needs no explanation.

For the *Mean Errors of the Tabular Geocentric Places of the Sun and Planets*, the observations have been collected into groups rarely exceeding a month in duration, and the mean of all the errors in each group, 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 in the group, an alteration of a unit or more being sometimes made, in order to refer R.A. and N.P.D. to the same day. 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 four small planets, Ceres, Pallas, Juno, and Vesta, 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 small planets, Ceres, Pallas, Juno, and Vesta,

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,

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

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

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

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

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

For the other planets, the following are used:—

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

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

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

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

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

In the expressions above, different quantities are neglected for the small planets and for the other planets. For the small planets, the latitude cannot be neglected 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 R.A. and N.P.D. 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 formed thus from the errors of azimuth and zenith distance given in the sections of Azimuths and Zenith Distances.

Let $\delta.R.A.$, $\delta.N.P.D.$, $\delta.A.$, $\delta.Z$, be the errors of Tabular R.A. (expressed in arc), N.P.D., 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,

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

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

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

The expression for $\delta.R.A.$ must be divided by 15 to give the error of Tabular R.A. in seconds of time.

A table of double entry, appended to the Introduction to the *Greenwich Observations* of 1854, is prepared, from which the values of p, q, r, s, are taken out at sight, with arguments Hour angle and N.P.D. of the Moon; and then the calculation is made by means of these formulæ.

§ 11. *Observations of γ Draconis with the Reflex Zenith-Tube.*

The details of the general construction of this instrument are given in Appendix I. to the *Greenwich Observations* for 1854. For the understanding of the tabular arrangement containing the successive steps of the reduction of the observations, the following explanation will suffice.

The micrometer was originally furnished with 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, nearly complete, were obtained between 1851 July 18 and August 15. By comparing then the number of revolutions of each micrometer corresponding to the interval 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 × the sine of star's N. P. D. To ensure, however the utmost accuracy, the hour-angle of each of the extreme observed wires on the two sides of wire "15" was found by successive addition of observed intervals (in time) of all the intermediate wires, assuming wire "15" to represent the meridian with sufficient accuracy; and the angular distance of wire "15" from each of the extreme wires was computed from these hour-angles. The intervals, in terms of the micrometer, of all the intermediate wires, were also added together, so as to exhibit the micrometrical distance of wire "15" from each extreme wire. 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

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

and in the other case the value was

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

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.

All the wires were found broken on 1876 March 14, and only the wires numbered "15" and "16" were replaced, these being the wires generally used for the bisection of the star. The interval in arc between these wires, as determined on 1876 May 6 and 9, is 3′. 37″·47. This value has been used throughout the year.

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, and therefore the level-indications will increase when the right or northern edge of the object-glass is raised.

Supposing this northern edge to be raised, the central ray of light for a zenithal star, descending through the focal centre and reflected up through the focal centre, meets the wire-frame (which is above the focal centre) 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 centre to wire-frame} × {$\frac{1}{2}$ sum of readings of level-scale} × {value of one division of level-scale}.

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

From statements made by the late Mr. William Simms, it is assumed that the focal centre coincides sensibly with the upper surface of the object-glass, and therefore that the distance of plane of wires from focal centre = $0^{\text{in}}{\cdot}25$; and that the value of one division of the level-scale is 6″ nearly. Also, the focal length of the object-glass, which is that of Troughton's transit instrument dismounted in the year 1851, is 116 inches.

With these data, the correction to zenith distance due to the readings of the level-scale is found to be 0″·00646 × 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. This constant is usually determined by forming for each day the half-sum of the two sums of equivalents in the two reversed positions of the instrument, and by taking the arithmetical mean of those half-sums determined on different days. 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 zenith distance north 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 but two of the tabular arrangement are found. When the observation (as is usually the case) is made in both positions of the instrument, the mean of the results is given in the last column but one.

The readings of a thermometer placed near the instrument are given in the last column.

§ 12. *Observations of the Solar Eclipse of* 1882 *May* 16, *with the Equations deduced from the Differences of Right Ascension, and from the Differences of North Polar Distance of the Limbs and Cusps.*

The observations of the beginning and end of the Eclipse require no special mention.

The measures of differences of R.A. and N.P.D. were made with the South-East Equatoreal.

The observations were arranged with the view of so combining, in different ways, the effects of the four different quantities which might require correction (namely, difference of R.A. of centres of Sun and Moon, difference of N.P.D. of centres of Sun and Moon, Sun's semidiameter, and Moon's semidiameter) that advantageous equations might be formed for determination of the numerical values of those four quantities.

For the observations in series 1 to 10 and 31 to 38, Difference of R.A. of Cusps, the clock movement was not used. The hour-circle was clamped firmly to the pier by the fixed clamp, and the polar axis was clamped to the hour-circle in each series by its independent clamp (unfurnished with slow motion). The transits of the cusps were observed by Mr. Christie, and recorded by galvanic contact on the chronograph-barrel, the times given being those of the Sidereal Standard clock.

For the observations in series 11 to 30, Difference of N.P.D. of Limbs of Sun and Moon and in series 39 to 56, Difference of N.P.D. of preceding and following Cusps, the clock movement was used. Mr. Christie, at the eye-end of the telescope, directed the instrument approximately to the cusp or limb, and clamped; Mr. Criswick read the two declination-microscope-micrometers, and gave the readings to an assistant, who entered them on a prepared sheet of paper. Mr. Christie listened to the beats of a chronometer, Brockbanks 436, and at the same time turned the micrometer-screw, and when a satisfactory contact was made gave the chronometer-time to the writer, and then read the micrometer and gave its reading to the writer. The times of observation given are those of the chronometer, Brockbanks 436, the error of which was inferred from comparisons with the Sidereal Standard clock. The hour-angle was found by comparing the sidereal time with the right ascension of the cusp or limb.

The adopted value of a revolution of the telescope-micrometer was obtained from observations of α Coronæ on 1860 December 1.

The refractions in N.P.D. are computed by the formula: Refraction = Number [log. = 1·7590] × tan (N.P.D.—P Q), where P Q is an angle depending on hour-angle only, and determined by the formula—

$$\tan \text{P Q} = \tan \text{colat.} \times \cos \text{hour-angle}.$$

The refractions in R.A. are computed by the formula—

$$\text{Refraction} = \frac{\text{Number [log.} = 0{\cdot}5829] \times \tan \text{Z Q}}{\sin \text{N.P.D.} \times \cos (\text{N.P.D.} - \text{P Q})},$$

where Z Q is determined by the formula—

$$\sin \text{Z Q} = \sin \text{colat.} \times \sin \text{hour-angle}.$$

The readings of the barometer and thermometer used in the calculation of the refractions were taken from the Meteorological Photographic Register.

This completes the description of the mode of making and reducing the observations.

The following applies to the mode of comparing them with the theoretical elements:—

The geocentric places were first interpolated, from the places in the Nautical Almanac, by second differences at convenient intervals, as exhibited in the tables of the section.

The Sun's Parallax in R.A. was computed by the formula—

$$\text{Parallax in R.A.} = \frac{\text{Hor. Eq. Parallax} \times r \sin \text{Z}' \text{Q}'}{15 \sin \text{N.P.D.}},$$

where r is the geocontric radius for Greenwich in terms of the equatoreal radius, and Z′ Q′ is determined by the formula: sin Z′ Q′ = sin Geocentric colat. × sin hour-angle.

The Sun's Parallax in N.P.D. was computed by the formula: Parallax in N.P.D. = Hor. Eq. Parallax × r cos Z′ Q′ × sin (N.P.D. — P Q′), where P Q′ is determined by the formula: tan P Q′ = tan Geocentric colat. × cos hour-angle.

For computing the Moon's apparent place, the Moon's Normal-centric N.P.D. and Normal-centric Horizontal Parallax were formed as in the section of Observations with the Altazimuth.

With the R.A. and Normal-centric N.P.D., the Azimuth and Normal-centric Z.D. were computed; with a very approximate Z.D. (found by trial) the parallax at observation was computed, and thus the Apparent Z.D. was formed; from this and the azimuth the Apparent R.A. and Apparent N.P.D. of centres were computed.

The augmentation of the Moon's semidiameter was taken from Loomis' Tables.

These various apparent quantities having been independently computed for every 16^{m} for the Sun and 8^{m} for the Moon, interpolation with second differences was made for every 4^{m} for the Sun's place and for every 1^{m} for the Moon's; and interpolation with first differences only for further calculation of places.

Then the Tabular N.P.D. and R.A. of cusps were found by the following tentative process :—If A and α are the R.A., Δ and δ the N.P.D. of the centres of the Sun and Moon, x the N.P.D. of a cusp, S and s the two semidiameters, $(\alpha - A)$ the excess of R.A. of Moon's centre above that of Sun's centre, Z and z the excesses of R.A. of cusp above those of the two centres, then without sensible error—

$$Z^2 = \frac{S^2 - (\Delta - x)^2}{\sin \Delta \sin x},$$

$$z^2 = \frac{s^2 - (\delta - x)^2}{\sin \delta \sin x};$$

$$Z + z = (\alpha - A).$$

Different values were tried for x, and Z and z were computed by the first and second equation respectively ; and the process of trial and computation was repeated till the values found for Z and z satisfied the third equation.

If we differentiate these expressions, neglecting the variations of the quantities which will be multiplied by the small terms S^2, s^2, $(\Delta - x)^2$ and $(\delta - x)^2$, and if we put—

$$Q = \frac{\Delta - x}{Z \sin \Delta \sin x},$$

$$q = \frac{\delta - x}{z \sin \delta \sin x},$$

then $(Q + q)\, dx = d\,(\alpha - A) - \frac{S}{Z \sin \Delta \sin x}\, d\,S - \frac{s}{z \sin \delta \sin x}\, d\,s + Q\,d\,\Delta + q\,d\,\delta$;
and if y be the R.A. of the cusp, A and α being the R.A. of centres of Sun and Moon—

$$(Q + q)\, d\,y = q\,d\,A + Q\,d\,\alpha + \frac{q\,S}{Z \sin \Delta \sin x}\, d\,S - \frac{Q\,s}{z \sin \delta \sin x}\, d\,s + Q\,q\,(d\,\delta - d\,\Delta).$$

These give the numerical or symbolical changes in the N.P.D. and R.A. of the cusp produced by assigned numerical or symbolical changes in the tabular elements.

By substitution of the proper numerical values in these formulæ, and by equating the measured quantities to the corresponding tabular quantities increased by the terms representing (by means of these formulæ) the changes in these quantities due to symbolical errors of the different elements, the equations in the section were formed. Their further treatment is sufficiently explained in the section.

§ 13. *Micrometer Measures of the Positions of Saturn's Satellites, made with the South-East Equatoreal.*

The position-micrometer with a positive eye-piece giving a magnifying power of 285 was used on the South-East Equatoreal.

The method of making the observations is sufficiently explained in the Notes at the end of the section.

§ 14. *Differences of Right Ascension and North Polar Distance of Comet a* 1882, *Comet b* 1882, *and Comet c* 1882, *and Neighbouring Stars, observed with the Equatoreals.*

The observations of Comet a with the Naylor equatoreal, of Comet b with the Sheepshanks or East equatoreal, and of Comet c with the South-East equatoreal, were all made by taking transits over two thick cross-wires at right angles to each other, and each inclined 45° to the parallel of declination, the adjustment for inclination of the cross-wires being tested on each occasion by allowing the diurnal motion to carry a star along a wire bisecting the angle between the cross-wires.

§ 15. *Eclipses, Occultations, and Transits of Jupiter's Satellites, compared with the Nautical Almanac; and Occultations of Stars by the Moon, with the Equations deduced from the Occultations.*

The clocks used in these observations are in general compared with the Sidereal Standard or with the clock Hardy near the time of the observation, and the mean solar time is computed in the usual way. Sid. S. signifies "the Sidereal Standard clock," and G. 1 "Graham 1." Molyneux 1854 is a sidereal chronometer, the error of which was determined immediately after the observation by comparison with the Sidereal Standard.

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, and are used without alteration. The correction to be applied to the parallax of the Moon's centre in order to obtain that for the point of the limb at which the occultation takes place, is derived from the following Table, the principles of the formation of which are given in the volumes of the *Greenwich Observations* 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	+0·11	+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	+0·10	+0·12	+0·13	+0·14	+0·15	+0·15
40	320	+0·04	+0·05	+0·07	+0·08	+0·09	+0·11	+0·12	+0·13	+0·13	+0·13
50	310	+0·04	+0·05	+0·06	+0·08	+0·08	+0·10	+0·11	+0·11	+0·12	+0·12
60	300	+0·04	+0·05	+0·06	+0·07	+0·06	+0·08	+0·09	+0·10	+0·10	+0·10
70	290	+0·04	+0·04	+0·05	+0·06	+0·05	+0·07	+0·07	+0·08	+0·08	+0·08
80	280	+0·04	+0·04	+0·04	+0·05	+0·04	+0·05	+0·05	+0·06	+0·06	+0·06
90	270	+0·04	+0·04	+0·04	+0·04	+0·02	+0·04	+0·04	+0·04	+0·04	+0·04
100	260	+0·04	+0·03	+0·03	+0·02	+0·01	+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	−0·02	−0·01	−0·02	−0·03	−0·03	−0·03
130	230	+0·04	+0·02	+0·01	−0·01	−0·03	−0·03	−0·04	−0·04	−0·05	−0·05
140	220	+0·04	+0·02	0·00	−0·01	−0·04	−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	−0·05	−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 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 centre; 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 shown that

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

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

For the first step of the 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 numerical 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:—

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

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

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

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

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 the Moon's centre is thus found, by means of a subsidiary angle ψ:—

If log. tan ψ = log. diff. R.A. of Moon's centre and corresponding point + ½ log. sin N. P. D. of Moon's centre + ½ log. sin δ' — log. diff. N. P. D. of Moon's centre and corresponding point;

Then log. dist. = log. diff. N. P. D. — log. cos ψ,
or = log. diff. R.A. + ½ log. sin. N.P.D. of centre + ½ log. sin δ' — log. sin ψ.

The coefficients of small variations of the north polar distance 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 $\frac{m}{1000}$ × 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 =

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

The variation of the R.A. of the Moon's centre 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 $\frac{m}{1000}$ × 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:—

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

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

The computed distance, with addition of 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

§ 16. *Spectroscopic Observations in the Year* 1882.

The spectroscopes used for these observations (see page xiv.) were mounted on the South-east equatoreal, the object-glass of which (made by Merz and Son of Munich) has a clear aperture of 12·8 inches, with a focal length of about $17^{ft}\ 10^{in}$.

This section contains:—Observations of Solar Prominences; Observation of a Solar Storm; Observations of Spectra of Sun Spots; Measures of Displacement of Lines in the Spectra of Stars and Concluded Motions in the Line of Sight; and Observations of the Spectra of Uranus, of Sundry Stars, of Comets *a* and *b* 1882, and of the Aurora of 1882 November 17.

For the observations of solar prominences, the Greenwich mean solar times are given; and the position-angle from the Sun's axis of the two extremities of each prominence, together with its height in seconds of arc. The Sun's image was always placed centrally with respect to the position-circle, a radial excentricity being given to the spectroscope, so that the slit swept round the Sun's limb.

The position-angles have been first corrected for index-error of the position-circle, which is determined at the time of observation.

The method employed for this purpose has been to set the position-circle to 90° *plus* the approximate index-error, so that the slit points approximately E. and W., and to move the telescope by the slow-motions until either the north or the south limb of the Sun just comes into the middle of the field. The position-circle is then read, and the spectroscope rotated through 180°, the telescope remaining rigidly clamped, and as the diurnal motion brings the Sun up to the slit again, the limb previously observed is again brought to the centre of the field by means of the rotation of the spectroscope. The position-circle is read a second time, and the mean of the two readings is taken as the zero of the position-circle.

The corrected position-angles have then been converted into Heliographic N.P.D. by applying as a correction the position-angle of the Sun's north pole, taken from the "Auxiliary Tables for determining the Angle of Position of the Sun's Axis, and the Latitude and Longitude of the Earth referred to the Sun's Equator," by Warren De La Rue, F.R.S.

The heights of the bright lines seen in the prominences or chromosphere were read off on a pearl scale, divided to 0·005 inch (corresponding to 2″·4), and carried by the micrometer of the spectroscope. Other particulars are given in the note at the head of this section.

The measures of displacement of lines in the spectra of stars were made with a micrometer in the viewing telescope of the "Half-prism" Spectroscope. The eyepiece used gives a magnifying power of 14. Estimations of the displacement, in terms of the apparent breadth of the bright comparison-line, were also made; the breadth corresponding to any given width of slit being determined by a careful observation under similar conditions. $1^{rev.}$ of the screw for opening the slit corresponds to 0·01 inch, or 10″. It has not been thought necessary to give in detail all these particulars of the reductions. The values used in each case may be inferred from the observed motion, which is the algebraic sum of the concluded motion and of the Earth's motion. One tenth-metre corresponds at D to a motion of 31·7 miles per second, at *b* to a motion of 36·1 miles, and at F to a motion of 38·4 miles. For comparison with the spectrum of hydrogen or other chemical element, an image of the vacuum tube or electrodes is formed on the slit, by means of a transparent plate of glass placed at an angle of 45° with the axis of the collimator, in connexion with a collimating lens, so that the cone of rays from the comparison-light, as well as that from the star, fills the whole of the object-glass of the collimator.

Whenever the star-line was sufficiently distinct to allow of its being seen at the same time as the bright comparison-line, a direct comparison of the two was made; in other cases the bright line was compared with the pointer or bright line of the micrometer which had just previously been placed on the star-line, giving an indirect comparison.

The reading of the position-circle is given, as it is conceivable that the results might be affected by the position of the spectroscope. The slit lies north and south when the reading is 5°.

With regard to the other observations contained in this section, it is sufficient to remark that curves have been laid down in the usual manner, connecting scale or micrometer readings and wave-lengths, and that for each series of observations a correction for index-error has been deduced from observations of comparison-lines and applied to the observed readings, to reduce them to the standard curve, from which the corresponding wave-lengths have been read off. The tabular wave-lengths of comparison-lines have been taken from Ångström's *Spectre Normal du Soleil*, or in the case of the spectra of carbon compounds, from Ångström and Thalén's *Récherches sur les Spectres des Métalloides*.

§ 17. *Measures of Positions and Areas of Spots and Faculæ upon the Sun's Disk on Photographs taken at the Royal Observatory, Greenwich, and at Dehra Dûn in India in the year* 1882; *with the deduced Heliographic Longitudes and Latitudes.*

The photographs from which these measures were made were taken either at Greenwich or at Dehra Dûn, North-West Provinces, India.

The photographs of the Greenwich series were taken with the Dallmeyer Photo-heliograph returned from the Transit of Venus expedition to New Zealand.

In the process adopted up to 1882 November 28 iodized cadmium collodion was used in connexion with the pyro-gallic acid development. Since that date bromo-iodized gelatine dry plates with alkaline development have been regularly used.

The Indian photographs, which were used to fill the gaps in the Greenwich series, were taken under the superintendence of J. B. N. Hennessey, F.R.S., Deputy Superintendent, Trigonometrical Survey of India, with a Dallmeyer photoheliograph giving an image of the Sun 4 inches in diameter, except for the period from 1882 November 7 to December 18, when another secondary magnifier, giving an image of the Sun nearly 8 inches in diameter, was adapted to the photoheliograph under the auspices of the Solar Physics Committee. In the process adopted at Dehra Dûn bromo-iodized collodion has been used in connexion with iron development.

Photographs of the Sun were taken at Greenwich on 221 days, and Indian photographs on 142 days were used to complete the total of 343 days for which there are either Greenwich or Indian photographs of the Sun available in 1882.

The *first* column on each page contains the Greenwich Mean Solar Time at which each photograph was taken, expressed by the day of the year and decimals of a day, reckoning from Greenwich mean noon of January 1, and also by the day of the month (civil reckoning), which latter is placed opposite the total area of Spots and Faculæ for the day. The photographs taken in India are distinguished by the letter I.

The *second* column contains the initials of the two persons measuring the photograph; the initial on the left being that of the person who measured the photograph on the left of the centre of the measuring instrument, and that on the right being that of the person who measured on the right of the centre.

The following are the signatures of those persons who measured the photographs for the year 1882:—

E. W. Maunder	M	J. Knowles	K
H. P. Hollis	H	F. Finch	F
J. Power	JP	J. Hawton	JH
H. T. James	J		

The *third* column gives the No. of the group. The groups are numbered in the order of their appearance.

The *next two* columns give the Distance from the Centre of the Sun in terms of the Sun's Radius, and the Position-Angle from the Sun's Axis, reckoned from the Sun's North Pole in the direction *n, f, s, p*, both results being corrected for the effects of instrumental distortion and astronomical refraction.

The measures of the four-inch photographs were made with a large position-micrometer, specially constructed by Mr. Simms. The photograph is held with the collodion-side uppermost, on two cross-slides, which give the means of accurately centering it on the large position-circle, which rotates with it. A positive eye-piece, having at its focus a glass diaphragm, ruled into squares, with sides of one-hundredth of an inch (for measurement of areas), is carried by a micrometer-screw diametrically across the photograph, the diaphragm being nearly in contact with the photographic film, so that parallax is avoided.

For the measurement of the eight-inch photographs a larger position-micrometer, constructed by Messrs. Troughton and Simms on the same principle but with some improvements, has been used. In this instrument the distance of a spot or facula from the Sun's centre is read off to 1-250th of an inch by means of a scale and vernier instead of a long micrometer-screw.

The following is the process of measurement of a photograph :—

By means of the cross-slides mounted on the position-circle, the image of the Sun is centred as accurately as possible by rotation. The position-circle is then set to the readings 0°, 90°, 180°, and 270° in succession, and the micrometer-readings taken for the two limbs. The mean difference of the readings for the two limbs is taken as the Sun's mean diameter on the photograph, and the mean of the half-sum as the reading for the Sun's centre.

At the principal focus of the photoheliograph are two cross-wires which serve to determine the zero of position-angles on the photograph.

The zero of the Dallmeyer Photoheliograph employed at Greenwich has been determined by allowing the diurnal motion to carry the spot or Sun's limb along the wire, a correction for the inclination of the Sun's path being applied to the reading of the position-circle so obtained, and also by running the image along the wire by the use of the R.A. slow motion, the mean of the two determinations being adopted as the zero.

Date.			Corrected Zero of Position-Circle from transit.		Zero of Position-Circle obtained when using R. A. Slow Motion.	
			Wire *a*.	Wire *b*.	Wire *a*.	Wire *b*.
			° ′	° ′	° ′	° ′
1881,	December	23	354. 0	83. 54	354. 0	83. 54
1882,	January	7	354. 7	84. 1	354. 6	84. 0
	March	14	354. 5	84. 4	353. 57	83. 58
	March	25	353. 16	..	353. 10	..
	April	21	353. 36	263. 36	353. 36	263. 33
	May	10	353. 9	..	353. 6	..
	May	10	353. 27	83. 30	353. 24	83. 27
	June	17	353. 12	83. 10	353. 12	83. 10
	July	26	353. 16	83. 10	353. 18	83. 12
	August	24	353. 18	83. 12	353. 15	83. 9
	August	24	353. 48	83. 42	353. 48	83. 42
	September	15	353. 16	83. 6	353. 10	83. 0
	October	20	353. 5	82. 59	353. 8	83. 2
	November	18	353. 13	83. 13	353. 18	83. 6
	December	13	353. 6	83. 6	353. 9	83. 5
1883,	January	2	353. 7	83. 6	353. 8	83. 4

In the use at Greenwich of the Dallmeyer Photoheliograph the position-circle has usually been set to some convenient reading near that for zero, so that the wires are respectively parallel and perpendicular to the circle of declination, and a correction for zero of position of the photoheliograph for the mean of the two wires has been applied to the zero of the position-circle of the micrometer. This latter has been determined from the readings of the position-circle for the four extremities of the two wires. The resulting combined correction is applied to all position-circle readings for spots and faculæ, so as to give true position-angles.

In the use of the Photoheliograph at Dehra Dûn the position-circle has always been set to the zero as determined by allowing the diurnal motion to carry a spot or the Sun's limb along the horizontal wire, and the accuracy of the adjustment has been tested at short intervals. No correction for zero of the photoheliograph has therefore been required for the reduction of the photographs taken in India.

The uncorrected distance from the Sun's centre for the four-inch images of the Sun is given by the difference between the micrometer-readings for spots and faculæ, and the centre-reading. In the new micrometer used for the measurement of the eight-inch photographs the zero of the scale is adjusted to coincide with the centre, and the distance from the centre is given directly.

Two sets of measures of the Sun's limb and of spots and faculæ on each photograph have been taken and the mean of the two sets adopted. The Greenwich photographs have been usually measured by Mr. Maunder and one of his assistants, the Indian photographs by Mr. Hollis and Mr. Power.

Corrections are then applied for optical distortion of the photoheliographs and for refraction. The distortion has been determined for the Dallmeyer photoheliographs used in the Transit of Venus 1874 from measures of photographs of a scale of equal parts, 16 feet long, constructed by Mr. De La Rue, and lent by him for this purpose. The scale has eight plates of iron with edges carefully planed, the plates being each exactly one foot in breadth, and attached to a braced iron framework so as to leave equidistant spaces of exactly one foot between the plates. The scale was photographed at a distance of about 1,200 feet, and extended completely across the field of view.

The following table gives the distortion for the Dallmeyer Photoheliographs for images of the Sun, of about four inches diameter thus determined for every tenth of an inch distance from the centre of the field :—

Distance from Centre.	Correction for Distortion.	Distance from Centre.	Correction for Distortion.	Distance from Centre.	Correction for Distortion.
r	r	r	r	r	r
0	0·000	9	+ 0·035	18	+ 0·010
1	+ ·006	10	+ ·036	19	+ ·004
2	+ ·012	11	+ ·035	20	− ·004
3	+ ·017	12	+ ·034	21	− ·012
4	+ ·022	13	+ ·032	22	− ·020
5	+ ·026	14	+ ·028	23	− ·029
6	+ ·029	15	+ ·024	24	− ·038
7	+ ·032	16	+ ·020	25	− ·047
8	+ ·034	17	+ ·016	26	− ·057

$1^{r} = 0^{in}\cdot10$, corresponding to $49''\cdot3$.

The distances as measured on the four-inch photographs whether taken at Greenwich or in India have been corrected for the corresponding distortion, and in cases where the centre of the Sun's image did not fall very close to the centre of the plate, a correction has been applied to the position-angles for the resolved part of the distortion. No correction has been applied to the measure of Sun's radius on account of distortion, the scales adopted in forming the tables having been so chosen that the distortion shall be 0 at the average place of the Sun's limb on the photographic plate; viz., $19^{r}\cdot5$.

No correction has been applied to the eight-inch photographs on account of distortion.

The correction for the effect of refraction has been thus found, the Sun's image being assumed to be sensibly an ellipse. The refraction being sensibly $c \tan z$ where $c = \sin 57''\cdot5 = \frac{1}{3600}$ nearly, and z is the apparent zenith distance, we shall have—

$$\frac{\text{Vertical Diameter}}{\text{Horizontal Diameter}} = \frac{1 - c \sec^2 z}{1 - c} = 1 - c \tan^2 z;$$

and thus the effect of refraction will be to diminish any vertical ordinate y by the quantity $c \tan^2 z$. Resolving this along and perpendicular to the radius vector r.

and putting v for the position-angle of the vertex, we have for δr and $\delta \theta$, the corrections to radius vector and position-angle for the effect of refraction—

$$\delta r = + c \,.\, \tan^2 z \times r \,.\, \cos^2 (\theta - v) = + c \,.\, \tan^2 z \times r \times \frac{1 + \cos 2 (\theta - v)}{2}$$

$$\delta \theta = - c \cdot \tan^2 z \,.\, \sin (\theta - v) \,.\, \cos (\theta - v) = - c \,.\, \tan^2 z \, \frac{\sin 2 (\theta - v)}{2}.$$

The quantity δr thus found is the correction, on the supposition that a horizontal diameter of the Sun is taken as the scale. But, as the mean of two diameters at right angles has been used, the scale itself requires the correction $\delta R = + c \,.\, \tan^2 z \times R \times \frac{1}{2} \left\{ \frac{1 + \cos 2 (\theta_0 - v)}{2} + \frac{1 + \cos 2 (\theta_0 + 90^\circ - v)}{2} \right\} = + \frac{1}{2} c \, R \,.\, \tan^2 z,$ where R is the Sun's mean radius and θ_0, $\theta_0 + 90^\circ$ the position-angles of the two diameters measured. Thus the final correction to r becomes—

$$\delta r = + c \,.\, \tan^2 z \times r \times \frac{\cos 2 (\theta - v)}{2}.$$

The quantities $c \tan^2 z$, $-\frac{\sin 2 (\theta - v)}{2}$, and $\frac{\cos 2 (\theta - v)}{2}$ have been tabulated for use as follows, $c \tan^2 z$ being expressed in circular measure and in arc for application to distances and position-angles respectively :—

$c \tan^2 z$.

z.	In Circular Measure.	In Arc.	z.	In Circular Measure.	In Arc.	z.	In Circular Measure.	In Arc.
°		′	°		′	°		′
80	·0089	31	70	·0021	7	60	·0008	3
79	·0073	25	69	·0019	6½	58	·0007	2
78	·0061	21	68	·0017	6	56	·0006	2
77	·0052	18	67	·0015	5½	54	·0005	2
76	·0045	15	66	·0014	5	52	·0005	2
75	·0039	13	65	·0013	4½	50	·0004	1
74	·0034	11½	64	·0012	4	45	·0003	1
73	·0030	10	63	·0011	4	40	·0002	1
72	·0026	9	62	·0010	3	30	·0001	0
71	·0023	8	61	·0009	3			

Factors for Refraction.

$\theta - v$	$\theta - v$	$-\frac{\text{Sin } 2(\theta-v)}{2}$	$\frac{\text{Cos } 2(\theta-v)}{2}$	$\theta - v$	$\theta - v$	$-\frac{\text{Sin } 2(\theta-v)}{2}$	$\frac{\text{Cos } 2(\theta-v)}{2}$
°	°			°	°		
0	180	·00	+ ·50	95	275	+ ·09	− ·49
5	185	− ·09	+ ·49	100	280	+ ·17	− ·47
10	190	− ·17	+ ·47	105	285	+ ·25	− ·43
15	195	− ·25	+ ·43	110	290	+ ·32	− ·38
20	200	− ·32	+ ·38	115	295	+ ·38	− ·32
25	205	− ·38	+ ·32	120	300	+ ·43	− ·25
30	210	− ·43	+ ·25	125	305	+ ·47	− ·17
35	215	− ·47	+ ·17	130	310	+ ·49	− ·09
40	220	− ·49	+ ·09	135	315	+ ·50	·00
45	225	− ·50	·00	140	320	+ ·49	+ ·09
50	230	− ·49	− ·09	145	325	+ ·47	+ ·17
55	235	− ·47	− ·17	150	330	+ ·43	+ ·25
60	240	− ·43	− ·25	155	335	+ ·38	+ ·32
65	245	− ·38	− ·32	160	340	+ ·32	+ ·38
70	250	− ·32	− ·38	165	345	+ ·25	+ ·43
75	255	− ·25	− ·43	170	350	+ ·17	+ ·47
80	260	− ·17	− ·47	175	355	+ ·09	+ ·49
85	265	− ·09	− ·49	180	360	·00	+ ·50
90	270	·00	− ·50				

The position-angle of the Vertex v is readily taken from a globe.

The distance from centre in terms of the Sun's radius given in the *fourth* column is then readily found by dividing the measured distance r_0, as corrected for distortion and refraction, by the measured mean radius of the Sun, R; and the Position-Angle from the Sun's Axis given in the *fifth* column is obtained by applying to then Corrected Position-Angle (from the N. point) the Position-Angle of the Sun's Axis derived from Warren De La Rue's Auxiliary Tables referred to in the preceding section.

The *sixth* and *seventh* columns give the Heliographic Longitude and Latitude computed by the formulæ $\sin \lambda = \cos \rho \,.\, \sin D + \sin \rho \,.\, \cos D \,.\, \cos \chi$; $\sin (L - l) = \sin \chi \,.\, \sin \rho \,.\, \sec \lambda$; where L, l are the Heliographic Longitudes from the ascending node, and D, λ the Heliographic Latitudes of the Earth and the Spot respectively, referred to the Sun's Equator, ρ the True Angular Distance from centre, and χ the Position-Angle from the Sun's Axis. The quantities L and D are derived from Warren De La Rue's Auxiliary Tables previously referred to, and log sin ρ and log cos ρ are taken from "Tables for the Reduction of Solar Observations, No. 2" by Warren De La Rue, F.R.S.

The Heliographic Longitude of the Spot is found from l, the Heliographic Longitude from Node, by subtracting the Reduction to Prime Meridian, which is the Longitude of the Node at the epoch of the photograph, referred to the assumed Prime Meridian, the latter being the meridian which passed through the ascending node at the epoch 1854·0. The period of rotation assumed is 25·38 days.

The measures of areas given in the *last three* columns were made with a glass diaphragm ruled into squares, with sides of one hundredth of an inch, and placed nearly in contact with the photographic film. The integral number of squares and parts of a square contained in the area of a spot or facula was estimated by the observer, two independent sets of measures being made by two observers. The mean of the two sets of measures has been taken for each photograph. The factor for converting the areas, as measured in ten-thousandths of a square inch, into millionths of the Sun's visible hemisphere, allowing for the effect of foreshortening, has been inferred by means of a table of double entry, giving the equivalent of one square for different values of the Sun's radius, and for different distances of the spot or facula from the Sun's centre, as measured by means of the Position-Micrometer.

The individual spots in a group have in some cases not been measured separately, but combined into a cluster of two or three small spots close together, the position of the centre of gravity and the aggregate area of the cluster being given. The actual number of individual spots is usually stated in the Notes.

The Mean Areas of Spots and Faculæ and the mean Heliographic Latitude of Spots for each Rotation of the Sun, and for the year 1882, are given at the end of this section, and require no further explanation.

As a general remark applying to every class of observation above mentioned, it is proper to state that the original entries of observations are in all cases preserved. The greater part of the regular observations with the transit-circle are entered in small memorandum books, in which the entries are made with a metallic pencil whose marks are not easily effaced; those with the altazimuth are entered in small books arranged for the purpose: and 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. The sheets punctured by the prickers of the electro-magnets in registration of transits by the chronographic method are also preserved. The proof sheets are read with the first skeleton forms in which the observations are entered; and in which, in fact, the examination for accidental errors, &c. is made. The solar photographs which have been measured are preserved.

W. H. M. CHRISTIE.

1884 *February* 9.

TRANSIT-CIRCLE TABLES, 1882.

EQUATOREAL INTERVALS OF THE TRANSIT WIRES.

The following are the intervals, determined from 200 transits of ordinary stars combined with 25 transits of polar stars, which were used throughout the year :—

			s
For wire N	=	+	41·302
O	=	+	27·690
P	=	+	13·830
Q	=	+	10·947
R	=	+	8·234
S	=	+	5·464
T	=		0·000
U	=	−	5·597
V	=	−	8·375
W	=	−	11·123
X	=	−	13·812
Y	=	−	27·725
Z	=	−	41·470

For λ Ursæ Minoris, assuming its declination = 88°. 56′ + n'':

			m s		s
Wire P	=	+	12. 23·28	+ n ×	0·197
Q	=	+	9. 48·23	+ n ×	0·158
R	=	+	7. 22·39	+ n ×	0·118
S	=	+	4. 53·52	+ n ×	0·079
T	=		0·00		
U	=	−	5. 0·68	− n ×	0·079
V	=	−	7. 29·97	− n ×	0·118
W	=	−	9. 57·69	− n ×	0·158
X	=	−	12. 22·31	− n ×	0·197

For Polaris, assuming its declination = 88°. 40′ + n'':

			m s		s
Wire P	=	+	9. 54·54	+ n ×	0·125
Q	=	+	7. 50·54	+ n ×	0·100
R	=	+	5. 53·90	+ n ×	0·075
S	=	+	3. 54·82	+ n ×	0·050
T	=		0·00		
U	=	−	4. 0·55	− n ×	0·050
V	=	−	5. 59·96	− n ×	0·075
W	=	−	7. 58·12	− n ×	0·100
X	=	−	9. 53·77	− n ×	0·125

For Cephei 51, assuming its declination = 87°. 13′ + n″:

			m s		s
Wire P	=	+	4. 44·82	+ n ×	0·029
Q	=	+	3. 45·44	+ n ×	0·023
R	=	+	2. 49·57	+ n ×	0·017
S	=	+	1. 52·52	+ n ×	0·011
T	=		0·00		
U	=	−	1. 55·26	− n ×	0·011
V	=	−	2. 52·48	− n ×	0·017
W	=	−	3. 49·07	− n ×	0·023
X	=	−	4. 44·46	− n ×	0·029

For δ Ursæ Minoris, assuming its declination = 86°. 36′ + n″:

			m s		s
Wire P	=	+	3. 53·21	+ n ×	0·019
Q	=	+	3. 4·59	+ n ×	0·015
R	=	+	2. 18·84	+ n ×	0·011
S	=	+	1. 32·13	+ n ×	0·008
T	=		0·00		
U	=	−	1. 34·38	− n ×	0·008
V	=	−	2. 21·22	− n ×	0·011
W	=	−	3. 7·56	− n ×	0·015
X	=	−	3. 52·90	− n ×	0·019

APPARENT CORRECTIONS TO ADOPTED LEVEL ERRORS, DEDUCED FROM A COMPARISON OF REFLEXION AND DIRECT OBSERVATIONS OF RIGHT ASCENSION MADE IN THE YEAR 1882.

Name of Star.	Approx. N.P.D.	Approx. R.A.	Seconds of R.	Seconds of D.	R − D.	Deduced Correction to Level Error.	Number of Observations. R.	Number of Observations. D.	Weight.
	° ′	h m	s	s	s	″			
α Draconis S.P.	−25. 3	14. 1	11·350	11·450	−0·100	+ 0·70	1	1	1
8 Draconis S.P.	−23. 55	12. 50	46·130	46·620	−0·490	+ 3·15	1	1	1
λ Draconis S.P.	−20. 1	11. 24	22·980	23·120	−0·140	+ 0·68	1	4	1
Groomb. 2091 S.P.	−20. 0	14. 9	52·340	52·505	−0·165	+ 0·82	1	2	1
Groomb. 2029 S.P.	−18. 9	13. 34	21·120	21·440	−0·320	+ 1·34	1	1	1
Bradley 1147 S.P.	−13. 53	8. 4	40·735	40·525	+0·210	− 0·61	2	2	2
19 Ursæ Minoris S.P.	−13. 49	16. 14	12·170	12·340	−0·170	+ 0·49	1	1	1
Bradley 1446 S.P.	−13. 40	10. 25	1·690	1·450	+0·240	− 0·69	1	1	1
Groomb. 1151 S.P.	−11. 54	6. 22	8·040	8·260	−0·220	+ 0·53	1	1	1
Cephei 51 S.P.	− 2. 47	6. 44	47·840	45·636	+2·204	− 1·05	2	11	3
Polaris S.P.	− 1. 20	1. 15	29·970	28·945	+1·025	− 0·23	1	53	2

APPARENT CORRECTIONS TO ADOPTED LEVEL ERRORS, DEDUCED FROM A COMPARISON OF REFLEXION AND DIRECT OBSERVATIONS OF RIGHT ASCENSION MADE IN THE YEAR 1882—*concluded.*

Name of Star.	Approx. N.P.D.	Approx. R.A.	Seconds of R.	Seconds of D.	R−D.	Deduced Correction to Level Error.	Number of Observations. R.	Number of Observations. D.	Weight.
	° ′	h m	s	s	s	″			
δ Ursæ Minoris	3. 24	18. 10	21·820	22·595	−0·775	− 0·41	1	11	2
Piazzi IX. 37	8. 9	9. 20	8·210	9·110	−0·900	− 1·09	1	1	1
τ Draconis	16. 51	19. 17	48·820	49·150	−0·330	− 0·76	1	1	1
50 Cassiopeiæ	18. 9	1. 53	22·770	22·910	−0·140	− 0·34	1	1	1
φ Draconis	18. 43	18. 22	26·150	27·040	−0·890	− 2·25	1	1	1
λ Draconis	20. 1	11. 24	23·110	23·012	+0·098	+ 0·26	3	5	3
Bradley 3125	20. 17	23. 22	17·980	17·630	+0·350	+ 0·95	1	1	1
55 Camelopardi	21. 10	8. 1	2·960	3·075	−0·115	− 0·32	1	2	1
7 Draconis	22. 33	12. 42	44·330	44·820	−0·490	− 1·45	1	1	1
3 Draconis	22. 36	11. 35	52·585	52·793	−0·208	− 0·62	2	4	2
9 Draconis	22. 45	12. 55	27·090	27·475	−0·385	− 1·15	1	2	1
42 Draconis	24. 30	18. 25	38·570	38·530	+0·040	+ 0·13	1	1	1
α Draconis	25. 3	14. 1	11·400	11·567	−0·167	− 0·54	1	3	1
76 Ursæ Majoris	26. 38	12. 36	23·870	24·330	−0·460	− 1·55	1	1	1
α Ursæ Majoris	27. 36	10. 56	25·790	26·003	−0·213	− 0·74	1	3	1
31 Camelopardi	30. 8	5. 44	23·400	24·220	−0·820	− 3·10	1	1	1
Castor	57. 51	7. 27	4·150	4·178	−0·028	− 0·19	2	4	2
β Tauri	61. 29	5. 18	49·730	49·965	−0·235	− 1·67	1	4	1
Pollux	61. 41	7. 38	5·550	5·605	−0·055	− 0·40	1	6	2
31 Comæ	61. 49	12. 45	57·000	57·010	−0·010	− 0·07	2	1	1
ψ Boötis	62. 35	14. 59	23·420	23·325	+0·095	+ 0·69	1	2	1
α Arietis	67. 5	2. 0	31·520	31·361	+0·159	+ 1·23	1	7	2
n Tauri	68. 1	5. 12	11·270	11·210	+0·060	+ 0·47	1	1	1
β Arietis	69. 46	1. 48	7·220	7·384	−0·164	− 1·33	1	5	1
η Boötis	71. 0	13. 49	3·860	3·918	−0·058	− 0·48	1	4	1
λ Geminorum	73. 14	7. 11	18·700	18·677	+0·023	+ 0·21	1	3	1
γ Geminorum	73. 30	6. 30	53·720	53·660	+0·060	+ 0·52	1	7	2
β Leonis	74. 46	11. 43	2·467	2·430	+0·037	+ 0·34	3	6	3
f Tauri	77. 27	3. 24	21·590	21·467	+0·123	+ 1·15	1	3	1
ε Virginis	78. 24	12. 56	18·135	18·192	−0·057	− 0·55	2	6	2
ω Aquilæ	78. 37	19. 12	16·690	16·643	+0·047	+ 0·45	1	6	2
o Tauri	81. 23	3. 18	27·760	27·777	−0·017	− 0·18	1	3	1
δ Aquilæ	87. 7	19. 19	32·860	32·938	−0·078	− 0·87	1	5	1
γ Piscium	87. 22	23. 11	2·910	2·888	+0·022	+ 0·24	1	5	1
κ Piscium	89. 23	23. 20	53·100	52·990	+0·110	+ 1·28	1	7	2
δ Orionis	90. 23	5. 25	58·620	58·640	−0·020	− 0·24	1	2	1
α Aquarii	90. 54	21. 59	43·430	43·357	+0·073	+ 0·89	1	6	2
λ Aquarii	98. 12	22. 46	27·570	27·472	+0·098	+ 1·42	1	5	1
θ Aquarii	98. 22	22. 10	36·400	36·345	+0·055	+ 0·81	1	2	1
2 Aquilæ	99. 10	18. 35	48·730	48·740	−0·010	− 0·15	1	9	2
ε Eridani	99. 51	3. 27	22·310	22·280	+0·030	+ 0·46	1	2	1
δ Eridani	100. 10	3. 37	36·020	35·733	+0·287	+ 4·40	1	3	1
Bradley 2402	109. 28	19. 1	20·790	20·670	+0·120	+ 2·56	1	1	1

Combining these with the weights above attached to them we have—

From 27 South Stars, Mean Correction to Level Error +0″·39, weight 38.

„ 27 North Stars, „ „ „ −0″·32, „ 35.

FACTORS FOR INSTRUMENTAL ERRORS.

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

FACTORS FOR INSTRUMENTAL ERRORS—*concluded.*

N.P.D.	Collimation. $\frac{1}{15 \sin N.P.D.}$	Level. $\frac{\cos Z.D.}{15 \sin N.P.D.}$	Azimuth. $\frac{\sin Z.D.}{15 \sin N.P.D.}$	N.P.D.	Collimation. $\frac{1}{15 \sin N.P.D.}$	Level. $\frac{\cos Z.D.}{15 \sin N.P.D.}$	Azimuth. $\frac{\sin Z.D.}{15 \sin N.P.D.}$
° ′				° ′			
37. 0	+0·111	+0·111	−0·003	82. 0	+0·067	+0·049	+0·046
38. 0	+0·108	+0·108	−0·001	83. 0	+0·067	+0·048	+0·047
39. 0	+0·106	+0·106	+0·001	84. 0	+0·067	+0·047	+0·048
40. 0	+0·104	+0·104	+0·003	85. 0	+0·067	+0·046	+0·048
41. 0	+0·102	+0·101	+0·004	86. 0	+0·067	+0·045	+0·049
42. 0	+0·100	+0·099	+0·006	87. 0	+0·067	+0·044	+0·050
43. 0	+0·098	+0·097	+0·007	88. 0	+0·067	+0·043	+0·051
44. 0	+0·096	+0·096	+0·009	89. 0	+0·067	+0·042	+0·052
45. 0	+0·094	+0·094	+0·011	90. 0	+0·067	+0·041	+0·052
46. 0	+0·093	+0·092	+0·012	91. 0	+0·067	+0·040	+0·053
47. 0	+0·091	+0·090	+0·013	92. 0	+0·067	+0·040	+0·054
48. 0	+0·090	+0·088	+0·015	93. 0	+0·067	+0·039	+0·054
49. 0	+0·088	+0·087	+0·016	94. 0	+0·067	+0·038	+0·055
50. 0	+0·087	+0·085	+0·017	95. 0	+0·067	+0·037	+0·056
51. 0	+0·086	+0·084	+0·018	96. 0	+0·067	+0·036	+0·057
52. 0	+0·085	+0·082	+0·020	97. 0	+0·067	+0·035	+0·057
53. 0	+0·083	+0·081	+0·021	98. 0	+0·067	+0·034	+0·058
54. 0	+0·082	+0·080	+0·022	99. 0	+0·067	+0·033	+0·059
55. 0	+0·081	+0·078	+0·023	100. 0	+0·068	+0·032	+0·060
56. 0	+0·080	+0·077	+0·024	101. 0	+0·068	+0·031	+0·060
57. 0	+0·080	+0·075	+0·025	102. 0	+0·068	+0·030	+0·061
58. 0	+0·079	+0·074	+0·026	103. 0	+0·068	+0·029	+0·062
59. 0	+0·078	+0·073	+0·027	104. 0	+0·069	+0·028	+0·063
60. 0	+0·077	+0·072	+0·028	105. 0	+0·069	+0·027	+0·063
61. 0	+0·076	+0·070	+0·029	106. 0	+0·069	+0·027	+0·064
62. 0	+0·076	+0·069	+0·030	107. 0	+0·070	+0·026	+0·065
63. 0	+0·075	+0·068	+0·031	108. 0	+0·070	+0·025	+0·066
64. 0	+0·074	+0·067	+0·032	109. 0	+0·071	+0·024	+0·066
65. 0	+0·073	+0·066	+0·033	110. 0	+0·071	+0·023	+0·067
66. 0	+0·073	+0·065	+0·034	111. 0	+0·072	+0·022	+0·068
67. 0	+0·072	+0·064	+0·035	112. 0	+0·072	+0·021	+0·069
68. 0	+0·072	+0·063	+0·035	113. 0	+0·073	+0·020	+0·070
69. 0	+0·071	+0·061	+0·036	114. 0	+0·073	+0·018	+0·071
70. 0	+0·071	+0·060	+0·037	115. 0	+0·074	+0·017	+0·072
71. 0	+0·071	+0·059	+0·038	116. 0	+0·075	+0·016	+0·072
72. 0	+0·070	+0·058	+0·039	117. 0	+0·075	+0·015	+0·073
73. 0	+0·070	+0·057	+0·039	118. 0	+0·076	+0·014	+0·074
74. 0	+0·069	+0·056	+0·040	119. 0	+0·076	+0·013	+0·075
75. 0	+0·069	+0·055	+0·041	120. 0	+0·077	+0·012	+0·076
76. 0	+0·069	+0·054	+0·042	121. 0	+0·078	+0·011	+0·077
77. 0	+0·068	+0·053	+0·043	122. 0	+0·079	+0·009	+0·078
78. 0	+0·068	+0·053	+0·043	123. 0	+0·080	+0·008	+0·079
79. 0	+0·068	+0·052	+0·044	124. 0	+0·080	+0·007	+0·080
80. 0	+0·068	+0·051	+0·045	125. 0	+0·081	+0·005	+0·081
81. 0	+0·067	+0·050	+0·045	126. 0	+0·082	+0·004	+0·082
82. 0	+0·067	+0·049	+0·046				

ASSUMED MEAN RIGHT ASCENSIONS OF CLOCK STARS AND CIRCUMPOLAR STARS, WITH THE CORRECTIONS TO THE NAUTICAL ALMANAC, FOR 1882 JANUARY 1.

Star's Name.	Assumed Mean R.A. 1882 Jan. 1.	Correction to N.A.	Star's Name.	Assumed Mean R.A. 1882 Jan. 1.	Correction to N.A.
	h m s	s		h m s	s
α Andromedæ	0. 2. 17·342	— 0·003	κ Orionis	5. 42. 9·587	+ 0·025
γ Pegasi	0. 7. 9·591	— 0·005	α Orionis	5. 48. 46·979	— 0·025
ι Ceti	0. 13. 24·865	+ 0·052	1 Geminorum	5. 56. 56·843	
44 Piscium	0. 19. 21·216		ν Orionis	6. 0. 50·079	— 0·003
12 Ceti	0. 24. 0·967	+ 0·029	η Geminorum	6. 7. 45·257	— 0·001
ε Andromedæ	0. 32. 19·285		μ Geminorum	6. 15. 49·305	— 0·027
β Ceti	0. 37. 39·916	+ 0·056	β Canis Majoris	6. 17. 30·203	
δ Piscium	0. 42. 33·603	+ 0·058	ν Geminorum	6. 21. 57·359	
20 Ceti	0. 46. 58·571		γ Geminorum	6. 30. 53·645	— 0·016
μ Andromedæ	0. 50. 12·300		ξ Geminorum	6. 38. 40·008	+ 0·022
ε Piscium	0. 56. 49·184	— 0·051	Cephei 51	6. 44. 46·275	— 0·766
β Andromedæ	1. 3. 7·651	+ 0·002	θ Canis Majoris	6. 48. 42·433	— 0·006
ζ¹ Piscium	1. 7. 33·957		ε Canis Majoris	6. 53. 59·292	— 0·015
Polaris	1. 15. 28·437	+ 0·157	ζ Geminorum	6. 57. 6·582	
θ Ceti	1. 18. 7·494	+ 0·050	γ Canis Majoris	6. 58. 25·238	+ 0·003
η Piscium	1. 25. 10·170	+ 0·022	51 Geminorum	7. 6. 35·689	
ν Piscium	1. 35. 17·408	+ 0·039	δ Geminorum	7. 13. 4·512	— 0·055
ο Piscium	1. 39. 9·771	+ 0·019	β Canis Minoris	7. 20. 45·065	— 0·008
β Arietis	1. 48. 7·308	+ 0·069	Castor	7. 27. 4·166	— 0·067
α Arietis	2. 0. 31·324	— 0·002	Procyon	7. 33. 7·423	— 0·080
ξ¹ Ceti	2. 6. 44·722		Pollux	7. 38. 5·610	— 0·028
67 Ceti	2. 11. 5·829	+ 0·027	ξ Argûs	7. 44. 19·905	— 0·016
ξ² Ceti	2. 21. 53·119	+ 0·025	6 Cancri	7. 56. 16·134	+ 0·015
ν Ceti	2. 29. 40·855		15 Argûs	8. 2. 31·109	— 0·017
δ Ceti	2. 33. 26·097		β Cancri	8. 10. 6·910	+ 0·004
γ² Ceti	2. 37. 11·148	— 0·020	d¹ Cancri	8. 16. 36·347	
σ Arietis	2. 44. 58·674	+ 0·041	η Cancri	8. 25. 53·008	+ 0·010
ε Arietis	2. 52. 27·932		γ Cancri	8. 36. 27·329	+ 0·008
α Ceti	2. 56. 6·648	— 0·002	ε Hydræ	8. 40. 31·564	— 0·030
δ Arietis	3. 4. 52·938	— 0·002	α Cancri	8. 52. 1·924	+ 0·005
τ¹ Arietis	3. 14. 24·884		κ Cancri	9. 1. 21·306	— 0·016
ο Tauri	3. 18. 27·861	— 0·019	83 Cancri	9. 12. 23·604	+ 0·012
f Tauri	3. 24. 21·544		α Hydræ	9. 21. 47·286	+ 0·020
ε Eridani	3. 27. 22·247	— 0·009	ξ Leonis	9. 25. 35·058	
11 Tauri	3. 33. 43·455		ο Leonis	9. 34. 51·094	+ 0·018
δ Eridani	3. 37. 35·771		ε Leonis	9. 39. 9·081	— 0·051
η Tauri	3. 40. 28·246	+ 0·017	μ Leonis	9. 46. 2·998	+ 0·003
γ¹ Eridani	3. 52. 31·413	+ 0·045	π Leonis	9. 53. 58·627	+ 0·005
A¹ Tauri	3. 57. 43·147	— 0·014	Regulus	10. 2. 5·180	— 0·019
ω¹ Tauri	4. 2. 17·539		γ¹ Leonis	10. 13. 27·898	— 0·012
o¹ Eridani	4. 6. 6·307	+ 0·053	μ Hydræ	10. 20. 23·036	+ 0·031
γ Tauri	4. 13. 4·699	— 0·014	ρ Leonis	10. 26. 35·841	— 0·029
ε Tauri	4. 21. 43·567	+ 0·017	34 Sextantis	10. 36. 31·830	
Aldebaran	4. 29. 8·988	— 0·016	l Leonis	10. 43. 3·222	+ 0·024
τ Tauri	4. 35. 9·787		d Leonis	10. 54. 27·957	+ 0·039
μ Eridani	4. 39. 36·149	0·000	χ Leonis	10. 58. 55·779	+ 0·017
ι Aurigæ	4. 49. 18·527	— 0·018	δ Leonis	11. 7. 49·893	— 0·043
ε Leporis	5. 0. 27·962	+ 0·069	δ Crateris	11. 13. 26·502	+ 0·009
Rigel	5. 8. 52·001	+ 0·014	τ Leonis	11. 21. 52·113	+ 0·041
β Tauri	5. 18. 49·969	— 0·057	υ Leonis	11. 30. 54·383	+ 0·029
δ Orionis	5. 25. 58·678	— 0·030	β Leonis	11. 43. 2·392	+ 0·002
α Leporis	5. 27. 31·508	— 0·051	β Virginis	11. 44. 32·901	
ε Orionis	5. 30. 13·507	+ 0·018	π Virginis	11. 54. 49·563	— 0·002
α Columbæ	5. 35. 22·641	+ 0·024	ο Virginis	11. 59. 11·910	

ASSUMED MEAN RIGHT ASCENSIONS OF CLOCK STARS AND CIRCUMPOLAR STARS, WITH THE CORRECTIONS TO THE NAUTICAL ALMANAC, FOR 1882 JANUARY 1—*concl.*

Star's Name.	Assumed Mean R.A. 1882 Jan. 1.	Correction to N.A.	Star's Name.	Assumed Mean R.A. 1882 Jan. 1.	Correction to N.A.
	h m s	s		h m s	s
ε Corvi	12. 4. 3·422	− 0·026	λ Sagittarii	18. 20. 41·264	+ 0·004
η Virginis	12. 13. 52·105	+ 0·033	α Lyræ	18. 32. 56·553	− 0·031
δ^2 Corvi	12. 23. 45·664	− 0·042	2 Aquilæ	18. 35. 48·700	
β Corvi	12. 28. 11·323	+ 0·095	β^1 Lyræ	18. 45. 43·368	− 0·001
ρ Virginis	12. 35. 54·694		ε Aquilæ	18. 54. 15·955	+ 0·036
35 Virginis	12. 41. 50·909		ζ Aquilæ	18. 59. 59·132	+ 0·072
31 Comæ	12. 45. 57·074		ψ Sagittarii	19. 8. 18·242	
δ Virginis	12. 49. 39·586	− 0·007	ω Aquilæ	19. 12. 16·631	+ 0·044
ε Virginis	12. 56. 18·182	+ 0·003	δ Aquilæ	19. 19. 32·865	+ 0·042
θ Virginis	13. 3. 50·436	+ 0·027	α Vulpeculæ	19. 23. 47·697	
Spica	13. 18. 58·598	+ 0·025	μ Aquilæ	19. 28. 19·465	
ζ Virginis	13. 28. 40·846	− 0·011	h^2 Sagittarii	19. 29. 31·532	+ 0·097
m Virginis	13. 35. 25·137		e^1 Sagittarii	19. 33. 57·710	
τ Boötis	13. 41. 39·275	− 0·005	γ Aquilæ	19. 40. 38·959	− 0·027
η Boötis	13. 49. 3·974	− 0·024	λ Ursæ Minoris	19. 42. 4·626	− 1·876
τ Virginis	13. 55. 38·490	− 0·003	α Aquilæ	19. 45. 1·530	− 0·009
94 Virginis	14. 0. 2·851		β Aquilæ	19. 49. 31·001	+ 0·018
κ Virginis	14. 6. 36·133		*c* Sagittarii	19. 55. 24·083	
Arcturus	14. 10. 16·733	− 0·035	θ Aquilæ	20. 5. 12·938	+ 0·020
f Boötis	14. 20. 58·131	− 0·032	α^2 Capricorni	20. 11. 30·383	+ 0·056
ρ Boötis	14. 26. 44·648	− 0·040	β Capricorni	20. 14. 22·805	
ϵ^2 Boötis	14. 39. 49·994	− 0·014	ρ Capricorni	20. 22. 7·694	+ 0·076
α Libræ	14. 44. 21·103	+ 0·013	ε Delphini	20. 27. 34·508	+ 0·039
ξ^2 Libræ	14. 50. 21·959		α Delphini	20. 34. 9·431	
ψ Boötis	14. 59. 23·356	− 0·041	ε Aquarii	20. 41. 17·219	+ 0·039
ι^1 Libræ	15. 5. 29·780		μ Aquarii	20. 46. 17·278	
β Libræ	15. 10. 39·435	+ 0·026	32 Vulpeculæ	20. 49. 31·842	+ 0·003
o^2 Libræ	15. 16. 26·923		θ Capricorni	20. 59. 18·750	+ 0·007
ζ^1 Libræ	15. 21. 36·184		ζ Cygni	21. 7. 54·814	+ 0·014
α Coronæ	15. 29. 41·495	− 0·046	α Equulei	21. 9. 55·477	
α Serpentis	15. 38. 27·343	− 0·014	ι Capricorni	21. 15. 40·495	
ε Serpentis	15. 44. 56·053	+ 0·013	β Aquarii	21. 25. 20·746	+ 0·047
γ Serpentis	15. 51. 0·188		ξ Aquarii	21. 31. 28·130	
β^1 Scorpii	15. 58. 34·593	+ 0·022	ε Pegasi	21. 38. 23·435	− 0·024
δ Ophiuchi	16. 8. 9·688	+ 0·029	δ Capricorni	21. 40. 31·582	
γ Herculis	16. 16. 42·870	+ 0·008	16 Pegasi	21. 47. 41·588	− 0·031
Antares	16. 22. 10·386	− 0·005	α Aquarii	21. 59. 43·326	+ 0·061
λ Ophiuchi	16. 24. 57·734		ι Pegasi	22. 1. 31·087	
ζ Ophiuchi	16. 30. 39·689	+ 0·007	θ Aquarii	22. 10. 36·346	+ 0·026
ζ Herculis	16. 36. 50·313	− 0·023	γ Aquarii	22. 15. 33·641	+ 0·029
κ Ophiuchi	16. 52. 4·940	+ 0·041	σ Aquarii	22. 24. 24·049	
ε Herculis	16. 55. 46·479		η Aquarii	22. 29. 17·516	+ 0·057
η Ophiuchi	17. 3. 36·634	+ 0·017	ζ Pegasi	22. 35. 34·579	+ 0·069
α^1 Herculis	17. 9. 15·986	− 0·018	μ Pegasi	22. 44. 18·500	
θ Ophiuchi	17. 14. 45·756	+ 0·013	λ Aquarii	22. 46. 27·379	+ 0·040
σ Ophiuchi	17. 20. 39·594	+ 0·010	Fomalhaut	22. 51. 7·638	+ 0·054
α Ophiuchi	17. 29. 27·366	+ 0·014	α Pegasi	22. 58. 52·986	+ 0·025
β Ophiuchi	17. 37. 38·554	+ 0·015	γ Piscium	23. 11. 2·842	+ 0·034
μ Herculis	17. 41. 50·408	− 0·011	κ Piscium	23. 20. 52·979	+ 0·019
89 Herculis	17. 50. 39·566		ι Piscium	23. 33. 52·866	+ 0·032
72 Ophiuchi	18. 1. 45·305	+ 0·022	δ Sculptoris	23. 42. 46·671	+ 0·028
μ Sagittarii	18. 6. 42·349	+ 0·070	ω Piscium	23. 53. 15·117	+ 0·019
δ Ursæ Minoris	18. 10. 23·135	− 0·702	2 Ceti	23. 57. 41·616	
η Serpentis	18. 15. 12·219	+ 0·022			

OBSERVATIONS FOR THE DETERMINATION OF THE PERSONAL EQUATIONS OF THE VARIOUS TRANSIT-OBSERVERS USING THE CHRONOGRAPHIC METHOD OF OBSERVING TRANSITS.

[The Observers in order of seniority are:—A D, T, L, H, H P, J P, A P, B, H C.]

Day, 1882.		Interval between mean of Groups of Clock Stars.	Order of Observation.		Excess of Clock Slow by Junior Observer.
		h			s
Jan.	27	2	A D	T	+ 0·03
Mar.	15	7	T	A D	− 0·03
May	12	9	T	A D	+ 0·13
,,	18	2	T	A D	+ 0·16
,,	20	1	A D	T	+ 0·03
June	20	2	A D	T	+ 0·15
,,	28	1	A D	T	+ 0·33
Aug.	1	12	A D	T	+ 0·27
,,	7	3	T	A D	+ 0·11
Oct.	30	5	T	A D	+ 0·13
Mar.	1	2	A D	L	+ 0·01
,,	3	2	L	A D	+ 0·11
,,	7	1	A D	L	+ 0·04
,,	13	10	L	A D	+ 0·34
,,	15	9	A D	L	− 0·16
,,	20	0	A D	L	− 0·03
,,	22	3	L	A D	+ 0·03
,,	24	2	A D	L	+ 0·03
,,	26	1	A D	L	+ 0·11
,,	30	2	L	A D	+ 0·08
April	1	2	A D	L	+ 0·02
,,	3	2	L	A D	+ 0·03
,,	5	1	A D	L	+ 0·02
,,	7	2	L	A D	+ 0·06
,,	10	1	A D	L	+ 0·13
,,	27	2	L	A D	+ 0·02
May	1	2	L	A D	+ 0·13
,,	3	1	A D	L	+ 0·08
,,	13	8	A D	L	− 0·14
Nov.	17	5	A D	L	+ 0·18
,,	26	5	L	A D	− 0·01
Dec.	13	4	A D	L	− 0·04
Jan.	6	2	A D	H	− 0·03
May	7	4	A D	H	− 0·20

Day, 1882.		Interval between mean of Groups of Clock Stars.	Order of Observation.		Excess of Clock Slow by Junior Observer.
		h			s
May	23	1	H	A D	− 0·12
,,	25	3	A D	H	− 0·23
,,	27	2	A D	H	− 0·09
,,	29	2	A D	H	− 0·18
,,	31	1	H	A D	− 0·15
June	4	1	H	A D	− 0·10
Nov.	7	7	H	A D	− 0·18
,,	26	5	A D	H	− 0·16
Dec.	4	7	A D	H	− 0·11
April	8	8	A D	H P	+ 0·07
Nov.	17	11	H P	A D	+ 0·21
Oct.	30	7	A D	A P	+ 0·06
Nov.	8	10	A D	A P	− 0·08
,,	14	3	A P	A D	− 0·02
May	8	11	B	A D	− 0·11
Feb.	8	1	H C	A D	+ 0·12
April	10	9	H C	A D	+ 0·13
Jan.	1	1	L	T	− 0·06
,,	3	2	T	L	− 0·04
,,	5	3	L	T	− 0·11
,,	7	1	L	T	− 0·18
,,	9	5	T	L	+ 0·02
,,	21	1	T	L	− 0·08
April	9	1	L	T	− 0·11
May	22	3	L	T	− 0·12
,,	26	3	T	L	− 0·18
,,	28	1	T	L	− 0·07
,,	30	1	T	L	− 0·21
June	1	2	T	L	+ 0·02
July	20	0	L	T	− 0·04
,,	24	3	L	T	− 0·10

OBSERVATIONS FOR PERSONAL EQUATIONS—*continued.*

Day, 1882.		Interval between mean of Groups of Clock Stars.	Order of Observation.		Excess of Clock Slow by Junior Observer.
		h			s
Aug.	2	8	T	L	− 0·07
Nov.	5	3	T	L	− 0·15
,,	20	4	L	T	− 0·02
,,	27	5	T	L	− 0·15
Dec.	21	10	L	T	− 0·10
Feb.	24	2	T	H	− 0·05
,,	26	1	T	H	− 0·09
Mar.	2	3	T	H	− 0·30
,,	4	0	T	H	− 0·19
,,	6	0	T	H	− 0·24
,,	14	9	H	T	− 0·28
,,	27	3	T	H	− 0·27
,,	31	3	T	H	− 0·29
April	4	3	H	T	− 0·20
,,	6	2	T	H	− 0·19
,,	20	1	H	T	− 0·21
,,	22	3	T	H	− 0·20
,,	28	0	H	T	− 0·34
,,	30	2	T	H	− 0·17
May	2	0	H	T	− 0·37
,,	4	1	H	T	− 0·31
,,	6	4	T	H	− 0·33
,,	12	7	H	T	− 0·28
Oct.	17	0	T	H	− 0·23
Nov.	27	8	H	T	− 0·33
Dec.	6	6	T	H	− 0·37
April	8	7	H P	T	− 0·08
,,	24	2	H P	T	− 0·25
June	7	1	H P	T	− 0·10
Aug.	5	1	H P	T	− 0·09
Oct.	4	2	H P	T	+ 0·04
July	7	6	T	J P	− 0·19
April	14	7	T	A P	− 0·11
Aug.	21	3	A P	T	− 0·10

Day, 1882.		Interval between mean of Groups of Clock Stars.	Order of Observation.		Excess of Clock Slow by Junior Observer.
		h			s
June	30	0	T	B	− 0·25
Nov.	5	4	T	B	− 0·21
Mar.	10	0	T	H C	+ 0·01
July	7	1	H C	T	− 0·04
Jan.	6	10	H	L	+ 0·03
,,	9	5	L	H	− 0·23
Feb.	1	3	L	H	− 0·34
Mar.	12	2	H	L	− 0·24
May	6	1	H	L	− 0·11
,,	19	3	L	H	− 0·18
June	23	3	H	L	− 0·21
,,	25	3	L	H	− 0·17
,,	27	0	H	L	− 0·13
,,	29	0	L	H	− 0·12
July	1	0	L	H	− 0·03
Aug.	8	2	H	L	− 0·20
Sept.	6	7	L	H	− 0·18
,,	27	9	L	H	− 0·26
Feb.	10	0	L	H P	+ 0·10
Sept.	8	6	H P	L	+ 0·08
,,	18	3	H P	L	+ 0·07
Nov.	4	7	H P	L	+ 0·18
,,	16	4	L	H P	+ 0·21
April	13	8	J P	L	− 0·21
July	8	7	J P	L	− 0·19
Nov.	1	9	J P	L	− 0·22
,,	20	9	J P	L	− 0·25
Feb.	10	9	A P	L	− 0·02
,,	15	7	L	A P	+ 0·09
Sept.	6	4	A P	L	− 0·06
,,	20	3	L	A P	− 0·02
May	24	1	B	L	− 0·15

OBSERVATIONS FOR PERSONAL EQUATIONS—*concluded.*

Day, 1882.		Interval between mean of Groups of Clock Stars.	Order of Observation.		Excess of Clock Slow by Junior Observer.	Day, 1882.		Interval between mean of Groups of Clock Stars.	Order of Observation.		Excess of Clock Slow by Junior Observer.
		h			s			h			s
July	10	2	L	B	− 0·04	Sept.	2	8	A P	H	+ 0·30
Sept.	8	7	L	B	− 0·16	May	7	10	H	B	− 0·18
Nov.	5	2	L	B	− 0·06	June	8	1	B	H	+ 0·12
,,	16	8	B	L	− 0·08	Sept.	7	10	J P	H P	− 0·22
Oct.	3	4	H C	L	− 0·04	Feb.	10	9	A P	H P	− 0·12
Jan.	24	3	J P	H	− 0·05	Nov.	16	11	B	H P	− 0·29
Mar.	29	1	J P	H	+ 0·03	Feb.	11	7	J P	H C	+ 0·11
July	23	3	H	J P	+ 0·02	Sept.	4	1	B	H C	+ 0·02
Aug.	3	6	J P	H	− 0·05						
Sept.	7	11	H	J P	+ 0·09						

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

For A D.

$$
\begin{aligned}
10\,(AD - T) &= -\,1^s{\cdot}31\\
22\,(AD - L) &= -\,1{\cdot}04\\
11\,(AD - H) &= +\,1{\cdot}55\\
2\,(AD - HP) &= -\,0{\cdot}28\\
3\,(AD - AP) &= +\,0{\cdot}04\\
AD - B &= +\,0{\cdot}11\\
2\,(AD - HC) &= -\,0{\cdot}25
\end{aligned}
$$

For T.

$$
\begin{aligned}
10\,(T - AD) &= +\,1{\cdot}31\\
19\,(T - L) &= +\,1{\cdot}75\\
21\,(T - H) &= +\,5{\cdot}24\\
5\,(T - HP) &= +\,0{\cdot}48\\
T - JP &= +\,0{\cdot}19\\
2\,(T - AP) &= +\,0{\cdot}21\\
2\,(T - B) &= +\,0{\cdot}46\\
2\,(T - HC) &= +\,0{\cdot}03
\end{aligned}
$$

For L.

$$
\begin{aligned}
22\,(L - AD) &= +\,1^s{\cdot}04\\
19\,(L - T) &= -\,1{\cdot}75\\
14\,(L - H) &= +\,2{\cdot}37\\
5\,(L - HP) &= -\,0{\cdot}64\\
4\,(L - JP) &= +\,0{\cdot}87\\
4\,(L - AP) &= +\,0{\cdot}01\\
5\,(L - B) &= +\,0{\cdot}49\\
L - HC &= +\,0{\cdot}04
\end{aligned}
$$

For H.

$$
\begin{aligned}
11\,(H - AD) &= -\,1{\cdot}55\\
21\,(H - T) &= -\,5{\cdot}24\\
14\,(H - L) &= -\,2{\cdot}37\\
5\,(H - JP) &= -\,0{\cdot}04\\
H - AP &= -\,0{\cdot}30\\
2\,(H - B) &= +\,0{\cdot}06
\end{aligned}
$$

For H P.

$$2\,(HP - AD) = +0^{s}.28$$
$$5\,(HP - T) = -0.48$$
$$5\,(HP - L) = +0.64$$
$$HP - JP = +0.22$$
$$HP - AP = +0.12$$
$$HP - B = +0.29$$

For J P.

$$JP - T = -0.19$$
$$4\,(JP - L) = -0.87$$
$$5\,(JP - H) = +0.04$$
$$JP - HP = -0.22$$
$$JP - HC = -0.11$$

For A P.

$$3\,(AP - AD) = -0.04$$
$$2\,(AP - T) = -0.21$$

For A P—*continued.*

$$4\,(AP - L) = -0^{s}.01$$
$$AP - H = +0.30$$
$$AP - HP = -0.12$$

For B.

$$B - AD = -0.11$$
$$2\,(B - T) = -0.46$$
$$5\,(B - L) = -0.49$$
$$2\,(B - H) = -0.06$$
$$B - HP = -0.29$$
$$B - HC = -0.02$$

For H C.

$$2\,(HC - AD) = +0.25$$
$$2\,(HC - T) = -0.03$$
$$HC - L = -0.04$$
$$HC - JP = +0.11$$
$$HC - B = +0.02$$

Now, since one of the quantities denoted by A D, T, L, &c. must evidently remain indeterminate, we will refer all the rest to A D as a standard; and, putting A D = 0, the initials T, L, H, &c. will represent the values of "clock slow" which would be given by the observations of Mr. Thackeray, Mr. Lewis, Mr. Hollis, &c., when that given by the observation of Mr. Downing = 0.

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

$$62\,T - 19\,L - 21\,H - 5\,HP - JP - 2\,AP - 2\,B - 2\,HC = +9^{s}.67$$
$$74\,L - 19\,T - 14\,H - 5\,HP - 4\,JP - 4\,AP - 5\,B - HC = +2.43$$
$$54\,H - 21\,T - 14\,L - 5\,JP - AP - 2\,B = -9.44$$
$$15\,HP - 5\,T - 5\,L - JP - AP - B = +1.07$$
$$12\,JP - T - 4\,L - 5\,H - HP - HC = -1.35$$
$$11\,AP - 2\,T - 4\,L - H - HP = -0.08$$
$$12\,B - 2\,T - 5\,L - 2\,H - HP - HC = -1.43$$
$$7\,HC - 2\,T - L - JP - B = +0.31$$

Solving these equations by successive approximations, that is by first substituting in each equation the approximately known values of all the personal equations, except that which has the largest co-efficient, thence deducing the value of that one personal equation, then using that deduced value for substitution in the other equations, and repeating the process, we get finally the following values:—

T = + 0ˢ·14	L = + 0ˢ·04	H = − 0ˢ·12	H P = + 0ˢ·12
J P = − 0·12	A P = + 0·03	B = − 0·08	H C = + 0·06

or, restoring A D:—

A D − T = − 0ˢ·14	A D − L = − 0ˢ·04	A D − H = + 0ˢ·12	A D − H P = − 0ˢ·12
A D − J P = + 0·12	A D − A P = − 0·03	A D − B = + 0·08	A D − H C = − 0·06

ERRORS OF DIVISION.

The following table contains the adopted result for errors of division for every degree. The errors are always considered in the nature of reading too much. $1^r = 61''\cdot4$ nearly.

Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.	Degree.	Excess of Reading.
°	r	°	r	°	r	°	r	°	r	°	r	°	r	°	r	°	r	°	r
0	0·052	36	0·057	72	0·054	108	0·059	144	0·084	180	0·053	216	0·041	252	0·047	288	0·054	324	0·082
1	·050	37	·053	73	·050	109	·064	145	·077	181	·055	217	·040	253	·051	289	·063	325	·079
2	·050	38	·051	74	·049	110	·060	146	·069	182	·053	218	·044	254	·057	290	·062	326	·078
3	·051	39	·056	75	·056	111	·055	147	·076	183	·053	219	·042	255	·063	291	·063	327	·072
4	·052	40	·057	76	·058	112	·058	148	·080	184	·053	220	·039	256	·067	292	·072	328	·075
5	·050	41	·059	77	·055	113	·059	149	·077	185	·044	221	·038	257	·066	293	·071	329	·076
6	·051	42	·062	78	·054	114	·067	150	·076	186	·038	222	·038	258	·066	294	·078	330	·068
7	·047	43	·062	79	·056	115	·069	151	·073	187	·044	223	·040	259	·064	295	·079	331	·062
8	·052	44	·056	80	·062	116	·071	152	·078	188	·047	224	·041	260	·073	296	·073	332	·066
9	·051	45	·051	81	·065	117	·074	153	·083	189	·045	225	·037	261	·080	297	·069	333	·071
10	·051	46	·055	82	·072	118	·071	154	·086	190	·035	226	·042	262	·077	298	·065	334	·081
11	·055	47	·060	83	·074	119	·074	155	·089	191	·031	227	·049	263	·087	299	·069	335	·075
12	·057	48	·069	84	·075	120	·078	156	·085	192	·035	228	·050	264	·085	300	·085	336	·074
13	·054	49	·067	85	·071	121	·083	157	·073	193	·039	229	·056	265	·084	301	·087	337	·069
14	·062	50	·056	86	·071	122	·086	158	·064	194	·037	230	·052	266	·085	302	·082	338	·065
15	·050	51	·053	87	·075	123	·090	159	·069	195	·036	231	·056	267	·086	303	·086	339	·064
16	·053	52	·058	88	·075	124	·096	160	·072	196	·039	232	·062	268	·085	304	·091	340	·069
17	·049	53	·075	89	·072	125	·088	161	·067	197	·035	233	·065	269	·081	305	·086	341	·066
18	·056	54	·068	90	·073	126	·093	162	·065	198	·036	234	·060	270	·078	306	·089	342	·075
19	·055	55	·073	91	·072	127	·088	163	·062	199	·043	235	·059	271	·072	307	·089	343	·069
20	·056	56	·070	92	·078	128	·086	164	·067	200	·039	236	·049	272	·063	308	·084	344	·063
21	·045	57	·067	93	·071	129	·082	165	·073	201	·044	237	·054	273	·062	309	·079	345	·070
22	·050	58	·071	94	·075	130	·076	166	·073	202	·047	238	·062	274	·060	310	·077	346	·067
23	·053	59	·073	95	·070	131	·082	167	·067	203	·047	239	·070	275	·068	311	·086	347	·064
24	·049	60	·070	96	·069	132	·072	168	·057	204	·044	240	·069	276	·069	312	·085	348	·068
25	·050	61	·068	97	·068	133	·070	169	·054	205	·045	241	·070	277	·073	313	·084	349	·063
26	·058	62	·067	98	·073	134	·076	170	·048	206	·046	242	·063	278	·082	314	·085	350	·051
27	·053	63	·064	99	·077	135	·080	171	·051	207	·047	243	·069	279	·078	315	·077	351	·053
28	·052	64	·071	100	·075	136	·084	172	·046	208	·043	244	·070	280	·074	316	·081	352	·051
29	·052	65	·062	101	·070	137	·087	173	·043	209	·045	245	·066	281	·073	317	·084	353	·054
30	·058	66	·060	102	·073	138	·081	174	·040	210	·054	246	·059	282	·076	318	·084	354	·047
31	·066	67	·058	103	·069	139	·079	175	·042	211	·056	247	·054	283	·077	319	·075	355	·041
32	·067	68	·059	104	·066	140	·078	176	·053	212	·047	248	·042	284	·072	320	·081	356	·045
33	·069	69	·063	105	·060	141	·080	177	·060	213	·043	249	·044	285	·065	321	·074	357	·055
34	·064	70	·063	106	·062	142	·083	178	·058	214	·041	250	·054	286	·063	322	·073	358	·054
35	·056	71	·061	107	·057	143	·089	179	·053	215	·037	251	·050	287	·054	323	·084	359	·052

DIVISION CORRECTION.

(*Always Additive.*)

In this table the correction given for pointer-reading 0° is assumed to apply to all readings between 0° and 1°, and so on throughout.

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

When the Pointer reads 0° the division under Microscope A is 270°. 30′; under Microscope C, 210°. 30′; under Microscope E, 150°. 30′; under Microscope B, 90°. 30′; under Microscope D, 30°. 30′; and under Microscope F, 330°. 30′.

The following are the corrections for errors of the 5′ divisions used in observations of the Nadir point and of close circumpolar stars, resulting from special examinations made in 1857, 1865, and 1880:—

For Nadir Point, the Pointer Reading being			179°. 35′,	the correction is	+0″·37
			179. 40,		+0·52
For Polaris,	,,	,,	322. 30,	,,	+0·69
			322. 25,	,,	+0·66
For Polaris S.P.	,,	,,	319. 40,	,,	+1·11
			319. 45,	,,	+1·13
For Cephei 51	,,	,,	323. 55,	,,	+0·83
			323. 50,	,,	+0·84
For Cephei 51 S.P.	,,	,,	318. 15,	,,	+0·63
			318. 20,	,,	+0·60
For δ Ursæ Minoris	,,	,,	324. 30,	,,	+0·74
			324. 25,	,,	+0·79
For δ Ursæ Minoris S.P.	,,	,,	317. 40,	,,	+0·68
			317. 45,	,,	+0·75
For λ Ursæ Minoris	,,	,,	322. 10,	,,	+0·74
For λ Ursæ Minoris S.P.	,,	,,	320. 0,	,,	+0·99
			320. 5,	,,	+1·08

The Division under Microscope A is Pointer Reading −89°. 30′.

These corrections have been applied additively to the circle-readings whenever they were needed throughout the year.

COMPARISON OF THE VALUES OF SUCCESSIVE HALF-REVOLUTIONS OF THE SCREW OF THE TELESCOPE-MICROMETER.

The following observations were made by Mr. Downing in 1882 to determine whether the separate portions of the screw's revolution are sensibly different. The telescope was directed to the nearly horizontal wire of the South Collimator, and the reading of the telescope micrometer was taken when its wire was in coincidence with the image of the wire in the South Collimator, the micrometer-head of which was alternately set to ʳ·000 and ʳ·720, the difference being the equivalent of a half-revolution of the telescope-micrometer. The observations in the first and second series were made on October 19, and in the third and fourth series on October 21.

Readings of Telescope-Micrometer. (1st Series.)	Intervals.	Readings of Telescope-Micrometer. (3rd Series.)	Intervals.	Readings of Telescope-Micrometer. (2nd Series.)	Intervals.	Readings of Telescope-Micrometer. (4th Series.)	Intervals.
r	r	r	r	r	r	r	r
15·999 16·499	0·500	16·006 16·506	0·500	15·740 16·246	0·506	15·742 16·246	0·504
16·504 17·009	0·505	16·509 17·016	0·507	16·256 16·753	0·497	16·251 16·746	0·495
17·015 17·520	0·505	17·014 17·517	0·503	16·764 17·272	0·508	16·760 17·265	0·505
17·529 18·035	0·506	17·537 18·043	0·506	17·266 17·773	0·507	17·260 17·763	0·503
18·037 18·545	0·508	18·042 18·542	0·500	17·786 18·292	0·506	17·776 18·277	0·501
18·546 19·047	0·501	18·550 19·054	0·504	18·275 18·775	0·500	18·268 18·769	0·501
19·089 19·590	0·501	19·078 19·574	0·496	18·754 19·260	0·506	18·752 19·252	0·500
19·562 20·068	0·506	19·556 20·050	0·494	19·255 19·758	0·503	19·252 19·754	0·502
20·006 20·502	0·496	20·015 20·515	0·500	19·766 20·262	0·496	19·759 20·262	0·503
20·517 21·022	0·505	20·514 21·016	0·502	20·263 20·767	0·504	20·250 20·747	0·497
21·005 21·506	0·501	21·002 21·502	0·500	20·763 21·264	0·501	20·750 21·252	0·502
21·488 21·994	0·506	21·478 21·979	0·501	21·250 21·748	0·498	21·243 21·748	0·505
22·030 22·527	0·497	22·037 22·541	0·504	21·745 22·250	0·505	21·733 22·235	0·502
22·489 22·985	0·496	22·479 22·979	0·500	22·262 22·765	0·503	22·252 22·754	0·502
23·007 23·511	0·504	23·008 23·511	0·503	22·734 23·238	0·504	22·733 23·235	0·502
23·521 24·028	0·507	23·511 24·010	0·499	23·221 23·720	0·499	23·222 23·724	0·502
				23·716 24·215	0·499	23·709 24·207	0·498

$1^{\text{rev.}} = 34''\cdot526.$

These observations appear to indicate that there is no sensible inequality in different parts of the micrometer-screw.

OBSERVATIONS FOR THE DETERMINATION OF THE ASTRONOMICAL FLEXURE OF THE TELESCOPE OF THE TRANSIT-CIRCLE.

Month and Day, 1882.	Order of Observation.	Concluded Circle Reading at bisection of Wire of North Collimator.	Mean Concluded Circle Reading, North Collimator.	Order of Observation.	Concluded Circle Reading at bisection of Wire of South Collimator.	Mean Concluded Circle Reading, South Collimator.
		° ′ ″	° ′ ″		° ′ ″	° ′ ″
Jan. 3	2	269. 41. 45·28		1	89. 41. 44·72	
	4	45·29		3	45·22	
	6	45·39		5	45·16	
	8	45·44		7	45·06	
	10	45·75	269. 41. 45·40	9	45·40	89. 41. 45·26
	12	45·59		11	45·59	
	14	45·53		13	45·29	
	16	45·33		15	45·27	
	18	45·18		17	45·27	
	20	45·17		19	45·58	
Jan. 3	22	269. 41. 45·23		21	89. 41. 45·32	
	24	45·45		23	45·21	
	26	45·07		25	45·29	
	28	45·01		27	45·43	
	30	45·23	269. 41. 45·24	29	45·29	89. 41. 45·25
	32	45·31		31	45·04	
	34	45·11		33	45·29	
	36	45·54		35	45·16	
	38	45·15		37	45·25	
	40	45·30		39	45·24	
Dec. 30	2	269. 35. 22·99		1	89. 35. 23·25	
	4	23·35		3	23·09	
	6	23·33		5	22·99	
	8	23·26		7	23·52	
	10	23·35	269. 35. 23·28	9	23·48	89. 35. 23·39
	12	23·30		11	23·34	
	14	23·06		13	23·51	
	16	23·21		15	23·37	
	18	23·37		17	23·66	
	20	23·53		19	23·69	

OBSERVATIONS FOR THE DETERMINATION OF THE ASTRONOMICAL FLEXURE OF THE TELESCOPE OF THE TRANSIT-CIRCLE—*concluded.*

Month and Day, 1882.	Order of Observation.	Concluded Circle Reading at bisection of Wire of North Collimator.	Mean Concluded Circle Reading, North Collimator.	Order of Observation.	Concluded Circle Reading at bisection of Wire of South Collimator.	Mean Concluded Circle Reading, South Collimator.
		° ′ ″	° ′ ″		° ′ ″	° ′ ″
Dec. 30	22	269. 35. 23·20		21	89. 35. 23·18	
	24	22·97		23	23·33	
	26	22·95		25	23·58	
	28	23·13		27	23·30	
	30	23·17		29	23·35	
	32	23·33	269. 35. 23·17	31	23·20	89. 35. 23·33
	34	23·23		33	23·42	
	36	23·23		35	23·29	
	38	22·95		37	23·29	
	40	23·51		39	23·38	

The separate corrections for astronomical horizontal flexure deduced from these observations are:—

Month and Day, 1882.	Mean Concluded Circle Reading.		Resulting Correction for Astronomical Horizontal Flexure.
	North Collimator.	South Collimator.	
	° ′ ″	° ′ ″	″
Jan. 3	269. 41. 45·318	89. 41. 45·254	+ 0·03
Dec. 30	269. 35. 23·221	89. 35. 23·361	− 0·07

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS OF ZENITH DISTANCES WITH THE TRANSIT-CIRCLE, 1882.

In this Table the Reflexion observations are not corrected for inclination of the vertical at the surface of the mercury to that at the centre of the instrument.

Star's Name.	Approx. N.P.D.	R−D.	No. of Obs. R. and D.	Weights.	Star's Name.	Approx. N.P.D.	R−D.	No. of Obs. R. and D.	Weights.
	° ′	″				° ′	″		
β Ursæ Majoris S.P.	−32. 59	−1·62	1	2	Cephei 51 S.P.	−2. 46	+0·43	6	8
δ Ursæ Majoris S.P.	−32. 19	−0·80	1	2	Polaris S.P.	−1. 19	−0·06	8	9
5 Lyncis S.P.	−31. 31	+0·78	1	2	λ Ursæ Minoris S.P.	−1. 3	−0·71	2	3
17 Lyncis S.P.	−29. 1	−1·00	1	2	λ Ursæ Minoris	1. 3	−0·02	1	2
10 Lyncis S.P.	−28. 26	−1·40	2	3	Polaris	1. 19	+0·10	5	7
8 Lyncis S.P.	−28. 25	−3·35	2	3	Cephei 51	2. 46	+0·61	4	6
Groomb. 1826 S.P.	−27. 56	−0·84	1	2	δ Ursæ Minoris	3. 23	−0·04	5	7
Groomb. 2055 S.P.	−27. 55	−0·52	1	2					
b Ursæ Majoris S.P.	−27. 36	−2·30	1	2	Groombridge 774	6. 57	+0·70	1	2
					Bradley 74	6. 56	+0·92	1	2
Groomb. 1853 S.P.	−26. 24	+0·26	1	2	Piazzi VI. 292	7. 22	+1·25	4	6
19 Camelopardi S.P.	−25. 55	−3·04	1	2	76 Draconis	7. 54	−1·06	1	2
α Draconis S.P.	−25. 4	−1·36	1	2	Bradley 48	8. 9	−0·82	1	2
Piazzi XI. 43 S.P.	−25. 1	−1·50	2	3	Piazzi IX. 37	8. 9	−0·98	1	2
Piazzi VII. 282 S.P.	−24. 0	−2·06	1	2	Piazzi VI. 334	8. 52	+2·70	1	2
8 Draconis S.P.	−23. 55	−1·76	1	2	Bradley 1458	8. 57	+0·26	1	2
Bradley 1429 S.P.	−23. 50	−1·78	1	2	Groombridge 3887	9. 13	−1·12	1	2
38 Ursæ Maj. S.P.	−23. 40	+0·80	1	2	Piazzi III. 160	9. 38	−0·68	1	2
Groomb. 1299 S.P.	−23. 26	−1·74	1	2	Piazzi VI. 75	10. 19	+0·18	1	2
9 Draconis S.P.	−22. 46	−0·72	2	3	Piazzi VII. 187	10. 12	−0·44	1	2
3 Draconis S.P.	−22. 36	−1·66	1	2	Groombridge 2900	10. 38	−0·94	1	2
Groomb. 2105 S.P.	−21. 41	−0·84	1	2	Piazzi IV. 269	10. 55	−0·16	1	2
Lalande 10769 S.P.	−21. 34	−0·58	1	2	Bradley 1508	11. 36	−1·16	2	3
					Bradley 1634	11. 44	−0·78	1	2
A Draconis S.P.	−20. 59	+1·86	1	2	28 Cephei	11. 49	−0·54	1	2
2 Draconis S.P.	−20. 1	+0·51	2	3	ζ Ursæ Minoris	11. 51	−0·82	1	2
λ Draconis S.P.	−20. 1	−3·11	2	3	Groombridge 1151	11. 55	+0·28	1	2
Groomb. 2091 S.P.	−20. 1	−0·99	3	5	κ^1 Cephei	12. 39	−1·14	1	2
Groomb. 2029 S.P.	−18. 9	+0·68	1	2	γ Cephei	13. 2	−2·12	1	2
Piazzi XIII. 109 S.P.	−17. 0	−0·25	2	3					
Groomb. 928 S.P.	−16. 52	−1·88	1	2	19 Ursæ Minoris	13. 50	+0·34	1	2
Piazzi IV. 204 S.P.	−16. 25	−1·92	1	2	Piazzi IV. 112	14. 17	−0·62	1	2
Groomb. 1446 S.P.	−15. 58	−2·78	1	2	3 Ursæ Minoris	14. 51	−0·79	2	3
Piazzi IV. 191 S.P.	−15. 55	−3·13	2	3	π Cephei	15. 15	+2·38	1	2
					Piazzi IV. 191	15. 55	−0·60	1	2
Bradley 1147 S.P.	−13. 53	+0·95	2	3	Piazzi IX. 187	16. 34	−0·60	1	2
19 Ursæ Min. S.P.	−13. 50	−0·64	1	2	Groombridge 771	16. 45	−0·94	2	3
5 Ursæ Minoris S.P.	−13. 47	+1·31	2	3	τ Draconis	16. 52	−0·20	1	2
Bradley 1446 S.P.	−13. 41	−1·26	1	2	31 Cephei	16. 58	−0·82	1	2
Groomb. 1151 S.P.	−11. 55	−1·38	1	2	Piazzi XIII. 109	17. 0	+1·12	1	2
Piazzi IV. 311 S.P.	−11. 49	−0·40	1	2	27 Ursæ Majoris	17. 13	+0·88	1	2
Piazzi IV. 269 S.P.	−10. 55	−1·10	2	3	11 Ursæ Minoris	17. 45	−0·44	1	2
Groomb. 1463 S.P.	− 9. 32	−2·50	1	2	ψ^1 Draconis (1st Star)	17. 48	−0·56	1	2
Bradley 1458 S.P.	− 8. 57	−1·56	1	2	ψ^2 Draconis	17. 59	−0·98	1	2
Piazzi VI. 334 S.P.	− 8. 52	−1·58	1	2	50 Cassiopeiæ	18. 9	+0·72	2	3
Groomb. 1845 S.P.	− 8. 29	+1·48	1	2	Groombridge 2917	18. 39	+0·56	1	2

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS OF ZENITH DISTANCES WITH THE TRANSIT-CIRCLE, 1882—*continued.*

Star's Name.	Approx. N. P. D.	R—D.	No. of Obs. R. and D.	Weights.	Star's Name.	Approx. N. P. D.	R—D.	No. of Obs. R. and D.	Weights.
	° ′	″				° ′	″		
φ Draconis	18. 44	+0·12	1	2	57 Camelopardi	27. 8	+0·25	3	5
					Piazzi III. 177	27. 17	−0·28	1	2
λ Draconis	20. 1	+0·06	5	7	Piazzi XV. 110	27. 19	+0·06	1	2
4 Draconis	20. 9	−1·06	1	2	θ Cephei	27. 24	−0·38	1	2
Bradley 3125	20. 17	+1·44	1	2	b Ursæ Majoris	27. 36	+1·72	1	2
Piazzi X. 126	20. 18	+0·72	1	2	α Ursæ Majoris	27. 37	+0·31	6	8
σ Draconis	20. 32	−0·84	1	2	Groombridge 2742	27. 46	−0·96	1	2
ω Draconis	21. 11	−0·86	1	2	α Cephei	27. 55	+1·00	1	2
55 Camelopardi	21. 11	+2·12	1	2	Groombridge 2055	27. 55	−0·52	1	2
Bradley 2636	21. 30	+1·38	1	2	41 Camelopardi	27. 59	−0·19	2	3
f Draconis	21. 47	+1·12	1	2					
Groombridge 2320	21. 53	+0·38	1	2	η Draconis	28. 13	+0·34	1	2
Groombridge 2214	22. 12	+1·24	1	2	19 Cephei	28. 18	+0·16	1	2
ρ Draconis	22. 28	−1·96	1	2	Piazzi III. 260	28. 27	−0·20	1	2
δ Draconis	22. 33	−1·48	2	3	Groombridge 48	28. 47	+0·92	1	2
ω Cassiopeiæ	22. 33	−0·04	1	2	12 Cassiopeiæ	28. 49	+1·02	1	2
7 Draconis	22. 34	−1·48	1	2	ο Ursæ Majoris	28. 53	+0·40	3	5
3 Draconis	22. 36	+0·75	4	6	Piazzi XVI. 140	28. 56	−3·12	1	2
Piazzi XVIII. 93	22. 37	−1·24	1	2	Bradley 90	29. 31	−1·40	1	2
9 Draconis	22. 46	+0·74	1	2	Piazzi IV. 22	29. 33	+1·82	1	2
Bradley 3166	22. 51	−0·11	3	5	β Camelopardi	29. 44	+1·94	1	2
Bradley 332	23. 8	+2·66	1	2	Piazzi VI. 293	30. 2	−0·12	1	2
					31 Camelopardi	30. 8	−1·64	1	2
Bradley 1429	23. 50	−1·02	1	2					
α Camelopardi	23. 52	−0·44	2	3	*m* Persei	47. 11	+0·66	1	2
8 Draconis	23. 55	+0·14	1	2	Piazzi XI. 146	47. 37	+1·66	1	2
Piazzi VII. 282	24. 0	+2·18	1	2	ζ Aurigæ	49. 6	+0·04	1	2
55 Cassiopeiæ	24. 2	+0·78	1	2	*f* Persei	49. 49	+0·46	1	2
ζ Draconis	24. 8	+0·46	1	2	τ Andromedæ	50. 1	−0·32	1	2
55 Draconis	24. 13	+0·46	1	2	10 Canum Venat.	50. 5	−0·42	1	2
A Ursæ Majoris	24. 27	+2·00	1	2	ε Persei	50. 20	+0·70	1	2
Groombridge 120	24. 30	+0·30	1	2	51 Aurigæ	50. 30	−0·02	1	2
42 Draconis	24. 31	+0·58	1	2	α Lyræ	51. 20	+0·84	6	8
Piazzi XIII. 184	24. 35	−0·70	1	2					
Bradley 448	24. 47	+1·42	1	2	72 Cygni	52. 0	+2·54	1	2
α Draconis	25. 4	−0·11	5	7	50 Persei	52. 16	−2·00	1	2
g Draconis	25. 11	+2·66	1	2	Piazzi I. 170	52. 38	+0·20	1	2
π Ursæ Majoris	25. 16	+0·10	2	3	38 Lyncis	52. 42	+0·16	1	2
Groombridge 1609	25. 28	+1·46	1	2	θ Aurigæ	52. 48	+0·42	1	2
Groombridge 1888	25. 33	+0·26	1	2	65 Aurigæ	53. 1	−1·58	1	2
Piazzi IX. 51	25. 33	−0·44	3	5	b^2 Cygni	53. 30	+0·60	1	2
28 Ursæ Majoris	25. 48	+0·26	1	2	Piazzi XVII. 3	53. 55	+0·87	3	5
					B. F. 1905	54. 45	+1·02	1	2
τ Ursæ Majoris	26. 0	−1·44	2	3	46 Leonis Minoris	55. 9	−0·35	3	5
h Ursæ Majoris	26. 25	+0·34	2	3	W. B. (2) I. 774	55. 21	−0·62	1	2
76 Ursæ Majoris	26. 38	+0·79	3	5					
Piazzi I. 159	26. 44	+1·02	1	2	8 Cygni	55. 48	0·00	1	2
ε Cassiopeiæ	26. 55	−0·62	1	2	15 Trianguli	55. 50	−0·84	1	2
Groombridge 329	27. 1	+0·82	1	2	55 Persei	56. 9	+1·54	1	2
Piazzi XV. 198	27. 2	−0·32	1	2	δ Boötis	56. 15	−1·02	1	2

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS OF ZENITH DISTANCES WITH THE TRANSIT-CIRCLE, 1882—*continued.*

Star's Name.	Approx. N. P. D.	R − D.	No. of Obs. R. and D.	Weights.	Star's Name.	Approx. N. P. D.	R − D.	No. of Obs. R. and D.	Weights.
	° ′	″				° ′	″		
υ Herculis	56. 46	+0·06	1	2	λ Leonis	66. 31	+1·02	1	2
7 Trianguli	57. 11	+0·30	1	2					
66 Cancri	57. 17	+0·43	2	3	17 Vulpeculæ	66. 43	+0·04	2	3
20 Leonis Minoris	57. 30	−0·14	2	3	1 Geminorum	66. 44	−0·82	1	2
Piazzi XIV. 103	57. 41	−0·20	1	2	3 Geminorum	66. 52	−0·56	1	2
Castor	57. 51	−0·14	5	7	τ Pegasi	66. 54	+0·96	1	2
χ Aurigæ	57. 54	−0·04	1	2	2 Boötis	66. 54	−0·30	1	2
22 Leonis Minoris	57. 57	+0·02	1	2	α Arietis	67. 6	−0·05	3	5
ζ Herculis	58. 11	+0·81	2	3	υ Pegasi	67. 15	+0·04	1	2
ε Herculis	58. 54	−0·06	1	2	1 Comæ	67. 15	+1·17	2	3
19 Lyræ	58. 55	−0·86	1	2	ξ Cancri	67. 29	−0·52	1	2
σ² Cancri	58. 58	+0·06	1	2	113 Herculis	67. 30	+0·76	1	2
Piazzi XVII. 176	59. 8	+0·26	1	2	δ Geminorum	67. 48	+0·18	3	5
σ³ Cancri	59. 19	+1·10	1	2	n Tauri	68. 2	+2·82	1	2
τ Geminorum	59. 34	−0·36	2	3	γ Cancri	68. 6	−0·47	2	3
50 Herculis	59. 59	+1·70	1	2	39 Comæ	68. 13	+1·38	1	2
41 Cygni	60. 1	+0·41	2	3	26 Comæ	68. 17	−1·50	1	2
					ε Arietis	69. 8	+0·22	1	2
υ Coronæ	60. 33	−0·02	1	2	ζ Geminorum	69. 15	−0·12	3	5
ι Cancri	60. 49	−0·80	2	3	τ¹ Arietis	69. 17	−0·48	1	2
α Trianguli	61. 0	+0·46	1	2	1 Boötis	69. 27	+1·66	1	2
39 Arietis	61. 15	+0·14	2	3	β Arietis	69. 46	+1·19	2	3
Piazzi XI. 111	61. 34	+2·48	1	2	Piazzi XVII. 109	69. 49	−0·12	1	2
Pollux	61. 41	+2·50	1	2	51 Pegasi	69. 52	+3·04	1	2
31 Comæ	61. 49	+0·98	1	2					
ι Geminorum	61. 58	+0·78	1	2	Arcturus	70. 12	+0·66	1	2
11 Boötis	62. 3	−0·16	1	2	52 Piscium	70. 21	+0·50	1	2
μ Herculis	62. 13	−0·20	2	3	ξ Boötis	70. 25	+0·46	1	2
23 Vulpeculæ	62. 33	+1·54	1	2	γ Herculis	70. 34	+0·87	2	3
ψ Boötis	62. 35	+2·30	1	2	δ Arietis	70. 43	−0·91	2	3
ε Coronæ	62. 47	+0·22	1	2	86 Leonis	70. 56	−0·05	2	3
α Coronæ	62. 53	+0·36	2	3	η Boötis	71. 1	+1·11	2	3
					54 Herculis	71. 23	+0·84	1	2
μ Leonis	63. 26	+0·09	2	3	71 Leonis	71. 55	−0·39	4	6
12 Comæ	63. 30	−0·42	1	2	τ Boötis	71. 57	−0·32	1	2
13 Leonis	63. 33	−0·58	1	2	δ³ Tauri	72. 21	+0·90	1	2
χ Herculis	63. 48	+1·48	1	2	ι Arietis	72. 46	−0·68	1	2
κ Pegasi	64. 54	+0·22	1	2	81 Leonis	72. 54	−0·38	2	3
56 Pegasi	65. 10	+0·44	1	2	20 Boötis	73. 9	−2·22	1	2
70 Herculis	65. 23	+1·70	1	2	λ Geminorum	73. 15	+0·53	3	5
α Vulpeculæ	65. 34	−0·04	1	2	γ Geminorum	73. 30	+0·82	1	2
84 Herculis	65. 37	−0·76	1	2	τ⁶ Serpentis	73. 36	+1·51	2	3
ω Geminorum	65. 37	−0·60	2	3	υ Boötis	73. 37	+1·27	2	3
ε Leonis	65. 41	−1·30	1	2	51 Geminorum	73. 39	+0·40	1	2
7 Tauri	65. 56	+1·08	1	2	Aldebaran	73. 44	−3·12	1	2
ζ Leonis	66. 0	−0·04	1	2	Piazzi XXII. 241	73. 47	+0·56	1	2
Piazzi XVIII. 100	66. 13	+0·92	2	3	68 Geminorum	73. 55	+1·56	1	2
Piazzi XXI. 114	66. 14	−1·46	1	2					
8 Comæ	66. 19	−0·28	1	2	β Serpentis	74. 12	−0·43	3	5
Piazzi XVIII. 132	66. 29	−0·20	1	2	14 Sagittæ	74. 18	+1·50	2	3

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS OF ZENITH DISTANCES WITH THE TRANSIT-CIRCLE, 1882—*concluded.*

Star's Name.	Approx. N. P. D.	R − D.	No. of Obs. R. and D.	Weights.	Star's Name.	Approx. N. P. D.	R − D.	No. of Obs. R. and D.	Weights.
	° ′	″				° ′	″		
76 Pegasi	74. 19	+1 ·48	1	2	ν Piscium	85. 7	+1 ·13	2	3
6 Comæ	74. 27	+0 ·22	1	2	β Ophiuchi	85. 23	+0 ·98	1	2
β Leonis	74. 46	+0 ·21	3	5	σ Ophiuchi	85. 45	−0 ·07	2	3
Piazzi XIII. 264	74. 46	−0 ·82	1	2	δ Aquilæ	87. 7	+0 ·69	2	3
88 Leonis	74. 59	−0 ·52	1	2	γ Piscium	87. 22	+1 ·50	2	3
ε Aquilæ	75. 5	−0 ·20	2	3					
k Leonis	75. 11	+0 ·68	1	2	κ Piscium	89. 23	+1 ·76	2	3
ν Orionis	75. 13	+0 ·52	1	2	ν Aquilæ	89. 54	+0 ·22	1	2
γ Pegasi	75. 28	+1 ·06	2	3	Lalande 34499	90. 24	+0 ·66	2	3
37 Leonis	75. 41	−0 ·22	1	2	α Aquarii	90. 54	+0 ·68	1	2
ζ Boötis	75. 46	+0 ·74	1	2	θ Aquilæ	91. 10	+2 ·30	2	3
ζ Aquilæ	76. 19	−0 ·23	2	3	20 Ceti	91. 47	+0 ·64	1	2
14 Boötis	76. 29	+1 ·72	1	2					
41 Virginis	76. 56	−0 ·26	1	2	λ Aquilæ	95. 3	−0 ·46	1	2
7 Serpentis	77. 1	+1 ·76	1	2	25 Ceti	95. 28	+4 ·10	1	2
B. A. C. 4005	77. 4	+0 ·68	1	2	β Aquarii	96. 5	+1 ·32	1	2
α Ophiuchi	77. 21	+2 ·40	1	2	30 Aquarii	97. 6	+0 ·92	1	2
Regulus	77. 27	+0 ·84	3	5	κ Aquilæ	97. 17	+1 ·23	5	7
f Tauri	77. 28	−2 ·36	1	2	67 Aquarii	97. 35	+0 ·76	1	2
					λ Aquarii	98. 12	+0 ·54	4	6
1 Canis Minoris	78. 6	+0 ·40	1	2	θ Aquarii	98. 22	+0 ·38	1	2
ε Virginis	78. 24	+0 ·90	2	3					
ω Aquilæ	78. 37	−0 ·56	1	2	2 Aquilæ	99. 10	+1 ·35	3	5
ε Delphini	79. 6	+1 ·94	1	2	μ Aquarii	99. 26	+1 ·42	1	2
ζ Pegasi	79. 47	−0 ·54	1	2	ι Ceti	99. 29	+1 ·63	2	3
κ Ophiuchi	80. 26	+2 ·26	1	2	ε Eridani	99. 52	+2 ·10	1	2
o Tauri	81. 23	−0 ·46	2	3	δ Eridani	100. 10	+2 ·02	1	2
ξ^1 Ceti	81. 42	+0 ·44	1	2	σ Aquarii	101. 17	+0 ·48	1	2
δ Piscium	83. 3	+1 ·82	1	2					
Lalande 34486	83. 25	+2 ·22	1	2	τ Ceti	106. 34	+1 ·08	1	2
ω Piscium	83. 47	+0 ·30	1	2	2 Ceti	108. 0	+0 ·92	1	2
β Aquilæ	83. 53	+2 ·33	2	3	Piazzi XX. 310	108. 28	+1 ·48	1	2
					β Ceti	108. 38	+0 ·54	1	2
ι Piscium	85. 1	+0 ·70	1	2	Bradley 2402	109. 28	+2 ·47	2	3

The weights used have been determined as follows:—Putting m and n for the number of Reflexion and Direct observations respectively, e for the probable error of one observation, and e_0 for the probable systematic error affecting all observations of the same star, the weight to be given to that star is proportional to $\frac{4\,m\,n}{m\,e^2 + n\,e^2 + 2\,m\,n\,e^2_0}$, or assuming $e^2_0 = \frac{1}{10}\,e^2$, which would make $e_0 = 0''\!\cdot\!16$, the weight becomes $\frac{4\,m\,n}{m + n + \frac{1}{5}\,m\,n}$, which has been adopted for use.

p 2

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

Extent of Group, 1882.	Weight.	Mean N. P. D.	Mean Value of R−D, corrected for Inclination of Verticals.
		° ′	″
β Ursæ Majoris S.P. to b Ursæ Majoris S.P.	20	− 29. 27	− 1·49
Groombridge 1853 S.P. to Lalande 10769 S.P.	28	− 23. 50	− 1·36
A Draconis S.P. to Piazzi IV. 191 S.P.	27	− 18. 21	− 1·28
Bradley 1147 S.P. to Groombridge 1845 S.P.	25	− 11. 35	− 0·61
Cephei 51 S.P. to δ Ursæ Minoris	42	+ 0. 21	+ 0·01
Groombridge 774 to γ Cephei	47	+ 9. 45	− 0·27
19 Ursæ Minoris to φ Draconis	37	+ 16. 43	− 0·57
λ Draconis to Bradley 332	53	+ 21. 43	+ 0·11
Bradley 1429 to 28 Ursæ Majoris	48	+ 24. 45	+ 0·35
τ Ursæ Majoris to 41 Camelopardi	49	+ 27. 12	+ 0·11
η Draconis to 31 Camelopardi	27	+ 29. 5	+ 0·02
m Persei to α Lyræ	24	+ 50. 0	+ 0·54
72 Cygni to W.B. (2) I. 774	28	+ 53. 41	+ 0·18
8 Cygni to 41 Cygni	52	+ 58. 0	+ 0·18
υ Coronæ to α Coronæ	32	+ 61. 49	+ 0·70
μ Leonis to λ Leonis	39	+ 65. 18	+ 0·15
17 Vulpeculæ to 51 Pegasi	57	+ 68. 4	+ 0·41
Arcturus to 68 Geminorum	58	+ 72. 15	+ 0·28
β Serpentis to f Tauri	55	+ 75. 39	+ 0·49
1 Canis Minoris to β Aquilæ	27	+ 81. 0	+ 1·03
ι Piscium to γ Piscium	16	+ 86. 3	+ 0·94
κ Piscium to 20 Ceti	15	+ 90. 32	+ 1·28
λ Aquilæ to θ Aquarii	25	+ 97. 11	+ 1·18
2 Aquilæ to 6 Aquarii	16	+ 99. 44	+ 1·62
τ Ceti to Bradley 2402	11	+108. 20	+ 1·55

In forming the mean values of R − D for groups in the last column of the above table, a correction of + 0″·16 sin Z. D. has been applied to the mean of each group for inclination of the vertical at the surface of the mercury in reflexion observations to that at the centre of the transit-circle, the mercury trough being mounted so as to describe a circle of 8 feet radius.

Assuming that the R − D correction can be represented by—

$$x + y \sin \text{Z.D. south},$$

it is found by calculation that the following expressions, when tabulated, will give the values which best agree with the errors in the table above, namely:—

For direct observations

$$+ 0''\cdot052 + 0''\cdot436 \sin \text{Z.D.}$$

For reflexion-observations

$$- 0''\cdot052 - 0''\cdot436 \sin \text{Z.D.} + 0''\cdot16 \sin \text{Z.D.}$$

or

$$- 0''\cdot052 - 0''\cdot276 \sin \text{Z.D.}$$

For use, these formulæ have been tabulated as follows; and the corrections have been applied to the mean result for N.P.D. of each star, and to every N.P.D. of Sun, Moon, and Planets in the section of Planetary Results, throughout the year.

CORRECTION FOR DISCORDANCE OF REFLEXION AND DIRECT RESULTS, 1882.

N. P. D.	Corrections to Results of Direct-Observations.	Corrections to Results of Reflexion-Observations.
°	"	"
− 45	− 0·38	+ 0·22
40	0·37	0·22
30	0·35	0·21
20	0·32	0·18
− 10	0·28	0·16
0	0·22	0·12
+ 10	0·16	0·08
20	0·09	+ 0·04
30	− 0·01	− 0·01
40	+ 0·06	0·06
50	0·14	0·11
60	0·21	0·15
70	0·28	0·20
80	0·34	0·24
90	0·39	0·27
100	0·44	0·30
110	0·47	0·31
120	0·48	0·33
+ 125	+ 0·49	− 0·33

The law assumed for these numbers is the same as that used in the years preceding 1862.

CORRECTION TO ASSUMED COLATITUDE, 38°. 31′. 21″·90.

FROM OBSERVATIONS IN THE YEAR 1882.

(Using Bessel's Refractions, as given in the *Tabulæ Regiomontanæ.*)

Star's Name.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations. Above Pole.	Below Pole.	Weight.	Star's Name.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations. Above Pole.	Below Pole.	Weight.
	° ′	″					° ′	″			
Groombridge 1119	1. 1	−1·89	1	1	1	Bradley 3166	22. 51	+0·14	6	2	3
λ Ursæ Minoris	1. 3	−0·44	29	21	12	Groombridge 1299	23. 26	+0·93	1	2	2
Polaris	1. 19	−0·18	80	81	16	Bradley 1429	23. 50	−0·55	2	2	2
α¹ Ursæ Minoris	1. 19	+1·37	2	1	2	Groombridge 3760	23. 53	−2·92	1	1	1
Cephei 51	2. 46	−0·53	34	45	14	Radcliffe 5671	23. 53	−1·54	1	1	1
δ Ursæ Minoris	3. 23	+0·02	40	19	12	8 Draconis	23. 55	+0·91	2	3	3
Bradley 1730	5. 56	+0·25	1	3	2	Piazzi VII. 282	24. 0	−0·06	2	2	2
Bradley 1731	5. 57	+0·09	1	3	2	55 Cassiopeiæ	24. 2	−0·66	2	2	2
Bradley 74	6. 56	+0·46	2	2	3	Groombridge 192	24. 17	−0·77	2	2	2
Groombridge 774	6. 57	+1·54	2	1	2	Groombridge 120	24. 30	−0·16	2	1	1
Bradley 3038	7. 28	−0·12	1	3	2	Lalande 2651–2	24. 30	+2·02	1	1	1
Bradley 48	8. 9	−0·59	2	1	2	Piazzi XIII. 184	24. 35	−0·76	3	1	1
Piazzi VI. 285	8. 32	−0·11	1	1	1	6 Ursæ Majoris	24. 57	+2·11	1	1	1
Piazzi VI. 334	8. 52	0·00	2	2	3	α Draconis	25. 4	−0·53	12	3	4
Bradley 1458	8. 57	+0·88	3	2	3	Groombridge 3588	25. 23	−1·81	1	1	1
Groombridge 856	9. 0	+0·50	1	1	1	Bradley 270	25. 28	−0·12	2	1	1
Bradley 344	9. 3	−0·27	2	2	3	Piazzi IX. 51	25. 33	+0·34	6	1	1
Piazzi III. 160	9. 38	+0·89	3	1	2	Groombridge 1888	25. 33	+0·44	2	1	1
Groombridge 2900	10. 38	−0·02	2	3	3	53 Cassiopeiæ	26. 11	−0·86	2	1	1
Piazzi IV. 269	10. 55	+0·33	2	5	4	Arg.Zone+63°.1618	26. 24	+1·51	1	1	1
Cephei 47	11. 3	+0·09	1	1	1	Groombridge 1853	26. 24	−0·88	2	2	2
Bradley 1508	11. 36	−0·73	4	2	3	*h* Ursæ Majoris	26. 25	+0·70	4	2	2
Bradley 1633	11. 54	−0·18	2	1	2	Piazzi I. 159	26. 44	−0·28	2	1	1
Groombridge 1151	11. 55	+0·45	2	2	2	ε Cassiopeiæ	26. 55	−0·21	2	3	2
κ¹ Cephei	12. 39	+0·17	2	2	2	Piazzi XXII. 42	27. 18	−0·52	1	2	1
19 Ursæ Minoris	13. 50	−1·09	3	2	3	Piazzi XII. 278	27. 20	−0·26	1	2	1
3 Ursæ Minoris	14. 51	−0·61	5	2	3	*b* Ursæ Majoris	27. 36	−1·20	2	3	2
π Cephei	15. 15	+2·44	2	2	2	α Ursæ Majoris	27. 37	+0·04	12	1	1
Piazzi IV. 191	15. 55	−0·24	2	4	4	25 Cephei	27. 47	+1·31	2	1	1
Radcliffe 1742	16. 13	+1·70	1	2	2	Groombridge 1838	27. 48	+0·51	2	2	2
Groombridge 4163	16. 15	−0·94	1	3	2	Groombridge 2055	27. 55	+0·49	2	2	2
Piazzi XIII. 109	17. 0	+0·05	2	4	3	α Cephei	27. 55	−0·70	4	2	2
50 Cassiopeiæ	18. 9	+0·57	5	1	2	Groombridge 1826	27. 56	−0·47	2	6	4
ψ Draconis	18. 44	+0·16	2	1	1	41 Camelopardi	27. 59	+0·60	4	2	2
11 Cephei	19. 14	+0·58	1	2	2	*c* Ursæ Majoris	28. 6	−0·44	2	1	1
Oeltz.Arg.(N.)4050(2dStar)	19. 30	−0·91	3	2	3	η Draconis	28. 13	−2·40	2	1	1
β² Cephei	19. 57	−1·49	1	1	1	8 Lyncis	28. 25	−0·62	3	6	4
λ Draconis	20. 1	−0·01	11	7	7	10 Lyncis	28. 26	−0·42	2	7	4
4 Draconis	20. 9	−0·14	2	1	1	Groombridge 225	29. 3	−1·40	1	1	1
Bradley 3125	20. 17	+0·33	2	3	3	Groombridge 2642	29. 24	−1·12	1	1	1
Groombridge 3590	20. 24	+0·31	1	1	1	Bradley 3195	29. 26	−0·73	2	1	1
Groombridge 628	20. 42	+0·76	2	2	2	Bradley 90	29. 31	−0·16	2	1	1
Lalande 10769	21. 34	+3·21	1	2	2	γ Cassiopeiæ	29. 55	−1·26	1	1	1
f Draconis	21. 47	+0·31	2	1	1	40 Camelopardi	29. 58	−0·52	1	2	1
Groombridge 2214	22. 12	+0·01	3	1	1	Piazzi VI. 293	30. 2	−2·29	3	1	1
o Cephei	22. 32	+1·07	3	1	1	12 Lyncis (1st Star)	30. 26	−0·13	1	1	1
3 Draconis	22. 36	−0·31	10	2	3	12 Lyncis (2nd Star)	30. 26	+0·17	1	1	1
9 Draconis	22. 46	+1·19	3	4	4	*b* Draconis	31. 16	−1·32	1	1	1

CORRECTION TO ASSUMED COLATITUDE—*continued.*

Star's Name.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations. Above Pole.	Below Pole.	Weight.	Star's Name.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations. Above Pole.	Below Pole.	Weight.
	° ′	″					° ′	″			
6 Lyncis	31. 45	−2·72	1	1	1	π^2 Cygni	41. 14	−3·41	2	1	
δ Ursæ Majoris	32. 19	−0·58	1	3	2	μ Persei	41. 54	−2·46	1	3	
ζ Cephei	32. 23	−0·08	1	1	1	λ Boötis	43. 22	−1·84	3	1	
η Cassiop. (1st Star)	32. 49	+0·49	2	1	1	Capella	44. 7	−1·74	1	1	
α Cassiopeiæ	34. 7	−1·11	1	2	1	λ Andromedæ	44. 11	+2·12	7	1	
γ Ursæ Majoris	35. 39	−0·12	2	1	1	λ Ursæ Majoris	46. 30	−2·22	3	2	
λ Cassiopeiæ	36. 8	+0·34	1	2	1	μ Ursæ Majoris	47. 54	−5·50	1	1	
γ Draconis	38. 30	−2·01	3	3	2						

The weights used in the above table are determined by use of the "Probable Errors of Greenwich Observations in Zenith Distance," given by Mr. Stone in the *Monthly Notices of the Royal Astronomical Society* for 1869 June 11, page 324. Putting n for the number of observations of a star above the pole, e for the probable error of one observation; n_1 and e_1, the similar quantities for the observations below the pole; e_0 the probable systematic error affecting all observations of the same star, and depending on outstanding division error, uncertainty in the constant of refraction, &c.; the formula employed to determine the weight to be given to that star is $\frac{n\,n_1}{n_1\,e^2 + n\,e_1^2 + 2\,n\,n_1\,e_0^2}$; or, assuming $e_0^2 = \frac{1}{10}\,e^2$, which would make $e_0 = 0''\cdot16$, the weight becomes $\frac{n\,n_1}{n_1\,e^2 + n\,e_1^2 + \frac{1}{5}\,n\,n_1\,e^2}$, which has been adopted for use in the investigation.

The observations of the last seven stars have not been used for the correction of the assumed colatitude.

If z be the correction to the assumed colatitude 38°. 31′. 21″·90, 2 z + the algebraic sum of determinations ought to be equal to 0. Combining the whole with the weights above attached to them, $2\,z - 0''\cdot099 = 0$, or $z = +\,0''\cdot050$. The colatitude determined from the observations of 1882 is therefore 38°. 31′. 21″·95.