

GREENWICH

ASTRONOMICAL OBSERVATIONS,

1896.

INTRODUCTION.

I. Personal Establishment and Arrangements.

At the commencement of the year 1896 the establishment of Assistants in the Astronomical Department of the Observatory consisted of the following persons :—

Chief Assistant,—Frank Watson Dyson, M.A., Fellow of Trinity College, Cambridge.

First Class Assistants,—George Stickland Criswick ; Edward Walter Maunder ; Thomas Lewis ; William Grasett Thackeray.

Second Class Assistants,—Henry Park Hollis, B.A. ; Andrew Claude de la Cherois Crommelin, B.A. ; Walter William Bryant, B.A.

Clerical Assistant,—Henry Outhwaite.

Mr. Philip Herbert Cowell, M.A., Fellow of Trinity College, Cambridge, was appointed additional Chief Assistant on April 20.

Mr. Criswick retired on January 30, and Mr. Hollis was promoted to fill the vacancy thus occasioned in the staff of First Class Assistants.

Mr. Charles Davidson, Mr. Robert Fermor Rendell, B.A., and Mr. William Bowyer were appointed established Computers on May 27.

In addition to the established Assistants and Computers nineteen Computers were employed in the Astronomical Department.

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

The Chief Assistants, in the absence of the Astronomer Royal, are empowered to act in all respects as his representatives, and to conduct confidential as well as routine

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business. In the ordinary transactions, the Chief Assistants superintend the calculations generally; and observe occasionally with any of the instruments. The Chief Assistants are always charged with the duty of examining the 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.

In the year 1896 Mr. Thackeray was charged with the meridian zenith distance reductions, the deduction of the results of the meridian observations, and with the general superintendence of the Computers of the Astronomical Reductions Branch, by whom the great mass of calculations and of reading proof-sheets is effected. Mr. Bryant was entrusted with the transit reductions.

Mr. Crommelin had charge of the altazimuth and of the Sheepshanks equatorial, and of the reduction of the observations made with them.

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, were confided to Mr. Lewis. Mr. Lewis also had charge of the 28-inch equatorial.

Mr. Criswick superintended the astrographic observations and reductions. On the retirement of Mr. Criswick, Mr. Hollis, who till then had assisted in the measurement of the photographs and the computations connected with them, was given the superintendence of this department.

The measurement of the solar photographs and the superintendence of the reductions connected with them were entrusted to Mr. Maunder.

Mr. Outhwaite had charge of the money-accounts, the stores and stationery, and distribution of the publications of the Observatory; and undertook part of the miscellaneous correspondence. The care of the library was also entrusted to him.

The course of observations and the succession of observers are arranged every Monday by one of the Chief Assistants 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 19^h mean solar time (7 o'clock

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in the morning) to the next 14^h. During the latter part of the lunation, when the Moon passes the meridian in the early morning between 14^h and 19^h, it is found necessary to appoint separate observers for the morning and the evening.

The observations with the transit-circle in 1896 were generally made by Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Bowyer, Mr. Davidson and Mr. Rendell. When the Moon passes the meridian in the early morning, or in the absence of the regular observers, one of the supernumerary Computers is charged with the observations.

Observations of the Moon with the altazimuth during the first and last quarters of the lunation were made by Mr. Hollis, Mr. Crommelin and Mr. Bryant.

Observations of Occultations and Phenomena of Jupiter's Satellites were generally made by the observer on duty with the transit-circle.

Observations of Comets, &c. with the Sheepshanks equatorial were assigned to the regular observers during the second and third quarters of the Moon. During the first and last quarters these observations were made by the observer on duty with the transit-circle or altazimuth.

Photographs with the astrographic equatorial were generally taken by Mr. Criswick, Mr. Hollis, Mr. Bowyer, Mr. Davidson and Mr. Rendell, or one of the supernumerary Computers.

Observations with the 28-inch refractor were made by Mr. Lewis and Mr. Bowyer.

Photographs of the Sun with the Dallmeyer photoheliograph were taken by Mr. Maunder or by one of the Computers under his direction.

The following are the signatures of those persons who have made observations in 1896 :—

W. H. M. Christie	WC	W. W. Bryant	- B	R. F. Rendell	- R
F. W. Dyson	- D	H. H. Furner	- HF	E. H. Banks	- EB
P. H. Cowell	- C	H. Appleyard	- HA	F. Turner	- FT
G. S. Criswick	- C	C. Davidson	- CD	P. G. Showell	- S
E. W. Maunder	- M	R. Cheeseman	- RC	A. J. Wilkin	- AW
T. Lewis	- L	D. Edney	- DE	W. M. Witchell	- W
W. G. Thackeray	- T	C. Lacey	- CL	W. Stevens	- WS
H. P. Hollis	- H	W. Bowyer	- WB	J. A. West	- JW
A. C. D. Crommelin	AC	G. F. Johns	- J		

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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 Equatorial ; the Zenith sector of Bradley and Maskelyne ; and the two Mural quadrants, which till 1887 November 17 were both mounted on their pier, the quadrant on the western side of the pier being included in the smaller fire-proof room of the Observatory. On 1887 November 18, in the course of operations for the extension of the computing rooms, the quadrant on the western side of the pier was removed to the Transit-circle room, that on the eastern side being now included (without having been disturbed) in the Lower Computing room ; and an extension of the pier was built to carry an equatorial. 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 focal length of its object glass is 11 feet 7 inches, and the clear aperture 8.1 inches. It was repolished by Messrs. Troughton and Simms in 1891 August and September. The full aperture is used in all observations, including those of the Sun. The power of the eye-piece ordinarily employed is 195, and of that used for observations of the Sun 180. 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, forming the Y. The Y's are firmly screwed down to the massive piers between which the instrument is mounted and have only been disturbed for adjustment, cleaning, &c., on the following occasions—1870 November 19, 1877 December 4, 1881 July 27–29, 1888 January.

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

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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.	Horizon- tal Error, Microme- ter Head to Right.	Vertical Error, Microme- ter Head Above.	N. P. D. Pointer Reading.	Horizon- tal Error, Microme- ter Head to Right.	Vertical Error, Microme- ter Head Above.	N. P. D. Pointer Reading.	Horizon- tal Error, Microme- ter Head to Right.	Vertical Error, Microme- ter Head Above.	N. P. D. Pointer Reading.	Horizon- tal Error, Microme- ter Head to Right.	Vertical Error, Microme- ter Head Above.
0	1	"	0	1	"	0	1	"	0	1	"
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. In 1891 October the galvanic wire system was rearranged : there are now ten wires so placed that the mean of the ten coincides nearly with the middle wire, which is also the middle wire of the eye-and-ear system. The intervals between the wires are given at the end of this Introduction.

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. In 1891 October a new screw was fitted to the micrometer by Messrs. Troughton and Simms, one revolution of which is nearly

equal to the distance between two close wires, viz. 37". The field of view is illuminated by the light from a central electric lamp of about 5 candle-power (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. The electric light was introduced on 1895 May 31, replacing a gas lamp.

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 24° , 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 two piers having been cut down, the collimators are mounted on upright cast-iron arms which turn about centres below, thus allowing them to be swung on one side when not in use. An alteration was also made in the mounting of the mercury

trough, by which it is raised about a foot. It is thus found practicable to observe stars by reflexion (with the full aperture of the object glass) from Z.D. 20° to Z.D. $67\frac{1}{4}^{\circ}$, an increase of range of nearly 30° on each side of the zenith. 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 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 $5\frac{1}{2}^{\circ}$ 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 R.A. 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.

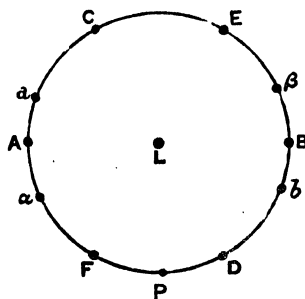
Since 1884 June a reversion-prism made by Messrs. Troughton and Simms has been used in observations with the collimators as well as with the transit-circle to reverse the apparent direction of measurement or of motion, a movement towards the left (as in transits of south stars) being converted into a movement towards the right, or downwards or upwards, according to the position of the plane of reflexion of the reversion-prism.

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 (at first of iron, but on 1889 September 26 furnished with a bottom of amalgamated copper, with very beneficial results as regards steadiness of the images; and on 1890 June 5 replaced by an amalgamated copper trough) 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 base 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 electric 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, the stone pier, the brass plate,

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the micrometers, and the eye-pieces. The number of microscopes is eleven ; they are arranged in the following order :—



L is the electric light for illumination. 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, or occasionally in observations of zenith distance during repair of the six ordinary microscopes.

The errors of division of the circle were investigated in 1851 and 1852 and again in 1856, and the means of the results, which have been adopted for use are given in the Transit-Circle Tables at the end of this Introduction. A re-determination of these errors agreeing sensibly with those in the table, was made in 1871, the divisions 30° , 90° , 150° , &c. being taken as the primary divisions instead of 0° , 60° , 120° , &c. as in the previous investigations.

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. At the end of 1885 new screws made of steel instead of gun-metal were applied by Mr. Simms to the six ordinary micrometers A, B, C, D, E, F ; and were brought into use on 1886 January 1. Observations for determining the errors of these screws are given in the Transit-Circle Tables at the end of the Introduction for 1886. (p. cxxxv.) Similar observations were made in 1893 and are given in the Transit-Circle Tables in the volume for 1894. The errors of the screws were again determined in 1896 November. The observations are given in the Transit-Circle

Tables at the end of this Introduction, and show that the wear of the screws is small and its effect almost entirely eliminated by the reversal of three of the screws.

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 eyepiece 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 $20^{\text{rev.}}$ corresponds nearly to the centre of the field of view. A new screw was applied to the micrometer by Messrs. Troughton and Simms in 1891 October, of the same pitch as that of the right ascension micrometer.

Observations for the determination of the value of $1^{\text{rev.}}$ of the telescope-micrometer screw are given at the end of the Introduction of the 1891 volume. Observations made at the same time showed the screw to be sensibly uniform. A determination made from 1896 December to 1897 March showed that the screw had worn considerably. The errors of the screw and the observations for determining them are given in the Transit-Circle Tables at the end of this Introduction.

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, $0^{\circ}050$ 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 contact 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 at the passage of the first and second vertical wires (if the star has large polar-distance), or of two or three of the galvanic wires (if the star is circum-polar), 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 noted), 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 contact, it is found perfectly easy to take those of the first and second limb over all the 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 over 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.

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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 Personal Equation Machine, constructed by Messrs. Troughton and Simms, and mounted in the Front Court on a brick pier, directly in view of the transit-circle telescope when horizontal and pointing north. This instrument has been devised in order to determine absolute personal equations in the observation of slow moving as well as of quick moving stars of various magnitudes (whether the motion be from right to left or the reverse) and of limbs of the Sun, Moon, or planets. Its construction is as follows:—A vertical plate with a circular aperture 6 inches in diameter (to represent the Sun or Moon) and carrying several small pin-holes (to represent stars of different magnitudes) is carried smoothly by clock-work from east to west, or west to east, at a rate which may be varied at will from that of a very close circumpolar star to three or four times that of an equatorial star. The contrivance for variation of rate, devised by Mr. James Simms, is as follows:—A horizontal circular brass plate is made to rotate with uniform velocity about its centre by a driving clock (belonging to one of the photoheliographs), and drives by rolling friction a brass disk turning about a horizontal axis, and placed with its rim in contact with the surface of the plate. This disk can be slipped along its spindle and clamped at any point, so that the point of contact of the wheel and plate can be adjusted at will to any distance from the centre of the latter, the angular velocity of the wheel varying directly as this distance, and changing sign at the centre. At the further end of the spindle is a screw, which communicates the motion to the vertical plate by means of a pulley wheel and cord. The vertical plate is placed in the focus of an object-glass of $7\frac{1}{2}$ inches aperture and about 51 feet focal length, which is attached to the dew cap of the transit-circle when horizontal and pointing north; and the apertures in the plate are illuminated by direct sunlight or moonlight reflected by a plane mirror in the direction of the object-glass, so that the transits of the artificial Sun or Moon and stars can be observed with the transit-circle under practically the same conditions as the real objects. At the same time the transits are registered automatically on a small chronograph by means of the contacts between two sets of platinum studs, one set corresponding to the artificial objects and carried with the plate, the other set fixed and corresponding to the wires of the transit-circle. The adjustment is secured by observations before and after the transits, in which the stud corresponding to the star or limb under observation is brought carefully into contact with those corresponding to each of the wires in succession, and the reading of the R.A. micrometer noted for bisection of the star with that wire. For observations of transits, the micrometer is then set to the mean of these readings.

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 (47 feet west and 29 feet south of the transit-circle), which is raised to such a height that the instrument commands the horizon in all directions above the buildings of the Observatory, except the Sheepshanks dome, the Great Equatorial dome, and the Octagon room.

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.

On 1883, January 11, a new system of nine horizontal and nine vertical wires was inserted. The seven interior wires of each set are placed at equal intervals for use in chronographic transits ; the exterior wires together with the first and last of the interior wires and the middle wires, form a system of five horizontal and five vertical wires at equal intervals, suitable for eye-and-ear observations ; and the middle wires, which are thicker than the others, are available for observations of comets. On 1894 November 19 the wires were found broken, and a new set similar to the former was inserted by Messrs. Troughton and Simms on the following day.

From 1888 November the observations of distant church spires have been used in combination with those of stars for determining the zero of azimuth. The first (Mark I.) is the spire of St. John's Church, Lewisham High Road, distant 6,600 feet from the altazimuth ; the second (Mark II.) is that of the Roman Catholic Church, Croom's Hill, distant 1,060 feet, for the observation of which a long-focus lens was mounted by Messrs. Troughton & Simms on 1889 May 24.

In 1894 June the upper pivot and bearing of the vertical axis were found worn and rusty. The pivot was re-ground and new bearings made by Messrs. Troughton and Simms.

In 1873 May 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 Read- ing.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Below.	Pointer Read- ing.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Below.	Pointer Read- ing.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Below.	Pointer Read- ing.	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 Read- ing.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.	Pointer Read- ing.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.	Pointer Read- ing.	Horizontal Error, Micrometer Head to Right.	Vertical Error, Micrometer Head Above.	Pointer Read- ing.	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 Reflex Zenith-Tube, constructed under the direction of Sir G. B. Airy by the late Mr. William Simms.—A detailed description of this instrument is given in

Appendix I. to the volume for 1854 ; in this place the following account will suffice. The object-glass (aperture 5 inches, focal length about 9 feet 8 inches) 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 eye-piece is a four-glass diagonal eye-piece 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, which till the end of 1888 was protected from tremors, with only moderate success, by an arrangement of caoutchouc supports, described in previous Introductions to 1880. From 1889 Feb. 13, an amalgamated copper trough has been used, with the result that the steadiness of the images has greatly improved. A prismatic focussing rod with scale reading to 1-200th of an inch and ivory point for contact with the surface of the mercury has been applied to the instrument in place of the former light brass rod and wooden float ; the focussing rod and the micrometer frame are both of gun metal. The image of the star, as it passes near to the zenith, is formed in the plane of the micrometer wires. 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.

The Shuckburgh Equatorial.—This instrument was constructed by Ramsden, and is one of that class usually called the "English equatorial." 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.

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The Sheepshanks Equatorial.—This instrument was erected in the year 1838. The aperture of the object-glass is about 6·7 inches, and its focal length about 8 feet 2 inches. The object-glass was made by M. Cauchoix, of Paris, and was presented to the Observatory by the Rev. R. Sheepshanks. Its definition is good: a small quantity of colour from the secondary spectrum, and a diffusion of light from brilliant objects, being the principal defects.

It is mounted in a 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 equatorial," and was constructed by the late Mr. T. Grubb, of Dublin. Besides several negative eye-pieces unfurnished with wires, this telescope has a wire micrometer, and a comet eye-piece with thick wires and position circle, which was supplied on 1890 November 10. On 1892 November 18 a new set of wires was mounted in this eye-piece as the wires were found to be bent.

The Great Equatorial.—This instrument now carries an object-glass of 28 inches aperture and 28 feet focal length on the mounting which was originally designed for the Merz object-glass of 12·8 inches aperture and 17 ft. 10 in. focal length. This mounting was constructed by Messrs. Ransomes and Sims (as engineers), and the late Mr. William Simms (as instrument maker), and a complete description of it, with engravings, is attached as Appendix to the volume for 1868. The form of the instrument is the "English equatorial," the polar-axis turning on pivots at its extreme ends, and including between its two sides the telescope and declination-circle, which are mounted on a declination-axis with pivots at its opposite extremities. The object-glass of 28 inches clear aperture and 27 ft. 10 in. focal length was made by Sir Howard Grubb from discs supplied by Messrs. Chance, of Birmingham. It is of special form, adapted to photography as well as to eye-observation, on the plan proposed by Sir George Stokes (in a letter to me dated 1886 August 16) of reversing the crown lens to correct for the spherical aberration introduced by the further separation of the lenses necessary for photographic correction. Mechanical means are provided for readily effecting this reversal and separation without risk. It is found by trial that the further separation required for photographic correction is about 3·5 inches, and that the focus is thereby shortened by about 23 inches. When the crown lens is in the position for visual observation, the radii of curvature of the surfaces are:—

1st surface—146 in. convex	} Crown.	3rd surface— 138 in. concave	} Flint.
2nd „ 134 in. „		4th „ 1000 in. convex	

and the edges of the lenses are separated by 0·4 inch, the minimum focal length being for rays about midway between D and E.

The telescope tube, made of steel and cast-iron by Sir Howard Grubb, is specially

adapted to the conditions, being provided with a sliding eye-end arranged for either direct or diagonal view, and permitting of observations near the zenith and the pole, when the eye-end is shortened sufficiently by the sliding motion to clear the floor and the inside of the polar frame. The Corbett telescope, of $6\frac{1}{2}$ inches aperture and 8 feet focal length, is mounted on the tube as a finder or guiding telescope. The position and transit micrometers and various eye-pieces supplied for the 12·8-inch Merz refractor, have been adapted to the new 28-inch telescope, and have been fitted with electric illumination of the field and wires.

The Dome was constructed by Messrs. T. Cooke and Sons and erected in 1893 April, replacing a cylindrical wooden dome. It is of a form specially adapted to accommodate the new 28-inch refractor whose diameter is greater than that of the tower on which it is carried. A description with diagrams is given in the *Monthly Notices*, R.A.S., vol. li., p. 436. The diameter of the dome is 36 feet at a height of 7 feet above the rail, contracting to 31 feet at the base; and the shutter-opening is 7 feet wide throughout on both sides of the zenith down to the horizon. The framework is of T-iron vertical and horizontal ribs bolted to a circular girder forming the base, the opening being framed with curved vertical girders, and the whole is covered with papier-mâché. The shutter is in two parts, with a division right down the middle, each half being a balanced shutter 3 ft. 6 in. wide, extending right over the dome from the curb, through the zenith, to the opposite part of the curb, and carried by a wheel running on a rail at the zenith. The dome rotates on a system of vertical rollers running freely on the planed surface of the wall-curb, as in the Lassell Dome.

The Spectroscope, carried by the Great Equatorial.—The direct-vision “half-prism” spectroscope, constructed by Mr. Hilger, has been used from 1877 July to 1891 November in connection with the 12·8-inch Merz refractor mounted on the Great Equatorial. 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 $18\frac{1}{2}^\circ$ from A to H, equivalent to that given by four flint prisms of 60° , is obtained, with two “half-prisms” a dispersion of about 80° from A to H, equivalent to that given by sixteen flint prisms of 60° , with three “half-prisms” a dispersion of about 300° , equivalent

*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.

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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 is used.

The spectroscope was mounted on the 28-inch refractor in 1894 June. It is planted with its axis parallel to the tube and below it (in the position for objects south of the zenith), the rays being thrown into the collimator by two reflections, first from the mirror for diagonal view in the telescope tube, placed about 26 inches within the focus, and then from a small rectangular prism close to the slit and 24 inches from the axis of the refractor, mounted in an adapter carried by the sliding eye-end. The spectroscope is firmly attached to the telescope tube by strong castings with suitable collars, having sliding adjustment for focus and allowing of rotation of the spectroscope for orientation of the slit parallel or perpendicular to the equator. By this arrangement the spectroscope is permanently mounted on the refractor, the mirror in the tube being inserted for spectroscopic observations and withdrawn for eye-observations.

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.

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.

The Double-Image Micrometer.—The general form of the Airy double-image eye-piece, together with the mode of use, and the advantages and disadvantages attending the use of it, are described fully by Sir G. B. Airy in the volumes for 1840 and for 1843 to 1849. It is a four-glass erecting eye-piece, 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 eye-piece 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 Great or the Sheepshanks Equatorial.

The Lassell Reflector, equatorially mounted, in a new dome in the South ground. This instrument was constructed by the late Mr. William Lassell, F.R.S., and, some years after his death, was presented by his daughters, the Misses Jane, Caroline, and Charlotte Lassell, to this Observatory in 1883 February. A description of the instrument is given in the *Memoirs of the Royal Astronomical Society*, vol. xviii., p. 15, &c. (Description of a machine for polishing Specula, &c.). It may be sufficient here to state that the metal speculum is 24 inches in diameter and of 20 feet focal length, and that the telescope is mounted equatorially on the plan devised by Mr. Lassell, the tube swinging between two "uprights," each 7 feet long, bolted to the large inverted cone which forms the polar axis. There are two large mirrors available for use. Various alterations have been made in the instrument since it was mounted here, amongst which the following may be specified:—An improved slow motion in R.A., which can be worked by means of a cord from the observing stage, without putting the clock out of gear, and a new slide for gearing the driving screw into the hour-circle; a firm declination clamp which can also be worked from the observing stage; an improved edge-suspension for the large mirror (consisting of a steel band which encircles the mirror and is suspended freely from brackets at six equidistant points of the circumference); a new and firmer mounting for the small mirror, and later a new small mirror (silver on glass) made by Mr. Calver; a stronger mounting for the eye-piece, which allows of its being tilted in any direction, for optical adjustment. The framed iron base which supports the instrument has been bricked up and filled with concrete, and this with other alterations has greatly increased the stability of the telescope. The teeth of the hour-circle have been re-cut and a number of minor repairs have been required.

In 1887 January some further additions were made to this instrument, a delicate slow motion in R.A. (with differential wheels) and a firm N.P.D. clamping arm with fine motion in N.P.D. being applied. The reflecting telescope was dismantled in 1891 November.

The Merz Refractor.—The clear aperture of the object-glass of this telescope is 12·8 inches and its focal length about 17 feet 10 inches. It is furnished with a position micrometer, and with an eye-piece with fixed wires for observations of comets, &c. This telescope was mounted on the Lassell Equatorial from 1891 November to 1895 July, and was in use for observations of double stars (*see* the volume for 1893),

till the erection of the 28-inch refractor, and for occasional observations of occultations, &c., since that date. It was dismantled in 1895 July for the lenses to be repolished, preparatory to its use as a guiding telescope to the new Thompson (26-inch) Photographic Refractor.

The Dome was constructed by Messrs. T. Cooke and Sons, of York, and was completed in March 1884. It is hemispherical, of 30 feet diameter, and is covered with papier-mâché, on a framework of angle-iron. It is carried by nine wheels or rollers (each 2 feet in diameter) fixed to the iron-curb of the Dome and running on a flat rail, horizontal rollers being provided to prevent excessive lateral motion from the force of the wind or other cause. The Dome can be turned with great ease either from the floor, or by means of an endless rope from the observing stage, which is attached to the Dome on the following side of the opening, and is carried with it in its motion. The shutter opening extends from beyond the zenith to the horizon, and is closed by a single curved shutter (3 feet 6 inches wide at the zenith and 6 feet wide at the horizon), which turns about a point in the dome-curb opposite to the opening, and runs on guiding rails at the horizon and near the zenith, the curved shutter being continued by an open framework to complete the semi-circle. The Dome was taken down in 1895 July and August, and was re-erected on the central portion of the new Physical Observatory in 1896 September.

The Astrographic Telescope, with 10-inch guiding telescope, mounted in a dome over the upper computing room. This instrument was constructed by Sir Howard Grubb, F.R.S., on the lines laid down by the *Congrès Astrophotographique International pour le levé de la Carte du Ciel* in 1887. The 13-inch photographic telescope and a 10-inch visual telescope are firmly connected, the tubes being of iron. The apertures of the object glasses are $0^m\cdot33$, or $13^{in}\cdot0$, and $10^{in}\cdot0$, and the focal lengths of both telescopes $3^m\cdot43$ or $135^{in}\cdot1$, so that $1^{mm}\cdot0$ on the plate corresponds to $1'\cdot0$. The photographic telescope is corrected, as regards spherical and chromatic aberration, for rays near Fraunhofer's line G. It is arranged to carry a plate 16^{cm} square, with special provision for exact focussing and orientation. The eye-piece of the 10-inch visual telescope is mounted on cross-slides (parallel and perpendicular respectively to the equator) which are furnished with scales reading to 1-12th of a millimetre or $5''$, and permit of the observation of a guiding star up to a distance of about $45'$ from the centre of the field. The mounting is of the German form, the details being such as to allow a range of $1\frac{1}{2}$ hours' motion on each side of the meridian without reversing the telescope. A large counterpoise is thus necessary, both because of the double weight, and of the distance from the polar axis of the two telescopes; but the movement in right ascension is very easy, owing to the arrangement adopted to relieve the friction of the polar axis. The greater part of both the transverse and end thrusts of the polar axis is received on a single anti-friction bearing, carried by a separate vertical column, disposed directly under the centre of gravity of the

instrument. The rollers of the bearing turn round horizontal axes, and a bevelled collar on the polar axis rests on them. The column transmits the weight to counterweight levers. The driving clock is placed inside the stand and is controlled electrically by a seconds pendulum. The detector of the control is similar in principle to that used in Dr. Gill's form ; and the system of correctors by differential wheels was devised by Sir Howard Grubb (*vide Proceedings, Institute of Mechanical Engineers*, 1888 July 31, page 311).

The Thompson Photographic Telescope by Sir H. Grubb is a refractor of 9 inches aperture and 8 feet 10 inches focal length, presented to the Observatory by Sir Henry Thompson. It is corrected for photographic rays and is provided with a prism of 9 inches diameter, by Mr. Hilger, which can be mounted in front of the object-glass for photographing spectra of stars. It was mounted below the Merz Refractor on the Lassell Equatorial and was in regular use as a photoheliograph till 1894 October 15, when the progress of building operations on the new Physical Observatory prevented its further use. A camera with a new doublet by Ross (mounted on 1892 December 13), and an exposing shutter specially designed to give very short exposures are attached to it. The image of the Sun in the primary focus is about one inch in diameter, and this is enlarged by the Ross doublet to nearly 8 inches on the photographic plate, the whole length of the instrument being about 12 feet 4 inches. The exposure is given (as in the Dallmeyer photoheliograph, *see below*) by a shutter at the primary focus, having a slit in it of adjustable width ; but whilst the shutter of the Dallmeyer photoheliograph travels in a groove, and is drawn downwards by the pull of a strong spring, in the Thompson photoheliograph the shutter, which is made of aluminium for the sake of lightness, turns about a pivot 18 inches from the exposing slit, under the action of a spring placed about midway between the pivot and the slit, and giving a very rapid motion to the latter.

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. From 1884 April 2 a new secondary magnifier has been used by which the image is enlarged to 8 inches diameter on the camera screen, the whole length of the instrument being increased to 9 feet 7 inches. The exposure is given by a shutter having a slit of adjustable 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 equatorially mounted and provided with a driving clock, 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.

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The Dallmeyer photoheliograph tube, which had been temporarily mounted on the tube of the new 28-inch telescope on 1893 October 12, was established on its equatorial mounting on the terrace roof of the South wing of the new Physical Observatory on 1894 April 24.

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 equatorial 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.

A portable transit-instrument with axis-view by Brauer of St. Petersburg and *a portable 18-inch altazimuth* by Troughton and Simms, obtained in the year 1866.

The following instruments, used in the Transit of Venus Expeditions, 1874 and 1882, are now transferred to the Observatory :—

Five 6-inch equatorials complete, viz. : the “Lee,” “Hodgson,” “Cooke,” “Simms No. 1” and “Simms 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 two 14-inch vertical circles or altitude instruments also by Troughton and Simms; and five photoheliographs by Dallmeyer. Several of these are, at the present time, lent to other Institutions. The Naylor 6-inch equatorial and a 14-inch altitude instrument, which had been employed at Bermuda for the observation of the Transit of Venus, 1882, were lost on the return voyage in the wreck of the “City of Brussels” at the entrance of the River Mersey. The “Cooke” equatorial used in the Transit of Venus Expedition, 1882, was transferred to the Observatory in 1884 to replace the Naylor equatorial.

One of the portable transit instruments is generally mounted in the *Transit Pavilion*, a brick building in the Front Court, the centre of which lies in Bradley's meridian. The roof of the building, which was completed in 1891 October, consists of a pair of semi-domes, which slide apart to leave an opening of uniform width (2 feet 6 inches) in the meridian. The pier for the transit is 19 feet west and 67 feet 10 inches north of the centre of the Transit Circle. The instrument is available for longitude operations without interrupting the work of the Transit Circle: or for practice observations by officers of the Royal Navy and others: or for time determinations on occasions when the Transit Circle is under repair, as in the period 1891 August 10 to October 3.

The Sidereal Standard Clock, constructed by Messrs. E. Dent and Co., is fixed to the north wall of the Magnet Basement, as in this apartment the temperature is kept

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 $0^{\text{s}}.3$ 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 and 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 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

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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. 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; another regulates the pendulum of a half-seconds clock placed on the foundation frame upon the south pier of the Great Equatorial, drives a tapper in that 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; and the third is at present out of use. 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 an automatic signal from the Sidereal Standard clock on an independent circuit, or from occasional comparisons with the clock Hardy, as explained on page xxxii.

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 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 the place of Hardy or of the Sidereal Standard clock; one in the Sheepshanks Dome, marked "Earnshaw," with a zinc and steel compensation pendulum; one in the Altazimuth Dome, marked "Graham 1," with a mercurial pendulum; one in the Astrographic Dome, marked "Dent 2017," with a zinc and steel pendulum; one marked "Dent 2009," with a wood rod pendulum in the Great Equatorial Dome; one marked "Mudge & Dutton," in the Reflex-Zenith-Tube room; and one marked "Graham 2," fitted with contact springs and with a zinc and steel pendulum, which is in the Transit Pavilion, and is available for use in Longitude determinations.

The Mean Solar Clock, "Dent 2012," is placed in the lobby at the foot of the Octagon-room staircase, near to the trigger of the ball-apparatus. This clock (which has been substituted for the electrical clock "Shepherd" formerly in use) has a zinc and steel pendulum, and is fitted with springs for sending out hourly signals to the Post Office and for working the Mean Solar dials distributed throughout the Observatory. On the Escape-wheel-arbor are two wheels, each containing 30 teeth, which close contact-springs alternately, one wheel at the even, the other at the odd seconds. The currents thus set up actuate a relay, by means of which various electro-magnetic clocks in different parts of the Observatory are driven synchronously with the Mean Solar clock. Arrangements are made so that in the case of failure of the clock "Dent 2012" the circuit can be readily shunted on to the electrical clock "Shepherd."

One of the synchronous 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. Until 1885 October 27 there was an automatic arrangement for reversing the direction of the current through this apparatus; but as this sometimes caused failure in the signal it was removed on that day, and the direction of the current is now reversed by hand from time to time. At every hour also the primary clock-current by relay-action causes galvanic currents to pass on a line of wire to the central station of the Post Office Telegraphs, St. Martin's-le-Grand,

London, where they are distributed daily, by automatic action of the "Chronopher," on some of the principal lines of railway and to important provincial towns. 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. 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. At Devonport and Portsmouth, local clocks, giving hourly time signals, are corrected daily by the help of the current at 10^h a.m. This time signal automatically starts an auxiliary seconds' pendulum, suspended freely just behind the clock pendulum, which is brought into coincidence of beat with the free pendulum by an attendant (by means of electro-magnetic action as in the Greenwich mean solar clock). The Devonport clock sends a return signal to Greenwich daily at 1^h. 0^m. 39^s.0, and the Portsmouth clock at 1^h. 0^m. 20^s.0, to serve as a test of the accuracy with which the local clocks have been corrected.

The following clocks are also in use in the Observatory as Mean Solar Clocks: "Dent 2," with a mercurial pendulum, in the Upper Chronometer Room; "Dent 2016," with a zinc and steel pendulum, in the Lower Chronometer Room; "Graham 3," with a mercurial pendulum, in the Ball Lobby, occasionally used for facilitating the regulation of the Mean Solar Clock (described below); "Dent 2014," with a wooden-rod pendulum, now in the South wing of the new Physical Observatory; and "Molyneux," with a wooden-rod pendulum, in the Magnetic Basement. Several chronometers are also kept in the Lower Computing Room for occasional use. Besides these there are two journeymen or assistant clocks; an electric clock by Shepherd, formerly used at Ashford; and a watchman's clock.

The following clocks are on loan: "Dent 1916" and "Dent 2013" at the Cape Observatory; "Dent 2011" at the Kew Observatory; "Arnold" at the Oxford Observatory; and "Dent 2010" at Devonport, where it is employed to drop the Time-Ball.

III. *Subjects of Observation in the Year 1896.*

The Sun, Moon and Moon-culminating stars have been observed on the meridian at every practicable opportunity.

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 14^h, excepting at times when the moon passes the

meridian later than 14^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.

In the meridian 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, and the circumpolar stars of which Ephemerides are given in the *Connaissance des Temps*, or in M. Loewy's "*Ephémérides des Étoiles de culmination lunaire et de longitude*."

The other stars observed are taken from a Working Catalogue containing all stars in the Harvard Photometry, or in Groombridge's Catalogue which have not been observed at Greenwich since 1867 ; 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, and finally, stars from Piazzini's Catalogue, selected to fill gaps in the list as opportunity offers.

The observations of the Moon with the Altazimuth have been generally 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 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), unless when γ Draconis passes the meridian very early in the morning. In these cases the observation is only made when the moon also passes in the early morning.

The Sheepshanks equatorial has been used for observing occultations of stars by the Moon, and for the phenomena of Jupiter's satellites. It has also been used for the observation of comets, and in 1890 November a new positive eyepiece with position circle was applied to it for the improvement of such observations.

The 28-inch refractor has been in use with the object-glass in the visual position for micrometric observations of double stars, and of the Satellite of Neptune.

Photographs of the Sun have been taken with the Dallmeyer photoheliograph on every day when the weather permitted.

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, and if the limb is defective the requisite correction for defect of illumination is given in the notes. 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. In the case of Mercury (and more rarely of Venus), whose limbs are sometimes very badly defined, a correction for defective illumination is applied when the estimated centre of the illuminated portion is observed, to reduce to the centre of the disc, see p. xxxiv. 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, or the British Association Catalogue.
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, or in the Supplement, referred to as Lalande, Lalande F. and Lalande F. (2) respectively.
8. The No. in Lacaille's Catalogue of Southern Stars, published by the British Association.

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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 Bonn "Durchmusterung" or in Schönfeld's continuation of the "Durchmusterung" (Bonn Catalogue Sections I., II., III., and IV., Bonn Observations Vols. III., IV., V. and VIII.) referred to as "B.D."
14. The No. in the Greenwich Catalogues ; in the British Association Catalogue, referred to as B. A. C. ; in the Cape Catalogue for 1880 ; or in the Harvard "General Catalogue of 4,260 Stars, with their approximate magnitudes, "reduced to the Epoch 1880," referred to as H.P.
15. As a last resource the star is defined by its approximate N.P.D.

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 letters (E & E) affixed to it. The letter R. denotes that the object was observed by reflexion in the trough of mercury. The letters *r* and *l* indicate cases where a reversion-prism eye-piece was used, the apparent motion of the star being towards the right and towards the left of the observer respectively.

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

The next *ten* 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 denoted by the letters M, N, O, T, X, Y, Z. The wires used for galvanic transits are denoted by the letters O, P, Q, R, S, T, U, V, W, X ; O, T, and X, being wires of the eye-and-ear system, and the others new wires inserted between O, T, and X. The intervals O-P, P-Q, R-S, S-T, U-V, V-W, W-X are nearly equal ; the interval Q-R is nearly double, and the interval T-U nearly treble the former. This system of ten wires for the galvanic transits was introduced on 1891 October 28, in substitution for the system of nine wires previously in use.

Polaris and other stars very near the pole are generally observed by turning the R.A. micrometer screw with the right hand until the star is bisected by the middle wire T (or sometimes one of the other wires) the instant of accurate bisection being

recorded on the chronograph with the left hand. The reading of the micrometer is then recorded, and the operation repeated until ten observations are obtained. The readings of the R.A. micrometer are always mentioned in the notes. As the "reduction to the centre wire" in this case depends on the value of successive revolutions of the micrometer screw, the errors of this screw were investigated on 1891 November 14, by Mr. Thackeray and Mr. Hollis after the introduction of a new screw. The eye-piece of the transit-circle was rotated through 90° ; and the instrument was turned on the S. Collimator. Successive intervals of $3^{\text{rev.}}$ of the transit-micrometer were compared with the same interval ($4^{\text{r.600}}$) of the S. Collimator micrometer; and likewise successive intervals of $1^{\text{rev.}}$ and $0^{\text{r.333}}$ of the transit-micrometer with intervals $1^{\text{r.540}}$ and $0^{\text{r.510}}$ of the S. Collimator micrometer, these intervals of the S. Collimator micrometer being nearly equal to the intervals of the R.A. micrometer with which they were compared. The results are given in the Transit-Circle Tables at the end of the Introduction for 1891, page cxii. It is considered that the errors are too small to necessitate correction, and this is confirmed by comparing the times of transit of circumpolar stars for intervals of successive revolutions.

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. Stars very near the pole are sometimes observed by the eye and ear method over the wires intended for the galvanic transits: but more generally over wire T (the middle wire) set to a series of readings of the transit micrometer as described above. The actual readings are always mentioned in the notes.

All transits of stars observed by galvanic contact are usually referred to the Sidereal Standard clock; but for stars observed by eye-and-ear, the clock Hardy is necessarily

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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 *fifteenth* 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 applied in each instance 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 equatorial intervals of the wires used are given in the Transit-Circle Tables 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 O, P, Q, &c., (or to M, N, O, &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 intervals 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 equatorial intervals 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

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

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.

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

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

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.

In cases where a defective limb of a planet has been observed, a 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 planet had passed or had not passed the opposition in right ascension,) is applied in forming the concluding transit, and is thus investigated :—The excess or defect of the difference of R.A. of the Sun and planet from 12^h , at the time of the planet's transit, expressed in arc, is multiplied by the cosine of the Sun's declination, to form an arc θ which represents the angle, upon the planet'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 .

Occasionally the limb of Mercury is so ill-defined that the observer records a transit of the "centre." This is considered to be the centre of gravity of the illuminated portion of the disc, and a correction of $\frac{4}{9\pi} (=0.424) \times$ defect of illumination should be applied for reduction to the centre of the actual disc. In practice this is applied in forming the concluded transit as $0.4 \times$ correction for defect of illumination in R.A., calculated as for a transit of a defective limb.

The *sixteenth* 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.

ERROR OF COLLIMATION.

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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 collimator, for coincidence of its nearly vertical wire with the image of that of the south collimator, is ascertained every day, and the micrometer-wire of the north collimator is then left in that position. The reading of the R.A. micrometer of the transit-circle, 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 $+ 0^{\circ}.008$ 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 years 1871-80, the annual means for which were sensibly accordant. But since 1880 the discordance has increased, though no satisfactory reason can be given for the change (*see* discussions by Mr. Turner in the *Monthly Notices of the Royal Astronomical Society*, Vol. xlv., p. 329, and Vol. lii., p. 146). It has not, however, been considered advisable to alter the correction at present.

During the year 1851 the observations of the collimators with the transit-circle 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 a day.

The R.A. micrometer 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 $37''.10$ for one revolution of the micrometer. The determination of the value of a revolution was made in 1891 November after the introduction of a new screw. The investigation is given in the Transit-Circle Tables at the end of the Introduction for 1891, page cxi. The errors of the screw were also investigated and found to be insensible. To the excess thus converted into arc is then applied $-0''.19$ for diurnal aberration ; and the result is the quantity which is given in the sixteenth 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,

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

Error of Level.

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

The process of determining the error of level 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 $37'' \cdot 10$ for 1^{rev} . 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 sixteenth column of the *Transits*, in curved brackets.

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 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 mentioned in the table of Determinations of the Error of Azimuth, following this section ; the method of using them is as follows :—

If two consecutive passages of one of these stars have been observed, the second transit (as corrected for the errors of collimation and level) 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 the azimuth factor corresponding to the apparent declination of the star for the day to obtain the azimuthal error in seconds of arc.

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 (corrected for errors of collimation and level) 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,

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

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.

1898G0ANM..58....1C

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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 in the Transit Circle tables at the end of this Introduction.

The *seventeenth* column contains the seconds of every transit, corrected for the three preceding errors; 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 *eighteenth* 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. exceeds 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 number 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.

The right ascensions are computed from the *Five-Year Catalogue of 258 Fundamental Stars for 1890* (Appendix to *Greenwich Observations*, 1891) by the use of the precessions of that Catalogue. The proper motions used are taken from Prof. Auwers' *Neue Reduction der Bradleyschen Beobachtungen, Erster Band* for all stars contained in that work, except μ Andromedæ for which Mr. Main's proper motion has been used as heretofore. For Cephei 51, the proper motion is taken from Prof. Auwers' *Catalog der Fundamental Sterne*, and for α Columbæ and δ Sculptoris from the Cape Catalogue, 1880. The corrections necessary to bring up the stars' right ascensions to the day of observation are computed by the formula $A a + B b + C c + D d + scC + \mu t$, given in Mr. Stone's *Tables for facilitating the Computation of Star Constants*. 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 1896.0 of all the stars which have been used for determining clock-errors or azimuth-errors, together with the corrections to the right ascensions of the Nautical Almanac stars for 1896.0.

The *nineteenth* column contains the error of the clock, found by subtracting the numbers in the seventeenth column from those in the eighteenth. 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 *twentieth* 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. Lewis and some other observer ; for example, between Mr. Lewis and Mr. Hollis ; since it has been the practice from the beginning of 1892 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. Lewis as the standard. Suppose then that transits have been observed on successive days by Mr. Lewis and Mr. Hollis, 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*, 1895, page cxxvi., that the clock-error given by Mr. Hollis' observations is less than that given by Mr. Lewis' observations by $0^s.19$, as deduced from observations suitable for the determination of this quantity in the year 1895 ; and this is the last determination of personal equation which is available for the daily reduction of observations in 1896. The quantity $0^s.19$ is therefore added to Mr. Hollis' clock-errors, and it is then considered that we have two sets of clock-errors (namely, Mr. Lewis' as unaltered, and Mr. Hollis' 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 Chief Assistant is guided in adopting the clock-rate to be used through the group of observations : this adopted clock-rate is set down in the twentieth 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 twentieth 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. Lewis or Mr. Hollis), 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

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clock-stars are observed by Mr. Hollis, and the other object by Mr. Lewis, a further correction $+ 0^s.19$ must be applied: if the clock-stars are observed by Mr. Lewis, and the object by Mr. Hollis $- 0^s.19$ 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 1896 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 1896 and referred to Mr. Bryant as Standard Observer :—

$B - D = + 0^s.14$	$B - CD = + 0^s.06$	$B - S = + 0^s.21$
$B - C = - 0^s.07$	$B - RC = + 0^s.09$	$B - R = + 0^s.13$
$B - L = 0^s.00$	$B - DE = + 0^s.10$	$B - W = + 0^s.03$
$B - H = + 0^s.23$	$B - WB = - 0^s.04$	$B - HA = + 0^s.02$
$B - AC = - 0^s.04$	$B - J = - 0^s.04$	$B - WS = 0^s.00$
$B - HF = + 0^s.13$	$B - EB = + 0^s.09$	

These have been applied to the collected results of transits for the Sun, Moon, and planets, whenever they were needed throughout the year 1896.

But those used in the adoption of clock-rate as explained above, and in the reduction of altazimuth observations, referred to Mr. Lewis as Standard, have been deduced from the observations in 1895. The investigation of these is given in the *Introduction to the Greenwich Astronomical Observations*, 1895, page cxvi.

In connection with the change of the Standard Observer in 1896, it is necessary to mention that Mr. Lewis had ceased to observe regularly with the transit-circle in 1896, and that the difference between his personal equation and Mr. Bryant's as determined in the years from 1894—1896 is very small, viz., $0^s.00$, $- 0^s.02$, $0^s.00$.

It has been the practice on favourable nights for the transit-circle observer to observe two "clock-stars" by the eye-and-ear method, at the same time making a careful comparison between the clock "Hardy" (used in observing by this method) and the Sidereal Standard, which is used in chronographic transits. It is then an easy matter to compare the values of the quantity "clock slow" as found by the same observer using the different methods. The discussion of these results is given in a table at the end of this Introduction.

Discussions of results obtained with the reversion prism eyepiece, for personality depending on the direction of motion, are given in the tables at the end of this Introduction.

PERSONAL EQUATIONS ; SEMIDIAMETERS OF PLANETS.

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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 the following corrections, depending on the respective observers, are applied to the Nautical Almanac semidiameter :—

Mr. Hollis	+ 0 ^s .05	Mr. Rendell	− 0 ^s .02
Mr. Crommelin	− 0 ^s .01	Mr. Bowyer	− 0 ^s .07
Mr. Bryant	− 0 ^s .01	Other Observers	− 0 ^s .01
Mr. Davidson	− 0 ^s .07		

These corrections have been determined from the observations of the respective observers during the current year.

The following table exhibits the results of observations for recent years :—

	H	AC	B	Other Observers.
1892	+ 0 ^s .02	− 0 ^s .04	− 0 ^s .05	− 0 ^s .09
1893	+ 0 ^s .03	− 0 ^s .07	− 0 ^s .05	− 0 ^s .04
1894	+ 0 ^s .03	− 0 ^s .05	− 0 ^s .06	− 0 ^s .07
1895	+ 0 ^s .03	− 0 ^s .03	− 0 ^s .06	− 0 ^s .07
1896	+ 0 ^s .05	− 0 ^s .01	− 0 ^s .01	− 0 ^s .01

From 1896 January 1 the value adopted in the Nautical Almanac for the Sun's semidiameter at the Earth's mean distance was changed from 16'. 1^{''}.82 to 16'. 1^{''}.18.

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

$$+ 0^s.026 + 0^s.027 \times \text{tabular duration of passage of semidiameter.}$$

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 *twenty-first* column contains the right ascension of the centre of the body observed : it is formed by adding the time from the seventeenth column, the clock-error at 0^h next preceding from the twentieth column, the proportional part of the rate in the same

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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 either Polaris, δ Ursæ Minoris, Cephei 51, or λ Ursæ Minoris, 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-second* 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 for 1896.0. It is computed in the following manner.

For stars in the list of the *Connaissance des Temps*, the mean R. A. of the *Connaissance des Temps* is subtracted from the apparent R. A. of the *Connaissance des Temps*: and similarly for polar stars which are in the *Ephemerides des Etoiles de culmination Lunaire et de Longitude pour 1896 par M. Loewy*; (to the quantity so found a correction is applied for the difference between Auwers's proper motion and that adopted in the *Connaissance des Temps*, multiplied by the fraction of the year when the correction amounts to more than $0''.05$ when reduced to arc), and its sign is changed.

For other stars, the corrections are computed by the formula

$$\begin{aligned} & \frac{A}{15} \cos R.A. \operatorname{cosec} N.P.D. \\ & + \frac{B}{15} \sin R.A. \operatorname{cosec} N.P.D. \\ & + C \sin R.A. \cot N.P.D. \times \text{numb. (log.} = 0.1261) \\ & + \frac{D}{15} \cos R.A. \cot N.P.D. \\ & + C \times \text{numb. (log.} = 0.4875) \\ & + \mu t, \end{aligned}$$

where μ is the annual proper motion in 'R.A. taken in order of preference from:—

- (1) Auwers's *Neue Reduction der Bradleyschen Beobachtungen*, or his *Catalog der fundamental Sterne für die Zonen-beobachtungen der Astronomischen Gesellschaft* (vols. xiv. and xvii. of the *Astronomische Gesellschaft's* publications) except in the cases of μ Andromedæ and δ Sculptoris.
- (2) The *Bonn Observations*, Vol. VII., pp. 109—113.
- (3) Other authorities mentioned in the notes.

STAR CORRECTIONS IN R.A. ; PROPER MOTIONS : DETERMINATIONS OF xlili
ERROR OF COLLIMATION.

The values of the day-constants log. A, log. B, log. C, log. D, are given in the Nautical Almanac for mean midnight of each day, and it has been the practice to interpolate values of these quantities for noon, 6^h, and 18^h on each day, and to use for any star the values corresponding to the epoch nearest to the time of observation. The values of the other quantities are computed by the aid of Mr. Stone's *Tables for facilitating the Computation of Star Constants*, printed as an Appendix to the *Cape Observations* for 1874. The logarithms have, however, been taken out to four places of decimals only. For stars near the pole, the additional correction depending on the longitude of the moon is also taken into account.

The sign of the computed quantity is changed before application.

§ 2. *Determinations of the Errors of Collimation, Level, and Azimuth of the Transit Circle.*

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 all 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 vii., 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 vii. and xxxiv). 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 " $+0.16 \times$ 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 $+ 0^{\circ}008$ 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 $-0''19$ 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.

Since the reversion-prism was applied, in 1884 June, it has been the practice, in each set of observations for coincidence of the collimators with each other, and of the transit-circle with either of them, to take three readings with the direction for increasing readings apparently towards the right, and three with the direction apparently towards the left, in order to eliminate any personality depending on the apparent direction of measurement. A series of observations, for the investigation of this personality, was made by different observers, with the direction for increasing readings apparently towards the right, towards the left, downwards and upwards respectively. The discussion of these observations, given in the Transit-Circle Tables for the year 1885, shows that the apparent direction of measurement has no appreciable influence on the results.

DETERMINATION OF THE LEVEL ERROR.

The method of making these observations has been described (pp. ix and xxxvi). 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.

DETERMINATION OF THE ERROR OF AZIMUTH.

The method of finding the error of azimuth has been fully explained on p. xxxvii. The hour given in the first column is the mean of the times of the two observations with weights proportional to their respective azimuth factors, and thus expresses the

DETERMINATIONS OF ERRORS OF LEVEL AND AZIMUTH ; OBSERVATIONS OF
MERIDIAN ZENITH DISTANCES ; MICROSCOPE-MICROMETERS. xlv

approximate mean solar time (astronomical reckoning) to which the determination of azimuth error refers. The names of the stars in the second column are given in the order of observation. The correction for clock-rate and change of R. A. in the fifth column, is that which is applicable to the second observation in order to reduce it to the epoch of the first. In the eighth column is given the factor of z (the azimuth-error), by which the difference of the two quantities in the sixth and seventh columns is to be divided in order to determine the Resulting Error of Azimuth, expressed in seconds of arc. This factor is the algebraic difference of the two multiples of z referred to on p. xxxvii.

§ 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 : the observer, beginning with the northern horizontal microscope, and passing the upper microscopes, the southern horizontal, and the lower ones, in the direction

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of the circle's circumference, reads them in the order A, C, E, B, D, F (see diagram, page x.). These readings in the observing books are placed in the order $\begin{smallmatrix} A, C, E \\ B, D, F \end{smallmatrix}$; 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 three or four tenths of a revolution, 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 micrometers never differs materially from $29^{\text{r}}.3$. Now, if the correction, by

RUNS ; CORRECTIONS FOR ERRORS OF DIVISION, AND FOR FLEXURE
OF TELESCOPE.

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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 $\frac{50}{51} \times 30^{\circ}000$, or $29^{\circ}4118$. If the sum of the runs is not exactly equal to this quantity, there will be a variable correction, after adding $\frac{1}{50}$ part of the mean of the readings of the microscopes. To determine this quantity, let the sum of the runs be $29^{\circ}412 - x$. 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

$$r'' \times \frac{30^{\circ}000}{29^{\circ}412 - x}$$

or

$$r \left\{ 1 + \frac{1}{50} + 0.03468 \times x \right\}$$

Hence the correction, after adding $\frac{1}{50}$ part of the mean of readings, will be $+ r x \times 0''.03468$. 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 $+ 3''.468 \times x$, 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 $\frac{50}{51} \times 20^{\circ}000 = 19^{\circ}608$. Hence the true reading in seconds of space will be

$$r'' \times \frac{20^{\circ}000}{19^{\circ}608 - x}$$

or

$$r \left\{ 1 + \frac{1}{50} + 0.05202 \times x \right\}$$

and the correction, after adding $\frac{1}{50}$ th part of the mean of readings, will be $+ r x \times 0''.05202$.

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 Appendices 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.

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A re-determination of the errors of the 5° divisions, 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 the previous investigations.

The observations for determination of the horizontal astronomical flexure of the transit-circle telescope are given at the end of this Introduction. In making these observations the nearly horizontal wire of the south collimator 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 10 successive readings. After each complete set of 5 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 eye-piece 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 it, 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° 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.

In 1891 October, a new steel screw was applied to the micrometer by Messrs. Troughton & Simms. Observations for the determination of the value of $1^{\text{rev.}}$ of this screw are given in the Transit-Circle Tables at the end of the Introduction for 1891, p. cxi, the resulting value being $37''.05$. The errors of the screw were also investigated and found to be insensible. (Transit-Circle Tables 1891, p. cxv.)

The value of $1^{\text{rev.}}$ of this screw and its errors were re-determined from 1896 December to 1897 February. The screw was found to have worn considerably, and corrections were obtained to the equivalents of the micrometer readings belonging to a uniform screw with $1^{\text{rev.}} = 37''.05$. An account of the observations and a table of the corrections is given in the Transit-Circle Tables at the end of this Introduction.

VERTICAL WIRES IN THE TELESCOPE-FIELD AT WHICH CIRCLE-OBSERVATIONS ARE TAKEN.—Omitting, in this Section, all reference to the wires P, Q, R, S, U, V, W,

VERTICAL WIRES IN THE TELESCOPE-FIELD AT WHICH CIRCLE-OBSERVATIONS
ARE TAKEN ; CORRECTIONS FOR CURVATURE AND INCLINATION. xlix

adapted to galvanic observation of transits, the telescope contains seven vertical or transit wires M, N, O, T, X, Y, Z, here called 1, 2, 3, 4, 5, 6, 7, placed at sensibly equal intervals of about $14^{\circ}8'$ for transit of an equatorial 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, or second or sixth, 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 ($\log = 6.43569$) $\times \sin 2 \text{ N. P. D. } \times t^2$, 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) $\times \sec. \text{ declination } \times \frac{\sin. \text{ Geoc. Z.D.}}{\sin. \text{ App. Z.D.}} \times \frac{14.8}{3600}$ (the logarithm of the last factor being 7.61396)." 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.

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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.

From 1886 January 1 no correction has been applied to nadir-observations for discordance between the results of this observation and the mean of those of North and South stars. From observations in former years a connexion was traced between this discordance and the errors of the screws of the microscope-micrometers, and it was hoped that the application of the new steel screws (one of each pair being reversed) would remove the discordance. This was found to be the case till 1892, the mean apparent correction to the nadir-observation as found from reflexion observations of stars since 1886, being as follows :—

1886	—	0 ^{''} 09	1892	—	0 ^{''} 26
1887	+	0 ^{''} 01	1893	—	0 ^{''} 34
1888	—	0 ^{''} 12	1894	—	0 ^{''} 27
1889	+	0 ^{''} 07	1895	—	0 ^{''} 31
1890	+	0 ^{''} 08	1896	—	0 ^{''} 34
1891	+	0 ^{''} 07			

In consequence of the discordance shewn in 1892, the errors of the microscope-micrometer-screws were redetermined in 1893. The observations on which these depend are given in the Transit-Circle Tables for 1894. Although signs of wear were shewn, the errors arising from this cause are so nearly eliminated by the reversal of three of the screws that it has not been considered advisable to apply any correction to the circle-reading for apparent error of the screws. Similar observations made in 1896 November confirm these results. These observations are given in the Transit-Circle Tables at the end of this Introduction. The discordance is diminished from — 0^{''}44 to — 0^{''}34, when corrections are applied for the wear of the telescope-micrometer screw referred to on p. xlviii ; this arises from the fact that in practice a greater range of the screw is used in reflexion observations than in observations of the Nadir which are generally made close to the reading 20^r000 of the Micrometer.

With a view of obtaining information as to the cause of this discordance, observations of the Nadir have been taken since 1895 July three times each day when practicable.

SECONDS OF CONCLUDED MERIDIAN CIRCLE-READING ; ZENITH-POINT
CORRECTION ; APPARENT ZENITH-DISTANCES.

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The following differences were found from observations in 1895 and 1896 respectively :—

	21 ^h —3 ^h . G.M.T.	3 ^h —9 ^h . G.M.T.	9 ^h —15 ^h . G.M.T.	No. of Days.
1895	+ 0".29	0".00	+ 0".27	54
1896	+ 0".20	0".00	+ 0".16	84

The + sign indicates a greater circle reading. The reflexion observations of stars are made between 3^h and 9^h, and the discordance will be diminished, if Nadirs taken about this time are alone used in the comparison.

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.

From an investigation made in 1887 it appears that the probable error of a complete determination of Zenith Point (four stars and a nadir observation) was about $\pm 0''.20$. The introduction of an amalgamated copper bottom for the trough in 1889 September, greatly improved the steadiness of the images, and it was found that the probable error of a bisection was reduced by one third ; but the probable error of a complete determination of Zenith Point has not been recomputed.

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 difference from 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 both limbs of the Moon are observed, it usually happens that one of them is slightly defective from the want 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

$$\tan \theta = \operatorname{Cosec} P. \cos \delta_m. \tan \delta_s - \cot P. \sin \delta_m ;$$

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

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

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

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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 semidiameter 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 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.

$$\text{Then} \quad \tan \delta_1 = \tan \delta_m \cdot \cos MP S_1.$$

$$\text{And} \quad \theta_1 = \delta_s - \delta_1.$$

$$\begin{aligned} \text{Also} \quad \sin \theta &= \sin \theta_1 \cdot \sin MS_1 P \\ &= \sin \theta_1 \frac{\sin MP}{\sin S_1 P} \\ &= \sin \theta_1 \frac{\cos \delta_m}{\cos \delta_1}. \end{aligned}$$

From which θ is found.

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

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

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 $\times \sin \theta$; 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.

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

The angle ϕ represents in this case the angle by which the lowest or

CORRECTION FOR DEFECTIVE ILLUMINATION OF MOON AND PLANETS ; liii
BAROMETER ; EXTERIOR AND INTERIOR THERMOMETERS.

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

$$\text{Planet's semidiameter} \times \text{versin } \phi.$$

In cases where the "centre" of Mercury is observed, a correction of $0.4 \times$ ordinary correction for defect of illumination in N.P.D. is applied for reduction to the actual centre of the disc. See p. xxxiv.

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 this barometer.

EXTERIOR THERMOMETER.—This thermometer is No. 45357 by Negretti and Zambra. 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 $4\frac{1}{2}$ feet, at a height of nearly seven feet from the ground.

The following are the results of comparisons with the Standard Thermometer made on 1889 March 15, 1892 May 23, 1894 December 28, and 1895 February 12 :—

1889 March 15.		1892 May 23.		1894 December 28.		1895 February 12.	
Temperature.	Error.	Temperature.	Error.	Temperature.	Error.	Temperature.	Error.
°	°	°	°	°	°	°	°
32.0	+ 0.1	32.0	+ 0.2	39.1	+ 0.3	14.3	+ 0.1
51.9	+ 0.1	57.9	+ 0.2	64.1	+ 0.3	23.4	+ 0.1
70.9	+ 0.2	83.8	+ 0.2	83.7	+ 0.2	32.0	+ 0.1
93.0	+ 0.2			89.9	+ 0.2		

A correction of -0.1 has been applied to the readings of the Exterior Thermometer from 1886 February 9 to 1894 December 31, and of -0.2 from 1895 January 1.

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

The following are the results of comparisons with the Standard Thermometer made on 1889 March 15, 1892 May 23 and 1894 December 28 :—

1889 March 15.		1892 May 23.		1894 December 28.	
Temperature.	Error.	Temperature.	Error.	Temperature.	Error.
°	°	°	°	°	°
32·0	+ 0·4	32·0	+ 0·6	38·7	+ 0·5
51·4	+ 0·6	59·5	+ 0·7	64·0	+ 0·7
67·5	+ 0·5	84·9	+ 0·7	64·9	+ 0·6
88·7	+ 0·4			89·7	+ 0·5

A correction of $-0^{\circ}5$ has been applied to the readings of the Interior Thermometer from 1889 March 15 to 1894 December 31, and of $-0^{\circ}6$ from 1895 January 1.

A thermometer, Negretti and Zambra, No. 44520 was mounted till 1891 March 3 on a revolving stand in the Front Court and occasionally read as a check on the Exterior Thermometer.

From the beginning of 1887 this thermometer has been used instead of the ordinary Exterior Thermometer for observations of southern objects made in the day time. It is considered that the temperature of the air on the southern side of the Transit-circle room would be represented better by the reading of this freely exposed thermometer than by that of the Exterior Thermometer which is mounted near the north wall of the building. On 1891 March 3 the post carrying the thermometer was removed in the course of the building of the New Transit Pavilion. From that date the reading of the Meteorological Standard thermometer, with which that of the Front Court thermometer had been found to agree well, has been similarly used for observations of the Sun.

A thermometer (Negretti and Zambra, No. 70661 was mounted in the Front Court in a screen allowing a free circulation of air on 1896 July 18.

The following are the results of comparisons with the Standard thermometer made on 1896 July 15 :—

Temperature.	Error.
°	°
65·5	+ 0·2
80·0	+ 0·2
93·9	+ 0·2

Comparisons with the readings of the exterior thermometer have been made throughout the year.

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—

$$\log. \text{parallax} = \log. \sin. (Z. D. - 11'.12'') + \text{ar. co. log. distance} + 0.94596.$$

For the Moon, the horizontal equatorial 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—

$$\text{Parallax} = \text{Hor. Equat. Par. from N.A.} \times \text{Sin Dist. from Geoc. Zenith} \times \text{Geocentric Radius} (\text{Log} = 9.9991136) + \text{Corr. derived from the following table :—}$$

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 equatorial parallax instead of its sine, for which the formula is,

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

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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.

SEMI- DIAMETER.—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 following corrections have been applied to the tabular semidiameter :—

Mr. Hollis	+ 0 ^{''} 18	Mr. Rendell	+ 0 ^{''} 19
Mr. Crommelin	− 0 ^{''} 05	Mr. Bowyer	+ 0 ^{''} 35
Mr. Bryant	− 0 ^{''} 32	Other Observers	+ 0 ^{''} 20
Mr. Davidson	− 0 ^{''} 31		

These corrections have been derived from the observations of the respective observers for the current year. The following table exhibits the results of recent observations :—

	H.	AC.	B.	Other Observers.
1892 .	− 0 ^{''} 66	− 0 ^{''} 36	− 0 ^{''} 74	− 1 ^{''} 01
1893 .	− 0 ^{''} 32	− 0 ^{''} 77	− 0 ^{''} 55	− 0 ^{''} 14
1894 .	− 0 ^{''} 32	− 0 ^{''} 76	− 0 ^{''} 97	− 0 ^{''} 48
1895 .	− 0 ^{''} 24	− 0 ^{''} 71	− 1 ^{''} 33	− 0 ^{''} 43
1896 .	+ 0 ^{''} 18	− 0 ^{''} 05	− 0 ^{''} 32	+ 0 ^{''} 20

From 1896 January 1 the value adopted in the Nautical Almanac for the Sun's semidiameter at the Earth's mean distance was changed from 16' 1^{''}82 to 16' 1^{''}18.

For Venus, the correction + 0^{''}392 + 0^{''}027 × tabular semidiameter, derived from an investigation mentioned at page xli 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, Semidiameter, 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 1896, are given in the lower part of the page. For the stars in the list of the

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Connaissance des Temps, the correction is found by subtracting the mean declination of the *Connaissance des Temps* from the apparent declination of the same; and similarly for polar stars which are in the "*Ephemerides des Etoiles de culmination Lunaire et de Longitude pour 1896 par M. Loewy*"; a correction being applied for the difference between the adopted Proper motion and that used in the *Connaissance des Temps*, in cases where such correction amounts to $0''.05$. For other stars, the numbers required to change Mean N. P. D. to Apparent N. P. D. are computed by the formula,

$$\begin{aligned} & A \cdot \sin N. P. D. \times \text{numb. (log.} = 9.6374) \\ & - A \cdot \sin R. A. \cos N. P. D. \\ & + B \cdot \cos R. A. \cos N. P. D. \\ & + C \cdot \cos R. A. \times \text{numb. (log.} = 1.3022) \\ & - D \cdot \sin R. A. \\ & + \mu' t, \end{aligned}$$

where μ' is the annual proper motion in N.P.D. given by Auwers, or taken from the *Bonn Observations*, Vol. VII. ; see p. xlii.

The values of the day-constants log. A, log. B, log. C, log. D, are given in the Nautical Almanac for mean midnight of each day, and it has been the practice to interpolate values of these quantities for noon, 6^h, and 18^h on each day and to use for any star the values corresponding to the epoch nearest to the time of observation.

The values of the other quantities are computed by the aid of Mr. Stone's *Tables for facilitating the computation of Star Constants*.

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 1896.*

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 $\frac{50}{51} \times 30''.000$, or to $29''.4118$; and, the fiftieth part of the micrometer-reading for the mean of the microscopes being added to the micrometer-reading, the remaining

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correction, depending on the difference between the values in the last columns of the tables in question and $29^{\circ}41'18''$, is computed in the way that has been explained (page xlvii).

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, see page l. The results are always divided into three groups, viz : those resulting from north stars, those from south stars, and those from nadir-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. In the few cases where observations of only North or only South stars have been obtained, a correction is applied for the R—D discordance in obtaining the Zenith point. The value of this correction which is given in a footnote in the tables of Zenith points is derived from the correction found in the previous year for the R—D discordance.

To obtain information as to the cause of the R—D discordance, observations were made between 1893 December 3 and 1894 April 22 of the zenith distances of stars directly and by reflexion, the direct observation being taken first. The observations were in other respects similar to the regular reflexion observations. These observations are printed in the Transit-Circle Tables for 1894, (pp. cxi-i.), and a discussion of them is given in a paper by Prof. Turner and Mr. Thackeray in the Memoirs of the Royal Astronomical Society, Vol. li.

During the year 1895 a new series of observations were made with a view of obtaining further information on the cause of the R—D discordance. Pairs of stars were chosen of nearly the same zenith-distance and a few minutes apart in right ascension. One star of each pair was observed by reflexion, the other directly at the same transit ; on the next night of observation the order was reversed, the star which had been observed previously by reflexion being observed directly. In this way a value of 2 (R—D) was derived. In order to test whether any change was taking

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place in the instrument, two readings of the circle were taken, one just before the star entered the field and the second just after the bisections with the telescope-micrometer had been made. The results of the observations are given in the Transit-Circle Tables at the end of this introduction, together with a comparison with the R—D discordance obtained in the usual way. These observations were continued in 1896 and the results are given in the transit-circle tables at the end of this Introduction.

§ 5. *Ledgers of Mean Right Ascensions and Mean North Polar Distances of Stars, deduced from each day's observation in the Year 1896.*

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

Half-weight has been given to the result for right ascension in cases where the transit was observed at two or three wires only, observations at a single wire only being rejected. When a star is observed with the reversion-prism r and l in right ascension at the same transit, the whole transit is treated as a complete observation, half-weight being given to each of the results r and l ; but a reflexion and a direct observation at the same transit are considered as separate observations with full weight.

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 xxx, but they are more rigorously followed.

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 twelve* 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 noted whenever they occur.

The *thirteenth* column is occupied by the personal equation of each observer, referred to Mr. Lewis as a standard, deduced from the observations of transits in the year

1895 (see Introduction to Greenwich Observations 1895, page cxxvi), as the observations of 1896 are not available for the daily reductions of 1896.

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 $-0^s.03$ 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 $8^{\text{rev.}}.5 - p$ of micrometer a , $8^{\text{rev.}}.5 - q$ of micrometer b , $8^{\text{rev.}}.5 - r$ of micrometer c , and $8^{\text{rev.}}.5 - s$ 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

$$\frac{5'}{4} \times \left\{ \frac{w}{8.5-p} + \frac{x}{8.5-q} + \frac{y}{8.5-r} + \frac{z}{8.5-s} \right\}$$

or

$$\frac{5'}{4 \times 8.5} \left\{ (w + x + y + z) + \frac{1}{8.5} (wp + xq + yr + zs) \right\}$$

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

$$\frac{5'}{4 \times 8.5} (w + x + y + z) \left(1 + \frac{p + q + r + s}{4 \times 8.5} \right)$$

or

$$\frac{5'}{4 \times 8.5} (w + x + y + z) \left(1 + \frac{1}{100} \times \text{correction for runs for } 100'' \right)$$

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

CORRECTION FOR RUNS OF ALTAZIMUTH ; ERRORS OF DIVISION OF HORIZONTAL CIRCLE ; INTERVALS OF VERTICAL WIRES. lxi

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	"	0	"	0	"	0	"	0	"	0	"
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

When the Pointer of the Horizontal Circle reads 0° the division under Microscope *a* is $65^\circ 0'$; under Microscope *b*, $155^\circ 0'$; under Microscope *c*, $245^\circ 0'$; and under Microscope *d*, $335^\circ 0'$.

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 seven 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 seven vertical wires. This correction is equal to the angular distance between the mean of the wires observed and the mean of the seven 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 in the year 1896. The designations of wires are 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 <i>s</i>	— $180''9$
<i>t</i>	— $119''7$
<i>u</i>	— $61''2$
<i>v</i>	— $0''3$
<i>w</i>	+ $59''4$
<i>x</i>	+ $121''3$
<i>y</i>	+ $181''4$

For wires used in observations by eye and ear:

Wire <i>r</i>	— $363''6$
<i>s</i>	— $180''8$
<i>v</i>	— $0''1$
<i>y</i>	+ $181''2$
<i>z</i>	+ $363''3$

In the observations of the marks, the correction to be made to the Circle-reading for reduction to the mean of the seven wires used in chronographic observations is $\mp 0''3$. When transits are observed by eye-and-ear, over the five wires *r*, *s*, *v*, *y*, *z*, the correction required to the Circle-reading is $\mp 0''1$.

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

The *twentieth* column contains the approximate apparent zenith distance taken from the tabular computations.

The *first* column on the right-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 seven vertical wires. The amount to be applied is error of collimation $\times$ 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 next *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 *tenth* column contains the concluded level indication. It is assumed from careful determinations with a level-prover in 1893, that for the mean of the four levels each division represents $1''.082$.

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 *eleventh* column as the Correction for level.

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

The *twelfth* 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.

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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 difference 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 semidiameter.

The Hour angle in the *thirteenth* 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, corrections are applied to the places given in the Nautical Almanac deduced from the "Five-Year Catalogue of 258 Fundamental stars for 1890." In the case of Nautical Almanac stars which are not Greenwich Clock-stars the places are taken from the Nautical Almanac without correction. 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 deduced from the Sidereal Time given in the *fifteenth* column of the first page.

The *fourteenth* 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 $= -x \frac{d x}{d y} = \frac{a^2}{b^2} y$, 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 $\tan l$, $= -\frac{d x}{d y} = \frac{a^2 y}{b^2 x} = \frac{a}{b} \cdot \frac{y}{\sqrt{b^2 - y^2}}$, whence $y = \frac{b^2}{\sqrt{\{b^2 + a^2 \cotan^2 l\}}}$; and the distance from the centre of the spheroid to the foot of the normal, measured along the Earth's axis, is $\frac{a^2 - b^2}{\sqrt{\{b^2 + a^2 \cotan^2 l\}}}$; or, in parts of the semi-major axis, it is $\frac{a^2 - b^2}{a \sqrt{\{b^2 + a^2 \cotan^2 l\}}}$. 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 to meet the line drawn from the Moon to the foot of the normal, the length of that perpendicular will sensibly be, $a \times [7.7174788] \times \sin$

Moon's N.P.D. ; the angle which it subtends as seen from the Moon will be $\frac{a}{\text{Moon's distance}}$
 $\times [7.7174788] \times \sin \text{Moon's N.P.D.} = [7.7174788] \times \sin \text{Moon's hor. equat.}$
 $\text{parallax} \times \sin \text{Moon's N.P.D.};$ and the value of this in seconds of arc will be
 $[3.0319039] \times \sin \text{Moon's hor. eq. par.} \times \sin \text{Moon's N.P.D.};$ or $[7.7174788]$
 $\times \text{seconds of Moon's hor. eq. par.} \times \sin \text{Moon's N.P.D.}$ In this manner the number
 in the fourteenth column has been computed. It is always subtractive.

The assumed colatitude $38^\circ. 31'. 22''.2$ is deduced from that assumed for the Transit-Circle, corrected by the quantity $+ 0''.3$ 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 $38^\circ. 31'. 22''.2$; the Tabular azimuth, and the Tabular normal-centric zenith distance are computed by the following formulæ :—

$$\text{Log tan } a = \text{log cos hour-angle} + \text{log tan normal-centric N.P.D.}$$

$$\beta = a - \text{colatitude.}$$

$$\text{Log tan zenithal angle} = \text{log sin } a + \text{log tan hour-angle} - \text{log sin } \beta.$$

$$\text{Log cotan zen. dist.} = \text{log cotan } \beta + \text{log cos zenithal angle.}$$

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

$\text{Log sin zenithal angle} + \text{log sin zen. dist.} = \text{log sin hour-angle} + \text{log sin N.P.D.};$
 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. Thackeray	+ 0.32	+ 0.75
Other Observers	+ 0.24	+ 0.69

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The *fifteenth* 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 $a \times [7.71748] \cos \text{Moon's N.P.D.}$, and therefore her angular semidiameter is diminished in the proportion of Moon's distance to Moon's distance $- a \times [7.71748] \times \cos \text{Moon's N.P.D.}$, or $1 : 1 - \sin \text{hor. eq. par.} \times [7.71748] \times \cos \text{Moon's N.P.D.}$; or, using the mean parallax $57'$, the proportion is $1 : 1 - [5.93708] \times \cos \text{Moon's N.P.D.}$. The correction required is taken out from a small table. The Correction to azimuth is computed by the formula $\frac{\text{Corrected semidiameter.}}{\text{Sine normal-centric zenith distance}} + \text{small correction.}$ The small correction $\frac{\Delta^3}{6} \sin 1'' \times \cot^2 \text{Z.D.} \times \text{cosec. Z.D.}$ (where Δ is the Moon's semidiameter) depending on the difference between the sine of semidiameter 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 but one 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 twelve* 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 *thirteenth* 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 seven horizontal wires (supposed free from error of observation), the body was at the point which represents the mean of all the seven 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

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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 seven 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 $\delta c_s \times \sin 1''$ (δc_s 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

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

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

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

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

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

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

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

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

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

Substituting this in the last term, we have

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

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

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

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

Mean of observed hour-angles in seconds of time =

$$C_s + \frac{\sin c}{7 \sin a \cdot \sin b \cdot \sin C_s \cdot 15 \sin 1''} \Sigma \cdot \delta c - \frac{\cot C \cdot 15 \sin 1''}{14} \cdot \Sigma \cdot (\delta C_s)^2.$$

As c refers to the point which is the mean of the seven wires, $\Sigma \cdot \delta c = 0$. For the convenient expression of the last term, let I be the interval in seconds of time from the

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first wire to the last. Then, for the first wire, $\delta C_s = -\frac{1}{2} I$; for the second, $\delta C_s = -\frac{1}{3} I$; for the third, $\delta C_s = -\frac{1}{6} I$; for the fifth, $\delta C_s = +\frac{1}{6} I$; for the sixth it is $+\frac{1}{3} I$; for the seventh, $+\frac{1}{2} I$.

Hence the equation becomes,

Mean of observed hour-angles in seconds of time =

$$C_s - \frac{\cot C \cdot 15 \sin 1''}{14} \frac{28}{36} \times I^2,$$

$$= C_s - \frac{5}{6} \cdot \sin 1'' \times \cot C \times I^2.$$

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

$$+ \frac{5}{6} \cdot \sin 1'' \times \cot C \times I^2.$$

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 $+\frac{25}{24} \sin 1'' \times \cot C \times (I_4)^2$.

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

When six consecutive wires are observed, if I_6 be the interval from the first to the sixth, the correction will be $+\frac{7}{8} \sin 1'' \times \cot C \times (I_6)^2$.

If the wires are not consecutive, the corresponding correction will be found in a similar manner.

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 *fourteenth* column is occupied by the personal equation (referred to Mr. Lewis

CORRECTION FOR WANT OF UNIFORMITY IN VERTICAL MOTION ; ERRORS OF
DIVISION OF VERTICAL CIRCLE OF ALTAZIMUTH. lxix

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 *sixteenth* 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 $\begin{smallmatrix} A & D. \\ B & C \end{smallmatrix}$.

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	"	0	"	0	"	0	"	0	"
1	+0.49	15	+0.09	30	+0.74	45	+0.30	60	+0.56	75	+0.43
2	0.52	16	0.06	31	0.78	46	0.28	61	0.64	76	0.36
3	0.56	17	0.03	32	0.82	47	0.25	62	0.73	77	0.28
4	0.59	18	0.00	33	0.86	48	0.22	63	0.81	78	0.20
5	0.56	19	0.05	34	0.82	49	0.20	64	0.83	79	0.19
6	0.54	20	0.10	35	0.78	50	0.19	65	0.85	80	0.18
7	0.51	21	0.14	36	0.74	51	0.17	66	0.86	81	0.17
8	0.49	22	0.19	37	0.70	52	0.16	67	0.88	82	0.16
9	0.46	23	0.24	38	0.66	53	0.14	68	0.90	83	0.15
10	0.40	24	0.32	39	0.60	54	0.19	69	0.84	84	0.20
11	0.34	25	0.41	40	0.54	55	0.24	70	0.78	85	0.26
12	0.27	26	0.49	41	0.48	56	0.29	71	0.71	86	0.31
13	0.21	27	0.58	42	0.42	57	0.34	72	0.65	87	0.37
14	0.15	28	0.66	43	0.36	58	0.39	73	0.59	88	0.42
	+0.12	29	+0.70	44	+0.33	59	+0.47	74	+0.51	89	+0.45

On 1889, May 14, it was found that there was rather a deep cut on the Vertical Circle of the Altazimuth between the divisions $249^{\circ} 0'$ and $249^{\circ} 5'$. It was accordingly decided to examine the divisions from $248^{\circ} 50'$ to $249^{\circ} 15'$ inclusive to ascertain whether the errors of division of the circle were sensibly affected by the cut. This was done on 1889, May 28, by means of a supplementary microscope furnished with two sets of cross-wires distant from each other $5'$ nearly, and it was found that the division $249^{\circ} 5'$ appeared to be slightly affected. No correction, however, has been applied to the observations on this account.

When the Pointer of the Vertical Circle reads 0° the division under Microscope A is $166^{\circ} 55'$; under Microscope B, $256^{\circ} 55'$; under Microscope C, $346^{\circ} 55'$; and under Microscope D, $76^{\circ} 55'$.

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 seven 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, *R, S, T, U, V, W, X, Y, Z*, then the corrections to reduce the several wires to the mean of the system of wires in use since 1894 November 19 are:—

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

S	— $104^{\circ} 9'$
T	— $69^{\circ} 0'$
U	— $35^{\circ} 1'$
V	— $1^{\circ} 1'$
W	+ $34^{\circ} 3'$
X	+ $69^{\circ} 6'$
Y	+ $106^{\circ} 2'$

For wires used in observations by eye-and-ear:

R	— $214^{\circ} 5'$
S	— $104^{\circ} 1'$
V	+ $0^{\circ} 1'$
Y	+ $107^{\circ} 1'$
Z	+ $211^{\circ} 4'$

INTERVALS OF HORIZONTAL WIRES OF ALTAZIMUTH ; BAROMETER ; THERMOMETERS. lxxi

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 marks, by applying to the mean of equivalents the entire correction corresponding to the single wire V.

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. In forming the level-indication in the *fifth* column it is assumed (from a careful determination with a level-prover in 1893) that for the mean of the two levels each division represents $1''\cdot038$.

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 altazimuth barometer require a correction of $-0^{\text{in}}\cdot01$, 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 following are the results of comparisons with the Standard Thermometer made on 1889 March 15, 1892 May 23 and 1894 December 28 :—

1889 March 15.		1892 May 23.		1894 December 28.	
Temperature.	Error.	Temperature.	Error.	Temperature.	Error.
0	0	0	0	0	0
32°0	+ 0·7	32°0	+ 0·7	40°1	+ 0·8
51°0	+ 0·8	59°5	+ 0·8	68°1	+ 0·6
66°6	+ 0·6	85°2	+ 0·8	87°9	+ 0·8
87°9	+ 0·8				

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A correction of $-0^{\circ}7$ has been applied to the readings of the Exterior Thermometer from 1889 March 15.

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 following are the results of comparisons with the Standard Thermometer made on 1889 March 15, 1892 May 23 and 1894 December 28 :—

1889 March 15.		1892 May 23.		1894 December 28.	
Temperature.	Error.	Temperature.	Error.	Temperature.	Error.
•	0	0	0	0	0
32°0	+ 1'3	32°0	+ 1'5	38°7	+ 1'5
52°2	+ 1'4	56°5	+ 1'5	63°3	+ 1'5
70°3	+ 1'2	84°0	+ 1'3	85°5	+ 1'2
88°7	+ 1'0				

A correction of $-1^{\circ}4$ has been applied to the readings of the Interior Thermometer from 1895 January 1.

An approximate zenith distance being obtained by the use of an approximate zenith-point, the refraction in the *ninth* column is computed for zenith distances less than 82° 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 $1:1.003282$. From 82° to 85° zenith distance the log. refractions are also taken from that appendix, but diminished by $.00100$. For zenith distances greater than 85° , the mean log. refractions of Bessel's *Fundamenta* are employed diminished by $.00066$, the other quantities being taken from the same appendix. These refractions have been thus computed since 1881 January 1, though by inadvertence it is stated in the Introductions for the years 1881 to 1884, that the refractions of the *Tabulæ Regiomontanæ* have been used throughout, as was really the case in the years 1879 and 1880. During the years 1868 to 1878 inclusive, the mean refractions of the *Tabulæ Regiomontanæ* diminished in the proportion of $1:0.99469$ were used (*see* the Introductions for these years). In the years 1857–1868 inclusive the same refractions were adopted as at present; and previous to that the refractions of the *Tabulæ Regiomontanæ* were used throughout. 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.

ZENITH POINT ; DEFECTIVE ILLUMINATION ; SMALL CORRECTIONS TO
TABULAR PLACE ; INSTRUMENTAL ERRORS FOR THE ALTAZIMUTH. lxxiii

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 table on page lxxv. The correction for reduction to the foot of the Normal is $-930'' \times [5.93708] \times \cos$ Moon's N.P.D., which never exceeds $0''.05$ and has therefore not been applied.

For computation of the Parallax ; in the first place, the horizontal equatorial 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 equatorial 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 $= \frac{1}{a \sin l} \frac{a^2}{b^2} = \frac{a}{\sqrt{b^2 \sin^2 l + a^2 \cos^2 l}}$; the logarithm of which is 0.0008851.

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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 $1 - [5.93708] \times \cos \text{Moon's N.P.D.}$. 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 $\times$ sine of observed zenith distance of limb + small correction. The small correction is the sum of two terms, namely, $-\frac{P^3}{6} \sin^2 1'' \cdot \sin \text{Z.D.} \times \cos^2 \text{Z.D.}$ (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 $\sin \text{Z.D.} \times$ Airy's correction as given in the section of Occultations. The table of corrections used is given on page lxxxvii.

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 but one 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 $-0^s.03$ 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 quantities for a low star. Then the true azimuth of the high star deduced from observation, face right, is

$$O_r + x \operatorname{cosecant} D_r + (L_r - y) \cdot \cotangent D_r - z ;$$

the computed azimuth corrected is

$$C_r + w ;$$

hence this observation gives the equation

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

The true azimuth determined from observation, face left, is

$$O_l - x \cdot \operatorname{cosecant} D_l - (L_l - y) \cdot \cotangent D_l - z :$$

and this observation therefore gives the equation,

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

Subtracting the first equation from the second,

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

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

A similar treatment of the observations of the low star gives

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

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

From 1888 November 26, the collimation error has been deduced from observations of Marks, which are sensibly in the horizontal plane ; the 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'_i , be the concluded readings of horizontal circle corrected for the adopted error of collimation. Then the first equations are,

$$\begin{aligned} O'_r + L_r \cdot \cotan D_r - C_r &= +y \cdot \cotan D_r + z + w, \\ O'_i - L_i \cdot \cotan D_i - C_i &= -y \cdot \cotan D_i + z + w. \end{aligned}$$

Whence
$$\frac{(O'_r + L_r \cdot \cotan D_r - C_r) - (O'_i - L_i \cdot \cotan D_i - C_i)}{\cotan D_r + \cotan D_i} = y.$$

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. In June 1894 the upper pivot of the vertical axis was reground as it was found to be worn.

LEVEL ZERO ; ZERO OF AZIMUTH FOR ALTAZIMUTH OBSERVATIONS. lxxvii

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	1873 { Jan. 8 to Apr. 19	+ 38'52
1849	+ 2'33	1873 { Apr. 29 to May 19	+ 16'45
1850	+ 6'67	1873 { May 27 to Dec. 31	- 2'26
1851	+ 8'75	1874	- 1'96
1852	+ 10'50	1875	- 0'94
1853	+ 11'36	1876	+ 0'25
1854	+ 11'71	1877	+ 0'51
1855	+ 12'51	1878	+ 2'15
1856	+ 13'23	1879	+ 4'14
1857	+ 13'59	1880	+ 3'68
1858	+ 13'70	1881	+ 4'36
1859 { Jan. & Feb.	+ 13'75	1882	+ 4'40
1859 { Mar. to Dec.	- 4'23	1883	+ 4'71
1860	- 4'91	1884	+ 4'10
1861	- 5'48	1885	+ 4'21
1862	- 6'24	1886	+ 7'29
1863	- 5'39	1887	+ 8'20
1864	- 5'01	1888	+ 5'49
1865	- 4'56	1889	+ 9'40
1866	- 5'07	1890	+ 10'13
1867	- 4'30	1891	+ 8'13
1868	- 5'94	1892	+ 5'84
1869	- 5'06	1893	+ 3'29
1870	- 3'28	1894 { Jan. 10 to June 9	+ 6'95
1871	- 3'02	1894 { July 4 to Dec. 31	+ 5'53
1872	+ 3'47	1895	+ 4'34
		1896	+ 3'74

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 to 1887 November 26, the adopted zero of azimuth was formed by combining the observations of the stars with those of the azimuth-mark fixed to the parapet of the Royal Naval College. On 1887 November 27 the observations of this mark were discontinued in consequence of the obstruction of the view by the extension of the upper Computing Room, and the zero of azimuth was deduced from observations of stars alone until 1888 November 25, when three church spires were selected as new marks for observation, viz., the spire of St. John's Church, Lewisham High Road, distant 6,600 feet (referred to as Mark I.), that of the Roman Catholic Church, Croom's Hill, distant 1,060 feet (referred to as Mark II.), and that of the

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Congregational Church, Brockley Road, distant 6,930 feet, referred to as Mark III. Observations of Mark III. were, however, discontinued after 1889 June 5.

The tabular azimuth of a mark is deduced from observations of the mark and of stars made on the same days, the results obtained in any lunation being combined with those of the previous two lunations to form the adopted value for that lunation, provided the result for the lunation in question does not differ by more than $2''.5$ (*i.e.*, twice the probable error of the difference of results for two lunations) from that of the previous lunation; otherwise the result for the lunation in question is combined with those for the preceding and following lunations, giving weights in proportion to the number of observations.

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 a mark face right and face left respectively; or from observations of a star in the following manner:—

In two successive observations of the same star, face right and face left, let O_r and O_l be the observed circle-readings of the vertical circle corrected for level: C_r and C_l the computed Zenith Distances; e the possible error in star's place, which will be sensibly the same for both; Z the zenith point. Then we have

$$O_r - Z = \text{true Zenith distance with face right} = C_r + e.$$

$$Z - O_l = \text{true Zenith distance with face left} = C_l + e.$$

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

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

§ 9. *Catalogue of Mean R.A. and N.P.D. of Stars observed in 1896.*

The right ascensions in the catalogue are the means of all the separate determinations of the mean right ascension of each star, excluding those which are contained in brackets and giving half-weight to those marked with an asterisk.

The precessions for 1896 have been derived from the precessions and secular variations for 1890 which have been computed by the help of M. Folie's "*Douze Tables pour le calcul des reductions stellaires*," in which Struve's Constant of Precession is used.

The proper motions given in the following column are derived in the order of preference from Auwers's determinations, or from Vol. VII. of the *Bonn Observations*. See p. xlii.

The north polar distances in the catalogue are the means of the separate determinations (those contained in brackets being excluded) affected with the corrections for errors of division of the transit-circle, for discordance of direct and reflexion results,

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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 $38^{\circ}.31'.21''-90$, 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, these rules have been followed:—For stars whose N.P.D. does not exceed 15° , the observations above and below the pole are considered equally good; from N.P.D. 15° to N.P.D. 36° , those below pole have the weight $\frac{2}{3}$ for each observation: from N.P.D. 36° to N.P.D. 41° those below pole have the weight $\frac{1}{2}$: beyond 41° N.P.D. the observations are not combined.

The precessions in north polar distance are taken from M. Folie's "Douze Tables pour le calcul des reductions stellaires."

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

§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 148 measures of the value of this error made in 1896 is $+ 0^{\text{s}}.022$.

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 147 measures of the value of this error made in 1896 is $- 0''.04$.

For the duration of the passage of the Moon's diameter, the correction for defect of illumination is investigated as on p. xxxiv. From one determination the error of the Moon's tabular duration of passage made in 1896 is $+ 0^{\text{s}}.40$.

1898G0ANM..58....1C

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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 lii.). The mean of 22 determinations of the error of the Moon's tabular vertical diameter made in 1896 is $+ 0''.19$.

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 $+ 0''.18$, 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 lii. 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. $3^m. 47^s. 00$ — hours of Sid. time + solar equiv. for hours.
4. $10^s. 00$ — minutes of Sid. time + solar equiv. for minutes.
5. $3^s. 00$ — 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

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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 the quantities given on page xli. 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 xl.).

The tabular errors of right ascension of the Sun's centre, deduced from the mean of two limbs, are for the different observers :—

	H	AC	B	CD	R	WB	Other Observers.
	s	s	s	s	s	s	s
1895	+ 0°049 ₃₄	+ 0°073 ₄₄	+ 0°119 ₃₂				+ 0°127 ₁₀₀
1896	+ 0°040 ₁₅	+ 0°034 ₂₇	+ 0°155 ₂₇	+ 0°129 ₁₂	+ 0°110 ₈	+ 0°128 ₉	+ 0°123 ₄₈

the subscript numbers denoting in each case the number of observations.

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 *Tabula Regiomontanae* and assumed colatitude 38°. 31'. 21''·90 have been used throughout in the reductions. The tabular right ascensions and north polar distances are taken without correction from the Nautical Almanac.

The tabular errors of N.P.D. of the Sun's centre, deduced from the mean of two limbs, are for the different observers :—

	H	AC	B	CD	R	WB	Other Observers.
	"	"	"	"	"	"	"
1895	+ 0°10 ₃₆	+ 0°24 ₂₉	+ 0°23 ₃₁				+ 0°26 ₉₉
1896	— 0°54 ₁₆	0°0 ₂₇	— 0°11 ₃₀	+ 0°30 ₁₄	+ 0°15 ₁₀	+ 1°25 ₁₁	+ 0°05 ₅₅

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 xxxiv.) 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

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Nautical Almanac) the sidereal duration of passage of semidiameter, which is given in the same section of the Nautical Almanac.

The tabular errors of Right Ascension of the Moon's centre from observations of the first and second limbs are, for the different observers—

	H.	A.C.	B.	1 L. C.D.	R.	W.B.	Other Observers.
1895	^{s.} -0°120 ₁₅	^{s.} -0°196 ₁₄	^{s.} -0°135 ₁₅	^{s.}	^{s.}	^{s.}	^{s.} -0°170 ₂₈
1896	-0°201 ₈	-0°300 ₁₅	-0°150 ₁₃	-0°208 ₄	-0°218 ₄	-0°177 ₃	-0°175 ₁₂
				2 L.			
1895	-0°113 ₁₆	-0°011 ₁₈	+0°149 ₁₁				+0°113 ₁₇
1896	-0°114 ₃	-0°081 ₁₀	+0°088 ₁₆	+0°126 ₃	+0°028 ₈	+0°058 ₄	+0°094 ₁₄

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) and for the motion in N.P.D. during the passage from the mean of wires to the true meridian.

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

The tabular errors of North Polar Distance of the Moon's centre from observations of the north and south limbs are, for the different observers—

	H.	A.C.	B.	N. L. R.	C.D.	W.B.	Other Observers.
1895	+0°02 ₁₇	+0°18 ₂₄	-0°50 ₁₅	"	"	"	-0°49 ₁₅
1896	+0°33 ₇	-0°35 ₁₄	+0°18 ₁₉	-0°92 ₆	+0°16 ₈	-0°52 ₄	-0°59 ₁₅
				S. L.			
1895	-0°06 ₂₃	+0°47 ₁₈	+0°54 ₁₂				-0°82 ₂₁
1896	+0°32 ₉	+1°01 ₁₆	+1°44 ₁₅	+0°55 ₄	+0°13 ₄	+1°93 ₃	+0°63 ₁₆

For all the planets, the right ascensions are extracted from the twenty-first 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 appendices. For others the tabular places are taken from the *Berliner Jahrbuch*, or its Circulars; or occasionally from M.S. ephemerides mentioned in the notes.

When only one limb of a planet is observed, the number I. or II., or the letter N, S or C, in Columns 4 and 8, indicates that the first, second, North or South limb, or the estimated centre, was observed.

The investigation of the position of the Ecliptic has been made in the following manner. The mean of all the errors in each month, for R.A. and for N.P.D.,

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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 $x \cos l + y \sin l + z$, where l is the Sun's longitude. Weights are then assigned proportional to the number of observations of N.P.D. and the equations solved by the ordinary method of least squares. This method has been used since 1888, instead of the method of weighting and grouping the observations previously adopted.

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., giving half weight to observations of a single limb of the Sun in either element, 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,

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

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

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

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

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

For the other planets, the following are used :—

$$\begin{aligned} \text{Error of geocent. long.} = & \frac{R \times \cos (\lambda - L)}{\Delta} \times \text{error of planet's heliocentric longitude} \\ & - \frac{\sin (\lambda - L)}{\Delta \times \sin 1''} \times \text{error of projection of planet's radius vector} \\ & - \frac{r \times \cos (\lambda - l)}{\Delta} \times \text{error of Earth's heliocentric longitude} \\ & + \frac{\sin (\lambda - l)}{\Delta \times \sin 1''} \times \text{error of Earth's radius vector.} \end{aligned}$$

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

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 with those of the planets.

It is to be remarked that, in the column *Extent of Group*, the day given is, as in past years, the civil day (commencing at midnight) on which the observation was made, and that this occasionally differs by a unit from the astronomical day under which the observations may be found in the sections of *Transits observed*, and *Observations of Zenith Distance* : also in the column *Mean Day* the day given is the civil day corresponding 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.

Commencing with the year 1884, corrections representing the Moon's motion in R.A. and N.P.D. in the interval between the observed and tabular times of transit have been applied in forming the "Errors of the Moon's tabular place in R.A., N.P.D., Longitude, and E. N.P.D." The Apparent Errors of R.A. and N.P.D. in the section "Right Ascensions and North Polar Distances of the Centre of the Moon" are formed, as in past years, by simple subtraction of the "R.A. or N.P.D. from Observation" from the "R.A. or N.P.D. in Nautical Almanac," without application of the above-mentioned corrections.

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,

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

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

$$\begin{aligned}\delta . Z &= -p . \sin N.P.D. \times \delta . R.A. + q \times \delta . N.P.D. , \\ \delta . A &= -r . \sin N.P.D. \times \delta . R.A. - s \times \delta . N.P.D. .\end{aligned}$$

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.

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

By solution of these equations,

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

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. *Differences of Right Ascension and North Polar Distance of Comets a 1896, b 1896 and f 1896 (Perrine-Lamp, Swift and Perrine) and Neighbouring Stars, observed with the Sheepshanks Equatorials.*

The observations of Comets with the Sheepshanks equatorial are 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 system of wires contains also a thin wire bisecting one of the angles between the inclined wires. The adjustment for inclination of the cross-wires is tested on each occasion by allowing the diurnal motion to carry a star along the bisecting wire.

In 1895 November new wires were inserted ; the inclinations of the thick wires were found to be $45^{\circ} 6'$, and $135^{\circ} 7'$; the corrections for transits taken over these wires are, when the object is north of the centre

$$+ \frac{i''}{2} (6 + 7) \sin 1' = + i'' \times \cdot 0019 \text{ in R.A.}$$

$$\text{and } + \frac{15}{2} i'' (6 - 7) \sin 1' \sin \text{N.P.D.}$$

The sign of the correction in R.A. is reversed when the object is south of the centre.

On and after 1892 December 23 corrections for motion in the interval between crossing the wires were applied to the observed R.A. and N.P.D. of comets. If the increase of the comet's R.A. and N.P.D. in 1 second of time be α'' , δ'' respectively, then the correction in R.A. is $\frac{+ i \delta}{30 \sin \text{N.P.D.}}$ when it crosses north of the centre, the sign being reversed when it crosses south of the centre.

The correction in N.P.D. is $-\frac{15 i \alpha \sin \text{N.P.D.}}{2}$ when the comet is north of the centre, the sign being reversed when it is south of the centre.

Corrections are also applied for refraction.

§ 12. *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.

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 when given there. A supplementary list of other stars whose occultations were observed is given on p. 104. The Moon's geocentric place, semidiameter, and horizontal equatorial 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

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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.	ZENITH DISTANCE.									
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
0 0	"	"	"	"	"	"	"	"	"	"
0 360	+0.04	+0.01	-0.01	-0.03	-0.05	-0.06	-0.08	-0.09	-0.09	-0.09
10 350	+0.04	+0.01	-0.01	-0.03	-0.05	-0.06	-0.08	-0.08	-0.09	-0.09
20 340	+0.04	+0.01	-0.01	-0.03	-0.05	-0.06	-0.07	-0.08	-0.08	-0.09
30 330	+0.04	+0.02	0.00	-0.02	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08
40 320	+0.04	+0.02	0.00	-0.01	-0.04	-0.04	-0.05	-0.06	-0.06	-0.06
50 310	+0.04	+0.02	+0.01	-0.01	-0.03	-0.03	-0.04	-0.04	-0.05	-0.05
60 300	+0.04	+0.02	+0.01	0.00	-0.02	-0.01	-0.02	-0.03	-0.03	-0.03
70 290	+0.04	+0.03	+0.02	+0.01	-0.01	0.00	0.00	-0.01	-0.01	-0.01
80 280	+0.04	+0.03	+0.03	+0.02	+0.01	+0.02	+0.02	+0.01	+0.01	+0.01
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	+0.04	+0.04	+0.05	+0.04	+0.05	+0.05	+0.06	+0.06	+0.06
110 250	+0.04	+0.04	+0.05	+0.06	+0.05	+0.07	+0.07	+0.08	+0.08	+0.08
120 240	+0.04	+0.05	+0.06	+0.07	+0.06	+0.08	+0.09	+0.10	+0.10	+0.10
130 230	+0.04	+0.05	+0.06	+0.08	+0.08	+0.10	+0.11	+0.11	+0.12	+0.12
140 220	+0.04	+0.05	+0.07	+0.08	+0.09	+0.11	+0.12	+0.13	+0.13	+0.13
150 210	+0.04	+0.05	+0.07	+0.09	+0.10	+0.12	+0.13	+0.14	+0.15	+0.15
160 200	+0.04	+0.06	+0.08	+0.10	+0.11	+0.13	+0.14	+0.15	+0.15	+0.16
170 190	+0.04	+0.06	+0.08	+0.10	+0.11	+0.13	+0.15	+0.15	+0.16	+0.16
180 180	+0.04	+0.06	+0.08	+0.10	+0.12	+0.13	+0.15	+0.16	+0.16	+0.16

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

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

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

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

$$F = \log. \sin \text{ star's hour-angle} + \log. \text{ seconds of corrected eq. hor. parallax} + 9.4942224.$$

$$G = \log. \sin \text{ star's N.P.D.} + \log. \sin \text{ star's hour-angle} + \log. \text{ seconds of corrected eq. hor. parallax} + 9.8913935.$$

(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 :—

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

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

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

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 :—

$$\text{If } \log. \tan \psi = \log. \text{ diff. R.A. of Moon's centre and corresponding point} + \frac{1}{2} \log. \\ \sin \text{ N.P.D. of Moon's centre} + \frac{1}{2} \log. \sin \delta' - \log. \text{ diff. N.P.D. of} \\ \text{Moon's centre and corresponding point ;}$$

$$\text{Then } \log. \text{ dist.} = \log. \text{ diff. N.P.D.} - \log. \cos \psi, \\ \text{or} = \log. \text{ diff. R.A.} + \frac{1}{2} \log. \sin. \text{ N.P.D. of centre} + \frac{1}{2} \log. \sin \delta' - \log. \sin \psi.$$

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 equatorial parallax in the proportion of $1 : 1 + \frac{m}{100}$ will alter all the deduced parallaxes (in R.A. and in N.P.D.) in nearly the same proportion : and therefore the R.A. of the corresponding point will be altered by $\frac{m}{1000} \times$ correction for parallax in R.A.
- 3rd. The alteration in the position of the Moon with regard to the meridian depending on the alteration of time t^s , will introduce an alteration in the correction for parallax. It is computed by the following formula :—

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

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

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 $\frac{m}{1000} \times$ correction for parallax in N.P.D.
- 3rd. The increase of hour-angle (considered positive when the Moon is west of the meridian), depending on the alteration of time t^s , will alter the correction for parallax in N.P.D. by the following quantity :—

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

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

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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.

For a planet, the R.A. and N.P.D. of the centre are used to find those of the corresponding point of the limb; the planetary parallax is subtracted from that of the moon; and the distance of the corresponding point is equated to the sum (or difference) of the semi-diameters.

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

	$\log. \left(\frac{\text{Arc.}}{\sin} \right)$	$\log. \left(\frac{\sin}{\text{Arc.}} \right)$		$\log. \left(\frac{\text{Arc.}}{\sin} \right)$	$\log. \left(\frac{\sin}{\text{Arc.}} \right)$
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

	$\log. \left(\frac{\text{Tan.}}{\text{Arc.}} \right)$		$\log. \left(\frac{\text{Tan.}}{\text{Arc.}} \right)$		$\log. \left(\frac{\text{Tan.}}{\text{Arc.}} \right)$		$\log. \left(\frac{\text{Tan.}}{\text{Arc.}} \right)$
2	0.0000000	8	0.0000008	14	0.0000024	20	0.0000049
3	0.0000001	9	0.0000010	15	0.0000027	21	0.0000054
4	0.0000002	10	0.0000012	16	0.0000031	22	0.0000059
5	0.0000003	11	0.0000015	17	0.0000035	23	0.0000065
6	0.0000004	12	0.0000018	18	0.0000039	24	0.0000071
7	0.0000006	13	0.0000021	19	0.0000044	25	0.0000077

§ 13. *Micrometric Observations of Double Stars.*

With a few exceptions these observations were made with a position-micrometer on the 28-inch refractor. The method of observation consists in turning the micrometer till its fixed wire is parallel to the line joining the stars (so that they can be simultaneously bisected by it, by moving the telescope with one of the slow motion rods) and reading the position-circle. The two movable wires, which are perpendicular to the fixed wire, are then moved till they bisect the two stars, and the readings of the micrometer heads are taken. This may be done in two ways, the wire moved by the right hand screw bisecting the star on the right or left, as the observer wishes, and the wire moved by the left hand screw bisecting the other star in each case. The zero of position angle is obtained by placing the fixed wire so that the diurnal motion carries a star along it. As the values of 1^{rev.} of the micrometer screws are equal, and their readings increase in opposite directions, the distance between the stars is obtained by taking the sum of the readings of the micrometer heads and subtracting the sum of the corresponding readings when the wires coincide; or if the measure has been made with wires reversed, by subtracting the sum of the readings from the reading for coincidence. When the observation has been made both *directly* and with wires reversed, the distance is half the difference of the sum of the micrometer readings in the two cases.

The value of one revolution of each micrometer screw is 12".06. It was determined in 1894 November from transits of stars near the Pole. The observations are given in the volume for 1894.

The stars observed are known or suspected binaries, and such double stars as could not be well separated with a smaller instrument.

The nomenclature of the stars in column 1 refers to the original observer's catalogue, viz. :— Σ to the Dorpat Catalogue of W. Struve, 1837; $\text{O}\Sigma$ to the Pulkova Catalogue, 1843; β to the various catalogues of Mr. Burnham. Column 2 gives the name adopted for the star in the Greenwich Catalogues. Columns 3 and 4 contain the approximate R.A. and N.P.D. for 1900. These have been derived from Dr. Romberg's Catalogue of 8634 stars, epoch 1875. Columns 5 and 6 give the measured position angle and distance on different nights, and the means. Column 7 gives the number of measures of each element on the separate nights. Column 8 gives the magnitudes derived from the Dorpat, Pulkova, or Mr. Burnham's Catalogues referred to above.

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Column 9 gives the epoch of the observations, or the fraction of the year from the beginning of 1896. In Column 10 the magnifying power used is given, and in Column 11 such remarks as appear necessary.

§ 14. *Measures of Positions and Areas of Sun Spots and Faculæ on Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn in India, and at the Royal Alfred Observatory, Mauritius, in the year 1896; with the deduced Heliographic Longitudes and Latitudes.*

The photographs from which these measures were made were taken either at Greenwich; at Dehra Dûn. North-West Provinces, India; or at the Royal Alfred Observatory, Mauritius.

The photographs of the Greenwich series were taken with the Dallmeyer Photoheliograph, returned from the Transit of Venus expedition to New Zealand, which, as now adapted, gives a solar image of 8 inches diameter on the photographic plate.

The photographs have been taken throughout the year on gelatine dry plates, "Lantern" plates supplied by R. W. Thomas and Co. being used, with hydroquinone development.

The Indian photographs, which have been forwarded by the Solar Physics Committee to fill the gaps in the Greenwich series, were taken under the superintendence of the Deputy Surveyor General, Trigonometrical Survey of India, with a Dallmeyer photoheliograph giving an image of the Sun nearly 8 inches in diameter. In the process adopted at Dehra Dûn bromo-iodized collodion has been used in connexion with iron development.

The Mauritius photographs were taken under the superintendence of Dr. C. Meldrum, Director of the Royal Alfred Observatory, Mauritius, with a Dallmeyer photoheliograph, giving an image of the Sun about 8 inches in diameter. At the Mauritius Observatory bromo-iodized gelatine dry plates have been used with alkaline development.

Photographs of the Sun were taken at Greenwich on 206 days, and Indian photographs on 139 days, and Mauritius photographs on 19 days have been received

from the Solar Physics Committee to complete the total of 364 days for which there are either Greenwich, Indian, or Mauritius photographs of the Sun available for measurement in 1896.

The *first* column on each page contains the Greenwich Civil Time at which each photograph was taken, expressed by the day of the year and decimals of a day, reckoning from Greenwich mean midnight January 1d. 0h., 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, and those taken in Mauritius by the letter M.

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 1896 :—

E. W. Maunder	-	M	A. J. Wilkin	-	AW
C. C. Lacey	-	CL	J. A. West	-	JW
C. F. Turner	-	FT			

The *third* column gives the No. of the group, and the letter for the spot. 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 astronomical refraction.

The measures of the photographs were made with a large position-micrometer specially constructed by Messrs. Troughton and Simms for the measurement of photographs of the Sun up to 12 inches in diameter. In this micrometer the photograph is held with its film-side uppermost on three pillars fixed on a circular plate, which can be turned through a small angle, about a pivot in its circumference, by means of a screw and antagonistic spring acting at the opposite extremity of the

diameter. The pivot of this plate is mounted on the circumference of another circular plate, which can be turned by screw-action about a pivot in its circumference, 90° distant from that of the upper plate, this pivot being mounted on a circular plate with position-circle which rotates about its centre. By this means small movements in two directions at right angles to each other can be readily given, and the photograph can be accurately centred with respect to the position-circle. When this has been done, a positive eye-piece, having at its focus a glass diaphragm ruled with cross-lines into squares, with sides of one-hundredth of an inch (for measurement of areas), is moved along a slide diametrically across the photograph, the diaphragm being nearly in contact with the photographic film, so that parallax is avoided. The distance of a spot or facula from the centre of the Sun is read off by means of a scale and vernier to 1-250th of an inch (corresponding to 0.001 of the Sun's radius for photographs having a solar diameter of 8 inches). The position-angle is read off on a large position-circle which rotates with the photographic plate. The photograph is illuminated by diffused light reflected from white paper placed at an angle of 45° between the photograph and the plate below.

The following is the process of measurement of a photograph:—By means of the screws attached to the circular plates carrying the pillars which hold the photograph, 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 scale readings taken for the two limbs. The scale being so adjusted that its zero coincides with the centre of rotation of the position-circle, the mean of the eight readings for the limb gives the mean radius of the Sun directly.

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

The zero of position-angles for the Dallmeyer Photoheliograph, employed at Greenwich, has been determined by the measurement of a plate which had been exposed to the Sun's rays twice, with an interval of about 100 seconds between the two exposures, the instrument being firmly clamped. Two images of the Sun, overlapping each other by about a fifth part of the Sun's diameter, were therefore produced upon the plate, and the exposures having been so given that the line joining the cusps passed approximately through the centre of the plate, the inclination of the wires of the photoheliograph to this line was measured with the position-micrometer, and a small correction for the inclination of the Sun's path was then applied. The

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following table gives the correction for zero of position for the mean of the two wires as thus determined :—

Date, Greenwich Civil Time.		Correction for Zero.
	d h	° '
1895 December	2. 12	+ 3. 2
	13. 12	+ 3. 4
1896 February	10. 12	+ 3. 0
March	5. 13	+ 3. 2
April	7. 12	+ 2. 59
June	2. 12	+ 2. 58
July	4. 12	+ 3. 11
	28. 11	+ 2. 52
September	15. 11	+ 2. 59
October	26. 11	+ 3. 4
November	19. 13	+ 3. 0
December	15. 14	+ 3. 14
	31. 11	+ 2. 48
1897 February	17. 11	+ 2. 52
	17. 12	+ 2. 57

The Dallmeyer Photoheliograph has been mounted throughout the year on the terrace roof of the South wing of the new Physical Observatory.

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 very nearly 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. The position-circle was set to the reading $354^{\circ}0$ throughout 1896.

The zero of the position-circle of the micrometer 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 faculae, so as to give true position-angles.

In the use of the Photoheliographs at Dehra Dûn and in Mauritius 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 position of the wires has therefore been applied for the reduction of the photographs taken in India or in Mauritius.

The uncorrected distance from the Sun's centre for spots and faculæ is read off directly to 1-250th of an inch by means of a scale and vernier, the zero of the scale of the new micrometer being adjusted to coincide with the centre of the instrument.

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.

No correction has been applied to the 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 $c = \sin 57''.5 = \frac{1}{3600}$ 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—

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

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 $\delta R = + c \cdot \tan^2 z \times R \times \frac{1}{2} \left\{ \frac{1 + \cos 2 (\theta_0 - v)}{2} + \frac{1 + \cos 2 (\theta_0 + 90^\circ - v)}{2} \right\} = + \frac{1}{2} c R \cdot \tan^2 z$, 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—

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

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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.
0			0			0		
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.

$\theta - v$	$\theta - v$	$-\frac{\sin 2(\theta - v)}{2}$	$\frac{\cos 2(\theta - v)}{2}$	$\theta - v$	$\theta - v$	$-\frac{\sin 2(\theta - v)}{2}$	$\frac{\cos 2(\theta - v)}{2}$
0	0			0	0		
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				

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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 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 the Position-Angle (from the N. point) corrected for refraction the Position-Angle of the Sun's Axis derived 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 *sixth* and *seventh* columns give the heliographic longitude and latitude of the spot, which are thus computed.* Let r be the measured distance of a spot from the centre of the Sun's apparent disc, R the measured radius of the Sun on the photograph, (R) the tabular semidiameter of the Sun in arc, and ρ , ρ' the angular distances of a spot from the centre of the apparent disk as viewed from the Sun's centre and from the Earth respectively. Then we have—

$$\rho' = \frac{r}{R}(R); \text{ and } \sin(\rho + \rho') = \frac{r}{R},$$

$$\text{whence } \rho = \sin^{-1} \frac{r}{R} - \rho'.$$

Log $\sin \rho$ and log $\cos \rho$ as computed from this formula are given in "Tables for the Reduction of Solar Observations No. 2," by Warren De La Rue, F.R.S. Then, if D , λ are the heliographic latitudes of the Earth and the Spot respectively, referred to the Sun's Equator, and L , l the heliographic longitudes reckoned from the ascending node of the Sun's Equator on the ecliptic, and χ the position-angle from the Sun's axis, we have by the ordinary equations of spherical trigonometry—

$$\begin{aligned} \sin \lambda &= \cos \rho \sin D + \sin \rho \cos D \cos \chi \\ \sin(L - l) &= \sin \chi \sin \rho \sec \lambda. \end{aligned}$$

The quantities L and D are derived from Warren De La Rue's Auxiliary Tables before referred to, in the computation of which the following formulæ have been used—

$$\begin{aligned} \tan L &= \cos I \tan (\odot - N) \\ \sin D &= \sin I \sin (\odot - N) \end{aligned}$$

where I is the inclination of the Sun's Equator to the ecliptic, N the longitude of the ascending node, and $\odot$ the longitude of the Sun.

* Researches on Solar Physics: Heliographical Positions and Areas of Sun Spots observed with the Kew Photoheliograph during the years 1862 and 1863, by W. De La Rue, B. Stewart, and B. Loewy. Phil. Trans. 1869.

The position-angle χ is given by the formula—

$$\chi = P + G + H$$

where P is the position-angle from the north point of the Sun, and G and H two auxiliary angles given by the formulæ—

$$\begin{aligned}\tan G &= \tan \omega \cos \odot \\ \tan H &= \tan I \cos (\odot - N)\end{aligned}$$

where ω is the obliquity of the ecliptic.

It will be seen that G is the inclination of two planes through the line joining the centres of the Earth and Sun passing through the poles of the Earth and of the ecliptic respectively, and that H is the inclination of two planes through the same line and the poles of the Sun and of the ecliptic. The values assumed for I , N , ω in the computation of the Tables are $7^\circ 15'$, $74^\circ 22'$, and $23^\circ 27'.5$ respectively.

The Heliographic Longitude of the Spot is found from l , the Heliographic Longitude from Node, by subtracting the Reduction to the 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 mean noon, 1854, Jan. 1. The period of rotation assumed is 25.38 days.

The Heliographic Longitude and Latitude of the Centre of the Sun's Disk at the time of the exposure of each photograph are also given (in brackets) in the *sixth* and *seventh* columns respectively. The Longitude of the Centre of the Disk is found by subtracting the Reduction to the Prime Meridian from L , the Longitude of the Centre from the Node. The Latitude of the Centre is of course the same as D , the Heliographic Latitude of the Earth.

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 as nearly as possible 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

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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.

§ 15. *Ledgers of Areas and Positions of Groups of Sun Spots deduced from the measurement of the Solar photographs for each day in the year 1896.*

In these Ledgers the daily results for each group are collected together from the measures of the individual spots and given in a condensed form. The first column gives for each day, on which the group was observed, the Greenwich civil time at which each photograph was taken, expressed by the day of the month (civil reckoning) and the decimals of a day reckoning from Greenwich mean midnight. The second and third columns give the sums, for each day, of the projected areas of all the umbræ and whole spots comprised in the group, the projected area being the area as it is measured upon the photograph, uncorrected for foreshortening, and expressed in millionths of the Sun's apparent disk. The fourth and fifth columns give the sums for each day of the areas of all the umbræ and whole spots comprised in the group, corrected for foreshortening, and expressed in millionths of the Sun's visible hemisphere. The sixth and seventh columns give the mean longitude and latitude of the group, found by multiplying the longitude and latitude of each separately measured component of the group by its area, and dividing the sum of the products by the sum of the areas. The last column gives the mean longitude of the group from the central meridian, and is found by subtracting the longitude of the centre of the disk from the mean longitude of the group. At the foot of these daily results for each group are given the mean areas of umbræ and whole spots and the mean longitude and latitude for the period of observation.

MEASURES OF PHOTOGRAPHS OF THE SUN.

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§ 16. *Total Projected Areas of Sun Spots and Faculæ, for each day, and Mean Areas and Mean Heliographic Latitude of Sun Spots and Faculæ, for each Rotation of the Sun, and for the Year 1896.*

This section requires 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.

Royal Observatory, Greenwich,
1898 August 4.

ROYAL OBSERVATORY, GREENWICH.

TRANSIT-CIRCLE TABLES, 1896.

EQUATORIAL INTERVALS OF THE TRANSIT WIRES.

The following are the intervals determined from measures with the transit-micrometer on the North and South Collimators respectively, which were in use to April 9 :—

For Wire M	=	+	17 ^r .956	=	+	44 ^s .411
N	=	+	11.973	=	+	29.614
O	=	+	5.999	=	+	14.839
P	=	+	4.998	=	+	12.362
Q	=	+	4.002	=	+	9.898
R	=	+	2.017	=	+	4.989
S	=	+	0.999	=	+	2.471
T	=		0.000	=		0.000
U	=	—	3.004	=	—	7.430
V	=	—	3.990	=	—	9.869
W	=	—	4.968	=	—	12.288
X	=	—	6.010	=	—	14.861
Y	=	—	11.971	=	—	29.608
Z	=	—	17.943	=	—	44.379

On April 2 wires O, P, Q, R, S, T, V and X were found broken, and were renewed on April 9. The following are the intervals of the whole set of wires determined with the transit-micrometer from measures on the North and South Collimators which were in use from April 10 to July 9 :—

For Wire M	=	+	17 ^r .962	=	+	44 ^s .427
N	=	+	11.984	=	+	29.641
O	=	+	5.984	=	+	14.800
P	=	+	4.999	=	+	12.364
Q	=	+	3.985	=	+	9.856
R	=	+	2.010	=	+	4.971
S	=	+	1.011	=	+	2.501
T	=		0.000	=		0.000
U	=	—	2.982	=	—	7.375
V	=	—	3.965	=	—	9.807
W	=	—	4.979	=	—	12.315
X	=	—	5.967	=	—	14.758
Y	=	—	11.954	=	—	29.566
Z	=	—	17.951	=	—	44.398

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On July 5 wire Z was found broken and was renewed on July 9, as well as wires T, U, V, W, X and Y, which were broken while the new wire was being inserted. The following are the intervals of the whole set of wires determined with the transit-micrometer from measures on the North and South Collimators which were in use from July 10 to the end of the year :—

For Wire M	= +	17 ^r .968	= +	44 ⁿ .441
N	= +	11.990	= +	29.655
O	= +	5.990	= +	14.815
P	= +	5.003	= +	12.374
Q	= +	3.989	= +	9.866
R	= +	2.018	= +	4.991
S	= +	1.019	= +	2.520
T	=	0.000	=	0.000
U	= -	2.953	= -	7.304
V	= -	3.955	= -	9.782
W	= -	4.966	= -	12.283
X	= -	5.993	= -	14.823
Y	= -	11.933	= -	29.514
Z	= -	17.947	= -	44.389

The adopted value of $1^{\text{rev.}}$ of the micrometer is $37''.10 = 2^{\text{s}}.4733$.

OBSERVATIONS WITH THE REVERSION-PRISM EYE-PIECE, FOR THE DETERMINATION OF
PERSONALITY DEPENDING ON THE DIRECTION OF MEASUREMENT.

Comparisons of the micrometer-readings for coincidence of the Collimators with each other, when the apparent direction of measurement is changed by rotation of the reversion-prism, have been made throughout the year and the results are here discussed.

A detailed series of observations, of which the results are given in the Transit-Circle Tables for 1885, shewed that there was no sensible difference between the results obtained with different apparent directions of measurement; but in order to eliminate any personality of this kind in each observation for coincidence of Collimators and of the Transit-Circle with either N. or S. Collimator, three readings are taken with the direction of increasing readings apparently towards the right,

OBSERVATIONS WITH THE REVERSION-PRISM EYE-PIECE.

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and three with the direction apparently towards the left, the mean of the six being adopted for use. At the same time further information is obtained as to the magnitude of this personality. The following are the mean differences between the two sets of readings for coincidence of collimators in the four quarters of the year 1896, the means for previous years from 1885 being added for comparison.

The quantity tabulated is the mean excess of three readings r over three readings l .

Observer.	H T		L		H		A C		B	
	$r-l$.	No. Obs.	$r-l$.	No. Obs.	$r-l$.	No. Obs.	$r-l$.	No. Obs.	$r-l$.	No. Obs.
From observations in 1885 ...	r -0'007	36	r 0'000	115	r -0'003	131	r		r	
From observations in 1886 ...	0'000	24	+0'001	99	-0'010	112				
From observations in 1887 ...	-0'011	12	-0'004	53	0'000	68				
From observations in 1888 ...	-0'011	8	-0'001	40	+0'013	63				
From observations in 1889 ...	+0'003	3	0'000	50	+0'026	57				
From observations in 1890 ...	+0'016	12	-0'001	50	+0'032	60				
From observations in 1891 ...	+0'010	4	0'000	33	+0'029	38	+0'002	28		
From observations in 1892 ...	...	...	0'000	42	-0'001	11	-0'018	52	+0'004	45
From observations in 1893 ...	...	...	-0'037	4	+0'006	80	-0'065	90	-0'028	68
From observations in 1894 ...	...	...	...	...	-0'006	20	-0'028	20	+0'020	4
From observations in 1895 ...	...	...	...	...	+0'007	127	-0'055	119	+0'002	133
1896. Jan.-Mar. ...	...	...	...	...	+0'018	29	-0'046	33	+0'004	34
Apr.-June ...	...	...	...	...	+0'027	21	-0'047	26	+0'004	38
July-Sept. ...	...	...	...	...	+0'008	21	-0'068	24	-0'031	21
Oct.-Dec. ...	...	...	...	...	-0'016	10	-0'086	31	-0'040	32

1^{rev.} of micrometer of North Collimator = 24".24.

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APPARENT CORRECTIONS TO ADOPTED LEVEL ERRORS, DEDUCED FROM A
COMPARISON OF REFLEXION AND DIRECT OBSERVATIONS OF RIGHT
ASCENSION MADE IN THE YEAR 1896.

Name of Star.	Approx. N.P.D.	Approx. R.A.	Seconds of		R. — D.	Deduced Correction to Level Error.	Number of Observations.		Weight.
			R.	D.			R.	D.	
α Ursæ Majoris S.P. ...	-27.41	10.57	18'680	18'760	-0'080	+0'68	1	3	1
Groombridge 1806 S.P.	-26.43	11.31	48'910	49'170	-0'260	+2'05	1	1	1
Piazzi XI. 43 S.P.	-25.5	11.16	40'510	40'605	-0'095	+0'69	3	6	3
6 Ursæ Majoris S.P. ...	-24.59	8.47	42'360	42'610	-0'250	+1'75	1	1	1
Groombridge 3739 S.P.	-24.23	22.14	8'680	8'890	-0'210	+1'40	1	$\frac{1}{2}$	1
Bradley 1429 S.P.	-23.54	10.16	37'940	37'925	+0'015	-0'10	1	2	1
α Camelopardi S.P. ...	-23.50	4.44	42'350	42'480	-0'130	+0'84	1	2	1
σ^1 Ursæ Majoris S.P.	-22.42	8.59	15'660	15'740	-0'080	+0'47	2	2	2
Oeltz. Arg. (N.) 11509 S.P.	-21.10	11.5	32'380	32'452	-0'072	+0'38	3	6	3
50 Cassiopeiæ S.P.	-18.5	1.55	33'090	33'058	+0'032	-0'16	1	4	2
τ Draconis S.P.	-16.50	19.17	33'280	33'600	-0'320	+1'21	1	$\frac{1}{2}$	1
49 Cassiopeiæ S.P.	-14.23	1.55	35'230	35'400	-0'170	+0'52	1	1	1
Bradley 1446 S.P.	-13.45	10.26	14'960	15'293	-0'333	+0'95	1	3	2
γ Cephei S.P.	-12.57	23.35	4'270	4'701	-0'431	+1'15	1	$8\frac{1}{2}$	2
Groombridge 1151 S.P.	-11.55	6.24	19'030	19'467	-0'437	+1'05	1	3	2
Piazzi IV. 269 S.P. ...	-10.53	5.5	24'130	25'120	-0'990	+2'18	1	1	1
Piazzi VI. 75 S.P.	-10.19	6.28	28'880	29'065	-0'185	+0'37	1	2	1
Bradley 344 S.P.	-8.59	2.33	46'990	47'708	-0'718	+1'23	1	4	2
Piazzi VI. 334 S.P. ...	-8.53	7.15	42'800	42'650	+0'150	-0'25	1	1	1
Polaris S.P.	-1.15	1.21	52'623	54'021	-1'398	+0'29	3	95	2
Groombridge 1119 S.P.	-1.3	7.53	46'030	37'855	+8'175	-1'44	$\frac{1}{2}$	$24\frac{1}{2}$	2
Polaris	+1.15	1.21	56'860	54'229	+2'631	+0'53	2	$90\frac{1}{2}$	5
Bradley 1672	1.43	12.14	24'700	22'942	+1'758	+0'49	1	$23\frac{1}{2}$	2
Bradley 3058	6.12	22.55	13'690	13'875	-0'185	-0'18	1	2	2
Bradley 3038	7.24	22.48	53'465	53'363	+0'102	+0'11	2	4	3
ϵ Ursæ Minoris	7.47	16.56	37'890	37'610	+0'280	+0'34	1	2	2
76 Draconis	7.51	20.50	6'800	6'910	-0'110	-0'13	$\frac{1}{2}$	$2\frac{1}{2}$	2
Groombridge 3887	9.9	22.39	11'440	10'930	+0'510	+0'69	5	4	8
Lalande F. 2523	9.53	14.36	30'410	30'173	+0'237	+0'35	1	3	3
Groombridge 1735	11.38	11.2	7'510	7'090	+0'420	+0'70	1	1	2
Bradley 1508	11.40	10.51	37'780	37'680	+0'100	+0'17	1	1	2
28 Cephei	11.45	22.26	55'470	55'530	-0'060	-0'10	1	2	2
Bradley 1634	11.48	12.7	19'670	19'297	+0'373	+0'62	1	3	3
4 Ursæ Minoris	11.58	14.9	15'030	15'207	-0'177	-0'30	1	3	3
θ Ursæ Minoris	12.18	15.34	30'330	29'925	+0'405	+0'71	1	4	3
Groombridge 2140	12.59	14.32	53'907	54'183	-0'276	-0'51	$1\frac{1}{2}$	3	3
5 Ursæ Minoris	13.50	14.28	44'690	44'623	+0'067	+0'13	3	3	5
Bradley 1147	13.55	8.6	29'010	28'110	+0'900	+1'77	1	1	2
Piazzi IV. 112	14.14	4.34	50'150	50'295	-0'145	-0'29	1	2	2
Bradley 1650	14.16	12.14	10'040	9'470	+0'570	+1'14	1	1	2
3 Ursæ Minoris	14.55	14.6	7'050	7'125	-0'075	-0'15	1	2	2
β Ursæ Minoris	15.25	14.51	0'390	0'326	+0'064	+0'15	2	12	5
10 Ursæ Minoris	15.42	15.5	40'420	40'440	-0'020	-0'04	1	1	2
Bradley 417	16.0	3.1	40'000	39'473	+0'527	+1'17	1	3	3
Groombridge 2719	16.2	18.48	22'230	22'125	+0'105	+0'24	1	2	2
79 Draconis	16.47	21.52	34'020	34'000	+0'020	+0'05	1	3	3
τ Draconis	16.50	19.17	33'248	33'078	+0'170	+0'38	4	8	6
Piazzi XIII. 109	17.4	13.23	29'190	28'880	+0'310	+0'72	$\frac{1}{2}$	1	2

APPARENT CORRECTIONS TO ADOPTED LEVEL ERRORS.

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APPARENT CORRECTIONS TO ADOPTED LEVEL ERRORS, DEDUCED FROM A
COMPARISON OF REFLEXION AND DIRECT OBSERVATIONS OF RIGHT
ASCENSION MADE IN THE YEAR 1896—continued.

Name of Star.	Approx. N.P.D.	Approx. R.A.	Seconds of		R. — D.	Deduced Correction to Level Error.	Number of Observations.		Weight.
			R.	D.			R.	D.	
16 Cephei	17. 19	21. 57	45 ^s .653	45 ^s .960	—0 ^s .307	—0 ^s .72	1 ¹ / ₂	2	3
γ Ursæ Minoris	17. 48	15. 21	53 ^s .570	53 ^s .414	+0 ^s .156	+0 ^s .38	1	10	3
ψ ¹ Draconis	17. 48	17. 44	47 ^s .010	47 ^s .205	—0 ^s .195	—0 ^s .48	1	2	3
50 Cassiopeiæ	18. 5	1. 55	33 ^s .280	33 ^s .060	+0 ^s .220	+0 ^s .54	1	5	3
Groombridge 2029.....	18. 13	13. 34	41 ^s .245	40 ^s .838	+0 ^s .407	+0 ^s .99	2	2	4
Bradley 2934	18. 24	22. 8	12 ^s .795	12 ^s .900	—0 ^s .105	—0 ^s .26	2	4 ¹ / ₂	4
19 Lyræ	58. 53	19. 8	46 ^s .600	46 ^s .670	—0 ^s .070	—0 ^s .47	1	2	2
32 Herculis.....	59. 17	16. 29	25 ^s .920	25 ^s .880	+0 ^s .040	+0 ^s .27	1	1	2
τ Geminorum.....	59. 35	7. 4	31 ^s .320	31 ^s .210	+0 ^s .110	+0 ^s .75	1	3	3
ξ Cygni	60. 11	21. 8	30 ^s .570	30 ^s .549	+0 ^s .021	+0 ^s .15	1	22 ¹ / ₂	3
β Coronæ	60. 32	15. 23	32 ^s .410	32 ^s .393	+0 ^s .017	+0 ^s .13	1	4	3
α Andromedæ	61. 29	0. 3	0 ^s .630	0 ^s .613	+0 ^s .017	+0 ^s .13	1	18	3
β Comæ	61. 35	13. 7	1 ^s .070	1 ^s .201	—0 ^s .131	—0 ^s .93	1	8	3
53 Geminorum	61. 55	7. 9	27 ^s .400	27 ^s .510	—0 ^s .110	—0 ^s .78	1	3	3
ι Geminorum.....	61. 59	7. 19	16 ^s .000	16 ^s .088	—0 ^s .088	—0 ^s .62	1	6	3
9 Boötis	62. 0	13. 51	49 ^s .240	49 ^s .245	—0 ^s .005	—0 ^s .04	1	4	3
11 Boötis	62. 6	13. 56	27 ^s .590	27 ^s .500	+0 ^s .090	+0 ^s .64	1	3	3
β Cygni	62. 15	19. 26	31 ^s .510	31 ^s .613	—0 ^s .103	—0 ^s .74	1	3	3
Bradley 2474	62. 15	19. 26	33 ^s .770	33 ^s .780	—0 ^s .010	—0 ^s .07	1	2	2
ε ² Boötis	62. 29	14. 40	26 ^s .580	26 ^s .672	—0 ^s .092	—0 ^s .66	1	24 ¹ / ₂	3
μ Leonis	63. 30	9. 46	51 ^s .000	50 ^s .957	+0 ^s .043	+0 ^s .32	1	12	3
3 Boötis	63. 46	13. 41	53 ^s .620	53 ^s .558	+0 ^s .062	+0 ^s .45	1	4	3
δ Boötis	64. 24	14. 5	39 ^s .285	39 ^s .339	—0 ^s .054	—0 ^s .40	2	9	5
16 Pegasi.....	64. 34	21. 48	19 ^s .710	19 ^s .750	—0 ^s .040	—0 ^s .30	1	10	3
ω Boötis	64. 34	14. 57	32 ^s .970	33 ^s .140	—0 ^s .170	—1 ^s .27	2	5	4
54 Leonis.....	64. 42	10. 49	59 ^s .010	58 ^s .923	+0 ^s .087	+0 ^s .65	1	8	3
κ Pegasi	64. 49	21. 40	56 ^s .150	56 ^s .105	+0 ^s .045	+0 ^s .34	1	2	2
11 Tauri	65. 0	3. 35	33 ^s .520	33 ^s .517	+0 ^s .003	+0 ^s .03	1	3	3
30 Vulpeculæ.....	65. 6	20. 40	22 ^s .350	22 ^s .410	—0 ^s .060	—0 ^s .45	1	2	2
α Vulpeculæ	65. 33	19. 24	22 ^s .630	22 ^s .624	+0 ^s .006	+0 ^s .05	1	9	3
ε Leonis	65. 44	9. 40	56 ^s .850	56 ^s .905	—0 ^s .055	—0 ^s .42	1	19	3
41 Leonis Minoris.....	66. 16	10. 37	45 ^s .650	45 ^s .688	—0 ^s .038	—0 ^s .29	1	4	3
Piazzi XVIII. 132	66. 29	18. 31	10 ^s .580	10 ^s .675	—0 ^s .095	—0 ^s .74	1	2	2
α Arietis	67. 1	2. 1	18 ^s .580	18 ^s .517	+0 ^s .063	+0 ^s .50	1	20	3
92 Leonis	68. 4	11. 35	22 ^s .440	22 ^s .573	—0 ^s .133	—1 ^s .06	1	3	3
109 Herculis	68. 17	18. 19	15 ^s .875	15 ^s .917	—0 ^s .042	—0 ^s .33	2	7	5
δ Leonis	68. 54	11. 8	34 ^s .673	34 ^s .649	+0 ^s .024	+0 ^s .19	3	21	6
β Arietis	69. 42	1. 49	53 ^s .700	53 ^s .579	+0 ^s .121	+0 ^s .98	1	15	3
ι Serpentis	70. 0	15. 37	54 ^s .705	54 ^s .767	—0 ^s .062	—0 ^s .50	4	10	6
Arcturus	70. 17	14. 11	55 ^s .110	55 ^s .015	+0 ^s .095	+0 ^s .79	1	42	2
γ Herculis	70. 36	16. 17	19 ^s .830	19 ^s .881	—0 ^s .051	—0 ^s .43	1	11	2
ω ¹ Tauri	70. 40	4. 3	6 ^s .330	6 ^s .370	—0 ^s .040	—0 ^s .33	1	2	2
η Boötis	71. 5	13. 49	43 ^s .950	43 ^s .939	+0 ^s .011	+0 ^s .10	1	18	2
κ Serpentis	71. 32	15. 44	3 ^s .490	3 ^s .468	+0 ^s .022	+0 ^s .18	3	9	5
γ Herculis	71. 54	15. 56	33 ^s .885	33 ^s .892	—0 ^s .007	—0 ^s .07	4	6	5
111 Herculis	71. 56	18. 42	25 ^s .540	25 ^s .668	—0 ^s .128	—1 ^s .07	1	4	2
τ Boötis	72. 1	13. 42	19 ^s .260	19 ^s .174	+0 ^s .086	+0 ^s .73	1	7	2
Piazzi XII. 20.....	72. 31	12. 10	56 ^s .320	56 ^s .400	—0 ^s .080	—0 ^s .68	1	2	2

APPARENT CORRECTIONS TO ADOPTED LEVEL ERRORS, DEDUCED FROM A
COMPARISON OF REFLEXION AND DIRECT OBSERVATIONS OF RIGHT
ASCENSION MADE IN THE YEAR 1896—concluded.

Name of Star.	Approx. N.P.D.	Approx. R.A.	Seconds of		R. — D.	Deduced Correction to Level Error.	Number of Observations.		Weight.
			R.	D.			R.	D.	
3 Comæ	72. 37	12. 5	13'640	13'556	+0'084	+0'75	6	13	7
κ Herculis	72. 40	16. 3	22'800	22'839	-0'039	-0'34	2	7	4
γ Geminorum.....	73. 30	6. 31	42'200	42'117	+0'083	+0'72	1	18	2
ν Boötis	73. 41	13. 44	27'620	27'670	-0'050	-0'43	1	1	2
6 Comæ	74. 31	12. 10	43'340	43'266	+0'074	+0'65	5	7	6
Bradley 2667	74. 32	20. 34	15'390	15'470	-0'080	-0'70	1	5	2
β Leonis	74. 50	11. 43	45'170	45'278	-0'108	-0'95	1	24	2
α ¹ Herculis	75. 29	17. 10	54'360	54'280	+0'080	+0'71	1	9	2
ζ Boötis	75. 50	14. 36	10'930	10'893	+0'037	+0'34	1	11	2
ζ Aquilæ	76. 17	19. 0	37'743	37'765	-0'022	-0'24	6	23	8
Regulus	77. 31	10. 2	50'020	50'003	+0'017	+0'17	1	30½	2
α Cancri	77. 44	8. 52	47'930	47'943	-0'013	-0'13	1	8	2
δ Aquilæ.....	78. 16	19. 20	0'690	0'677	+0'013	+0'13	1	3	2
ε Virginis.....	78. 29	12. 57	59'897	59'951	-0'054	-0'51	3	15	6
ω Aquilæ.....	78. 35	19. 13	56'087	56'053	+0'034	+0'30	6	18	8
δ Serpentis (N. Star)...	79. 6	15. 29	50'120	49'917	+0'203	+1'94	1	3	2
ο Leonis	79. 38	9. 35	35'980	36'005	-0'025	-0'27	1	12	2
γ Aquilæ.....	79. 38	19. 41	18'815	18'913	-0'098	-0'95	2	13	4
κ Ophiuchi	80. 27	16. 52	44'710	44'673	+0'037	+0'37	1	16	2
ε Pegasi	80. 36	21. 39	4'610	4'598	+0'012	+0'12	1	8	2
ο Virginis	80. 41	12. 0	54'670	54'675	-0'005	-0'05	1	14	2
α Aquilæ.....	81. 24	19. 45	42'530	42'505	+0'025	+0'26	2	20	4
κ Herculis	82. 34	16. 45	16'400	16'333	+0'067	+0'69	1	4	2
α Orionis.....	82. 37	5. 50	32'510	32'427	+0'083	+0'86	1	28	2
ζ ¹ Piscium	82. 58	1. 8	17'830	17'695	+0'135	+1'39	1	2	1
δ Piscium	82. 59	0. 43	17'190	17'145	+0'045	+0'47	1	4	2
ζ Hydræ	83. 39	8. 49	53'810	53'733	+0'077	+0'81	1	9	2
Procyon	84. 30	7. 33	51'540	51'530	+0'010	+0'11	2	26	4
δ Virginis	86. 2	12. 50	21'760	21'835	-0'075	-0'83	1	17	2
δ Aquilæ.....	87. 5	19. 20	15'360	15'243	+0'117	+1'32	1	11	2
ζ Virginis	90. 3	13. 29	23'630	23'559	+0'071	+0'86	1	14	2
ι Hydræ	90. 40	9. 34	32'643	32'670	-0'027	-0'34	3	11	4
τ ² Hydræ.....	90. 43	9. 26	4'785	4'792	-0'007	-0'10	4	5	4
φ Virginis	91. 46	14. 23	50'530	50'602	-0'072	-0'88	1	5	2
η Serpentis	92. 55	18. 16	55'720	55'662	+0'058	+0'73	1	34	2
69 Aquilæ	93. 14	20. 24	12'790	12'815	-0'025	-0'33	1	2	1
6 Aquilæ.....	94. 52	18. 41	39'290	39'390	-0'100	-1'32	1	2	1
3 Aquarii.....	95. 24	20. 42	14'840	15'005	-0'165	-2'25	1	2	1
12 Aquilæ	95. 53	18. 56	7'370	7'585	-0'215	-3'00	1	2	1
ε Orionis	97. 54	5. 19	56'160	56'070	+0'090	+1'28	1	1	1
1 Aquilæ.....	98. 19	18. 29	32'808	32'825	-0'017	-0'29	6	6	4
Rigel	98. 19	5. 10	32'320	32'368	-0'048	-0'70	1	18½	2
ψ Virginis	98. 58	12. 49	56'600	56'594	+0'006	+0'09	1	8	2
2 Aquilæ.....	99. 9	18. 36	34'703	34'693	+0'010	+0'15	3	12	3
ι Ceti	99. 24	0. 14	7'570	7'725	-0'155	-2'35	1	2	1
Spica	100. 37	13. 20	42'720	42'754	-0'034	-0'53	1	23	2
χ Ceti	101. 12	1. 44	28'540	28'525	+0'015	+0'25	1	8	2
λ Hydræ	101. 50	10. 5	31'020	31'045	-0'025	-0'42	1	2	1
μ Capricorni	104. 2	21. 47	37'590	37'558	+0'032	+0'56	1	4	2
ι Aquarii.....	104. 22	22. 0	49'230	49'240	-0'010	-0'18	1	2	1
η Ophiuchi	105. 36	17. 4	24'790	24'737	+0'053	+1'02	1	11	2

The weights used have been determined as follows :—

Putting m and n for the number of reflexion and direct observations respectively, the weight to be given to each Star, in deducing the mean correction to level error, is $\frac{4mn}{m+n+\frac{1}{2}mn} \times \cos. ZD$, which has been adopted for use to the nearest integer.

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

From 93 South Stars, Mean Correction to Level Error $-0''.04$, weight 261.

„ 54 North Stars, „ „ $+0''.38$, „ 134.

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FACTORS FOR INSTRUMENTAL ERRORS.

N.P.D.	Collimation.	Level.	Azimuth.	N.P.D.	Collimation.	Level.	Azimuth.
	$\frac{1}{15 \sin \text{N.P.D.}}$	$\frac{\cos \text{Z. D.}}{15 \sin \text{N.P.D.}}$	$\frac{\sin \text{Z. D.}}{15 \sin \text{N.P.D.}}$		$\frac{1}{15 \sin \text{N.P.D.}}$	$\frac{\cos \text{Z. D.}}{15 \sin \text{N.P.D.}}$	$\frac{\sin \text{Z. D.}}{15 \sin \text{N.P.D.}}$
—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.

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FACTORS FOR INSTRUMENTAL ERRORS—concluded.

N.P.D.	Collimation.	Level.	Azimuth.	N.P.D.	Collimation.	Level.	Azimuth.
	$\frac{1}{15 \sin N.P.D.}$	$\frac{\cos Z. D.}{15 \sin N.P.D.}$	$\frac{\sin Z. D.}{15 \sin N.P.D.}$		$\frac{1}{15 \sin N.P.D.}$	$\frac{\cos Z. D.}{15 \sin N.P.D.}$	$\frac{\sin Z. D.}{15 \sin N.P.D.}$
37. °	+0.111	+0.111	-0.003	82. °	+0.067	+0.049	+0.046
38. °	+0.108	+0.108	-0.001	83. °	+0.067	+0.048	+0.047
39. °	+0.106	+0.106	+0.001	84. °	+0.067	+0.047	+0.048
40. °	+0.104	+0.104	+0.003	85. °	+0.067	+0.046	+0.048
41. °	+0.102	+0.101	+0.004	86. °	+0.067	+0.045	+0.049
42. °	+0.100	+0.099	+0.006	87. °	+0.067	+0.044	+0.050
43. °	+0.098	+0.097	+0.007	88. °	+0.067	+0.043	+0.051
44. °	+0.096	+0.096	+0.009	89. °	+0.067	+0.042	+0.052
45. °	+0.094	+0.094	+0.011	90. °	+0.067	+0.041	+0.052
46. °	+0.093	+0.092	+0.012	91. °	+0.067	+0.040	+0.053
47. °	+0.091	+0.090	+0.013	92. °	+0.067	+0.040	+0.054
48. °	+0.090	+0.088	+0.015	93. °	+0.067	+0.039	+0.054
49. °	+0.088	+0.087	+0.016	94. °	+0.067	+0.038	+0.055
50. °	+0.087	+0.085	+0.017	95. °	+0.067	+0.037	+0.056
51. °	+0.086	+0.084	+0.018	96. °	+0.067	+0.036	+0.057
52. °	+0.085	+0.082	+0.020	97. °	+0.067	+0.035	+0.057
53. °	+0.083	+0.081	+0.021	98. °	+0.067	+0.034	+0.058
54. °	+0.082	+0.080	+0.022	99. °	+0.067	+0.033	+0.059
55. °	+0.081	+0.078	+0.023	100. °	+0.068	+0.032	+0.060
56. °	+0.080	+0.077	+0.024	101. °	+0.068	+0.031	+0.060
57. °	+0.080	+0.075	+0.025	102. °	+0.068	+0.030	+0.061
58. °	+0.079	+0.074	+0.026	103. °	+0.068	+0.029	+0.062
59. °	+0.078	+0.073	+0.027	104. °	+0.069	+0.028	+0.063
60. °	+0.077	+0.072	+0.028	105. °	+0.069	+0.027	+0.063
61. °	+0.076	+0.070	+0.029	106. °	+0.069	+0.027	+0.064
62. °	+0.076	+0.069	+0.030	107. °	+0.070	+0.026	+0.065
63. °	+0.075	+0.068	+0.031	108. °	+0.070	+0.025	+0.066
64. °	+0.074	+0.067	+0.032	109. °	+0.071	+0.024	+0.066
65. °	+0.073	+0.066	+0.033	110. °	+0.071	+0.023	+0.067
66. °	+0.073	+0.065	+0.034	111. °	+0.072	+0.022	+0.068
67. °	+0.072	+0.064	+0.035	112. °	+0.072	+0.021	+0.069
68. °	+0.072	+0.063	+0.035	113. °	+0.073	+0.020	+0.070
69. °	+0.071	+0.061	+0.036	114. °	+0.073	+0.018	+0.071
70. °	+0.071	+0.060	+0.037	115. °	+0.074	+0.017	+0.072
71. °	+0.071	+0.059	+0.038	116. °	+0.075	+0.016	+0.072
72. °	+0.070	+0.058	+0.039	117. °	+0.075	+0.015	+0.073
73. °	+0.070	+0.057	+0.039	118. °	+0.076	+0.014	+0.074
74. °	+0.069	+0.056	+0.040	119. °	+0.076	+0.013	+0.075
75. °	+0.069	+0.055	+0.041	120. °	+0.077	+0.012	+0.076
76. °	+0.069	+0.054	+0.042	121. °	+0.078	+0.011	+0.077
77. °	+0.068	+0.053	+0.043	122. °	+0.079	+0.009	+0.078
78. °	+0.068	+0.053	+0.043	123. °	+0.080	+0.008	+0.079
79. °	+0.068	+0.052	+0.044	124. °	+0.080	+0.007	+0.080
80. °	+0.068	+0.051	+0.045	125. °	+0.081	+0.005	+0.081
81. °	+0.067	+0.050	+0.045	126. °	+0.082	+0.004	+0.082
82. °	+0.067	+0.049	+0.046				

cxii INTRODUCTION TO GREENWICH ASTRONOMICAL OBSERVATIONS, 1896.

ASSUMED MEAN RIGHT ASCENSIONS OF CLOCK STARS AND CIRCUMPOLAR STARS
WITH THE CORRECTIONS TO THE R.A. OF THE NAUTICAL ALMANAC, FOR 1896^o.

Star's Name.	Assumed Mean R.A. 1896 ^o .	Correction to N.A.	Star's Name.	Assumed Mean R.A. 1896 ^o .	Correction to N.A.
	h m s	s		h m s	s
α Andromedæ	0. 3. 0 ^h 62 ^m 3	0 ^h 00 ^m 00 ^s	ω^1 Tauri	4. 3. 6 ^h 32 ^m 0	
γ Pegasi.....	0. 7. 52 ^h 74 ^m 6	0 ^h 00 ^m 00 ^s	ϕ^1 Eridani	4. 6. 47 ^h 25 ^m 9	— 0 ^h 00 ^m 1
ι Ceti	0. 14. 7 ^h 67 ^m 5	0 ^h 00 ^m 00 ^s	γ Tauri	4. 13. 52 ^h 37 ^m 8	0 ^h 00 ^m 0
44 Piscium	0. 20. 4 ^h 22 ^m 8		ϵ Tauri	4. 22. 32 ^h 54 ^m 9	— 0 ^h 00 ^m 2
12 Ceti	0. 24. 43 ^h 82 ^m 3	0 ^h 00 ^m 00 ^s	Aldebaran.....	4. 29. 57 ^h 09 ^m 2	+ 0 ^h 00 ^m 1
ϵ Andromedæ	0. 33. 3 ^h 48 ^m 6		τ Tauri	4. 36. 0 ^h 08 ^m 8	
β Ceti.....	0. 38. 22 ^h 13 ^m 1	0 ^h 00 ^m 00 ^s	μ Eridani	4. 40. 18 ^h 07 ^m 5	0 ^h 00 ^m 0
δ Piscium	0. 43. 17 ^h 09 ^m 9	0 ^h 00 ^m 00 ^s	ι Aurigæ	4. 50. 13 ^h 17 ^m 3	0 ^h 00 ^m 0
20 Ceti	0. 47. 41 ^h 49 ^m 6		ϵ Leporis	5. 1. 3 ^h 46 ^m 0	0 ^h 00 ^m 0
μ Andromedæ	0. 50. 58 ^h 63 ^m 4		Rigel	5. 9. 32 ^h 34 ^m 0	— 0 ^h 00 ^m 1
ϵ Piscium	0. 57. 32 ^h 64 ^m 7	0 ^h 00 ^m 00 ^s	β Tauri	5. 19. 43 ^h 00 ^m 7	0 ^h 00 ^m 0
β Andromedæ	1. 3. 54 ^h 42 ^m 8	0 ^h 00 ^m 00 ^s	δ Orionis	5. 26. 41 ^h 50 ^m 3	0 ^h 00 ^m 0
ζ^1 Piscium	1. 8. 17 ^h 73 ^m 5		α Leporis	5. 28. 8 ^h 55 ^m 2	+ 0 ^h 00 ^m 1
θ Ceti	1. 18. 49 ^h 43 ^m 3	— 0 ^h 00 ^m 2	ϵ Orionis	5. 30. 56 ^h 12 ^m 9	+ 0 ^h 00 ^m 1
Polaris	1. 20. 53 ^h 84 ^m 5	+ 0 ^h 04 ^m 6	α Columbæ	5. 35. 53 ^h 03 ^m 8	+ 0 ^h 02 ^m 3
η Piscium	1. 25. 54 ^h 98 ^m 0	+ 0 ^h 00 ^m 4	κ Orionis	5. 42. 49 ^h 40 ^m 0	+ 0 ^h 00 ^m 1
ν Piscium	1. 36. 1 ^h 04 ^m 4	0 ^h 00 ^m 00 ^s	α Orionis	5. 49. 32 ^h 44 ^m 8	0 ^h 00 ^m 0
ϕ Piscium	1. 39. 53 ^h 98 ^m 6	0 ^h 00 ^m 00 ^s	ι Geminorum	5. 57. 47 ^h 85 ^m 1	
β Arietis	1. 48. 53 ^h 56 ^m 4	— 0 ^h 00 ^m 1	ν Orionis	6. 1. 37 ^h 97 ^m 7	0 ^h 00 ^m 0
α Arietis.....	2. 1. 18 ^h 53 ^m 7	— 0 ^h 00 ^m 1	η Geminorum	6. 8. 35 ^h 96 ^m 7	0 ^h 00 ^m 0
ξ^1 Ceti.....	2. 7. 29 ^h 13 ^m 9		μ Geminorum	6. 16. 40 ^h 08 ^m 1	0 ^h 00 ^m 0
67 Ceti	2. 11. 47 ^h 69 ^m 1	0 ^h 00 ^m 00 ^s	β Canis Majoris ...	6. 18. 7 ^h 13 ^m 3	
ξ^2 Ceti.....	2. 22. 37 ^h 66 ^m 2	— 0 ^h 00 ^m 1	ν Geminorum	6. 22. 47 ^h 25 ^m 4	
ν Ceti	2. 30. 24 ^h 88 ^m 8		γ Geminorum	6. 31. 42 ^h 19 ^m 7	— 0 ^h 00 ^m 9
δ Ceti	2. 34. 9 ^h 03 ^m 3		ξ Geminorum	6. 39. 27 ^h 10 ^m 0	0 ^h 00 ^m 0
γ^2 Ceti.....	2. 37. 54 ^h 60 ^m 4	+ 0 ^h 00 ^m 1	θ Canis Majoris ...	6. 49. 21 ^h 42 ^m 0	0 ^h 00 ^m 0
σ Arietis.....	2. 45. 44 ^h 92 ^m 6	0 ^h 00 ^m 00 ^s	Cephei 51	6. 51. 45 ^h 33 ^m 3	+ 0 ^h 03 ^m 0
ϵ Arietis.....	2. 53. 15 ^h 79 ^m 4		ϵ Canis Majoris.....	6. 54. 32 ^h 25 ^m 1	— 0 ^h 01 ^m 6
α Ceti	2. 56. 50 ^h 49 ^m 5	+ 0 ^h 00 ^m 1	ζ Geminorum	6. 57. 56 ^h 40 ^m 7	
δ Arietis.....	3. 5. 40 ^h 79 ^m 3	— 0 ^h 00 ^m 1	γ Canis Majoris ...	6. 59. 3 ^h 12 ^m 7	0 ^h 00 ^m 0
τ^1 Arietis	3. 15. 13 ^h 25 ^m 0		51 Geminorum.....	7. 7. 23 ^h 93 ^m 7	
ϕ Tauri	3. 19. 12 ^h 88 ^m 6	— 0 ^h 00 ^m 1	δ Geminorum	7. 13. 54 ^h 69 ^m 1	0 ^h 00 ^m 0
f Tauri	3. 25. 7 ^h 77 ^m 0		β Canis Minoris ...	7. 21. 30 ^h 61 ^m 8	— 0 ^h 00 ^m 6
ϵ Eridani	3. 28. 1 ^h 75 ^m 5	0 ^h 00 ^m 00 ^s	Castor	7. 27. 57 ^h 86 ^m 7	+ 0 ^h 00 ^m 1
11 Tauri.....	3. 34. 33 ^h 50 ^m 9		Procyon.....	7. 33. 51 ^h 54 ^m 8	+ 0 ^h 02 ^m 1
δ Eridani	3. 38. 15 ^h 89 ^m 4		Pollux	7. 38. 57 ^h 14 ^m 1	+ 0 ^h 00 ^m 1
η Tauri	3. 41. 18 ^h 04 ^m 1	0 ^h 00 ^m 00 ^s	ξ Argus	7. 44. 55 ^h 16 ^m 6	0 ^h 00 ^m 0
γ^1 Eridani	3. 53. 10 ^h 54 ^m 9	0 ^h 00 ^m 00 ^s	Groombridge 1119..	7. 53. 38 ^h 06 ^m 8	
A^1 Tauri	3. 58. 32 ^h 71 ^m 6	— 0 ^h 00 ^m 1	6 Cancri.....	7. 57. 7 ^h 85 ^m 3	— 0 ^h 00 ^m 1

NOTE.—The Right Ascensions are deduced from the adopted Mean R.A. 1890^o in the Five-Year Catalogue of 258 Fundamental Stars for 1890, with the exception of the Five Polar stars. Groombridge 1119, Bradley 1672, Groombridge 2283, Groombridge 3548 and Bradley 3147, for which the Mean R.A. has been deduced from all the observations in the years 1887-1894. The Proper Motions are taken from Prof. Auwers' "Neue Reduction der Bradleyschen Beobachtungen, Erster Band," for all stars contained in that work except μ Andromedæ, for which Mr. Main's Proper Motion is used. For Cephei 51 the Proper Motion is taken from Prof. Auwers' "Catalog der Fundamental Sterne" and for α Columbæ and δ Sculptoris from the Cape Catalogue, 1880. For Groombridge 1119, Groombridge 2283, and Groombridge 3548, provisional Proper Motions derived from a comparison with Groombridge's, the Radcliffe and Carrington's Catalogues have been adopted, viz. :— $-0^s.1126$ for Groombridge 1119, $+0^s.0070$ for Groombridge 2283, and $+0^s.0334$ for Groombridge 3548.

ASSUMED RIGHT ASCENSIONS OF CLOCK STARS.

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ASSUMED MEAN RIGHT ASCENSIONS OF CLOCK STARS AND CIRCUMPOLAR STARS
WITH THE CORRECTIONS TO THE R.A. OF THE NAUTICAL ALMANAC, FOR 1896^o
—continued.

Star's Name.	Assumed Mean R.A. 1896 ^o .	Correction to N.A.	Star's Name.	Assumed Mean R.A. 1896 ^o .	Correction to N.A.
	h m s	s		h m s	s
ρ Argûs	8. 3. 6840	0 ^o 000	τ Boötis	13. 42. 19 ^o 161	0 ^o 000
β Cancri	8. 10. 52 ^o 479	0 ^o 000	η Boötis	13. 49. 43 ^o 944	+ 0 ^o 001
δ^1 Cancri	8. 17. 24 ^o 515		τ Virginis	13. 56. 21 ^o 143	0 ^o 000
γ Cancri	8. 26. 41 ^o 691	0 ^o 000	η Virginis	14. 0. 47 ^o 241	
γ Cancri	8. 37. 16 ^o 063	+ 0 ^o 001	κ Virginis	14. 7. 20 ^o 778	
ϵ Hydræ	8. 41. 16 ^o 056	+ 0 ^o 001	Arcturus	14. 10. 55 ^o 029	0 ^o 000
α Cancri	8. 52. 47 ^o 970	— 0 ^o 001	f Boötis	14. 21. 37 ^o 085	0 ^o 000
κ Cancri	9. 2. 6 ^o 870	— 0 ^o 001	ρ Boötis	14. 27. 20 ^o 849	0 ^o 000
δ^3 Cancri	9. 13. 10 ^o 606	0 ^o 000	ϵ^2 Boötis	14. 40. 26 ^o 673	0 ^o 000
α Hydræ	9. 22. 28 ^o 569	0 ^o 000	α Libræ	14. 45. 7 ^o 412	0 ^o 000
ξ Leonis	9. 26. 20 ^o 382		ξ^2 Libræ	14. 51. 7 ^o 410	
σ Leonis	9. 35. 35 ^o 984	0 ^o 000	ψ Boötis	14. 59. 59 ^o 351	0 ^o 000
ϵ Leonis	9. 39. 56 ^o 894	0 ^o 000	ι^1 Libræ	15. 6. 17 ^o 482	
μ Leonis	9. 46. 50 ^o 943	0 ^o 000	Groombridge 2283 ..	15. 10. 43 ^o 421	
π Leonis	9. 54. 43 ^o 040	0 ^o 000	β Libræ	15. 11. 24 ^o 524	0 ^o 000
Regulus	10. 2. 50 ^o 000	0 ^o 000	σ^2 Libræ	15. 17. 13 ^o 630	
γ^1 Leonis	10. 14. 14 ^o 340	+ 0 ^o 002	ζ^1 Libræ	15. 22. 23 ^o 380	
μ Hydræ	10. 21. 3 ^o 572	0 ^o 000	α Coronæ	15. 30. 17 ^o 028	+ 0 ^o 002
ρ Leonis	10. 27. 20 ^o 102	+ 0 ^o 001	α Serpentis	15. 39. 8 ^o 670	— 0 ^o 001
34 Sextantis	10. 37. 15 ^o 247		ϵ Serpentis	15. 45. 37 ^o 844	0 ^o 000
ι Leonis	10. 43. 47 ^o 438	0 ^o 000	γ Serpentis	15. 51. 38 ^o 923	
δ Leonis	10. 55. 11 ^o 344	— 0 ^o 001	β^1 Scorpii	15. 59. 23 ^o 223	— 0 ^o 005
χ Leonis	10. 59. 39 ^o 113	0 ^o 000	δ Ophiuchi	16. 8. 53 ^o 618	— 0 ^o 001
δ Leonis	11. 8. 34 ^o 670	0 ^o 000	γ Herculis	16. 17. 19 ^o 867	0 ^o 000
δ Crateris	11. 14. 8 ^o 388	0 ^o 000	Antares	16. 23. 1 ^o 741	+ 0 ^o 005
τ Leonis	11. 22. 35 ^o 301	0 ^o 000	λ Ophiuchi	16. 25. 40 ^o 009	
ν Leonis	11. 31. 37 ^o 365	0 ^o 000	ζ Ophiuchi	16. 31. 25 ^o 841	0 ^o 000
β Leonis	11. 43. 45 ^o 283	+ 0 ^o 001	κ Herculis	16. 37. 21 ^o 895	0 ^o 000
β Virginis	11. 45. 16 ^o 636		ζ Ophiuchi	16. 52. 44 ^o 672	— 0 ^o 001
π Virginis	11. 55. 32 ^o 584	0 ^o 000	ϵ Herculis	16. 56. 18 ^o 570	
σ Virginis	11. 59. 54 ^o 661		η Ophiuchi	17. 4. 24 ^o 706	+ 0 ^o 004
ϵ Corvi	12. 4. 46 ^o 473	+ 0 ^o 001	α^1 Herculis	17. 9. 54 ^o 262	— 0 ^o 002
Bradley 1672	12. 14. 22 ^o 768		θ Ophiuchi	17. 15. 37 ^o 244	— 0 ^o 001
η Virginis	12. 14. 35 ^o 036	0 ^o 000	σ Ophiuchi	17. 21. 21 ^o 204	0 ^o 000
δ^2 Corvi	12. 24. 28 ^o 914	0 ^o 000	α Ophiuchi	17. 30. 6 ^o 353	+ 0 ^o 001
β Corvi	12. 28. 55 ^o 355	0 ^o 000	β Ophiuchi	17. 38. 20 ^o 035	+ 0 ^o 002
ρ Virginis	12. 36. 37 ^o 197		μ Herculis	17. 42. 23 ^o 240	0 ^o 000
35 Virginis	12. 42. 33 ^o 634		89 Herculis	17. 51. 13 ^o 420	
31 Comæ	12. 46. 37 ^o 970		72 Ophiuchi	18. 2. 25 ^o 099	0 ^o 000
δ Virginis	12. 50. 21 ^o 840	— 0 ^o 001	δ Ursæ Minoris	18. 5. 50 ^o 650	— 0 ^o 019
ϵ Virginis	12. 56. 59 ^o 974	0 ^o 000	μ Sagittarii	18. 7. 32 ^o 569	— 0 ^o 001
θ Virginis	13. 4. 33 ^o 819	0 ^o 000	η Serpentis	18. 15. 55 ^o 626	0 ^o 000
Spica	13. 19. 42 ^o 765	0 ^o 000	λ Sagittarii	18. 21. 33 ^o 078	— 0 ^o 047
ζ Virginis	13. 29. 23 ^o 547	— 0 ^o 002	α Lyrae	18. 33. 25 ^o 006	0 ^o 000
m Virginis	13. 36. 9 ^o 102		2 Aquilæ	18. 36. 34 ^o 703	

The correction to the R.A. of Procyon for the effect of orbital motion from 1890 (the epoch of the Five-Year Catalogue) to 1896 is + 0^o020. This correction is derived from Prof. Auwers' Elements (*Astronomische Nachrichten*, Nos. 1371, 1372, 1373).

The Right Ascensions of the Nautical Almanac for 1896^o are derived from an advance MS. copy of the Greenwich Five-Year Catalogue, epoch 1890, except for stars south of N.P.D. 115°.

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ASSUMED MEAN RIGHT ASCENSIONS OF CLOCK STARS AND CIRCUMPOLAR STARS,
WITH THE CORRECTIONS TO THE R.A. OF THE NAUTICAL ALMANAC, FOR 1896.0
—concluded.

Star's Name.	Assumed Mean R.A. 1896.0.	Correction to N.A.	Star's Name.	Assumed Mean R.A. 1896.0.	Correction to N.A.
	h m s	s		h m s	
β^1 Lyræ	18. 46. 14.388	0.000	α Equulei	21. 10. 37.473	
ϵ Aquilæ	18. 54. 54.090	0.000	ι Capricorni	21. 16. 27.334	
ζ Aquilæ	19. 0. 37.762	0.000	Groombridge 3548..	21. 20. 20.767	
ψ Sagittarii	19. 9. 9.783		β Aquarii	21. 26. 5.017	0.000
ω Aquilæ	19. 12. 56.047	0.000	ξ Aquarii	21. 32. 12.908	
δ Aquilæ	19. 20. 15.246	0.000	ϵ Pegasi	21. 39. 4.619	0.000
α Vulpeculæ	19. 24. 22.643		δ Capricorni	21. 41. 18.017	0.000
λ Ursæ Minoris ...	19. 26. 59.778	+ 0.043	16 Pegasi	21. 48. 19.723	0.000
μ Aquilæ	19. 29. 0.500		α Aquarii	22. 0. 26.485	— 0.002
h^2 Sagittarii	19. 30. 22.706	+ 0.036	ι Pegasi	22. 2. 10.106	
e^1 Sagittarii	19. 34. 45.873		θ Aquarii	22. 11. 20.712	+ 0.003
γ Aquilæ	19. 41. 18.871	0.000	γ Aquarii	22. 16. 17.024	+ 0.001
α Aquilæ	19. 45. 42.499	0.000	σ Aquarii	22. 25. 8.592	
β Aquilæ	19. 50. 12.218	0.000	η Aquarii	22. 30. 0.667	0.000
c Sagittarii	19. 56. 15.755		ζ Pegasi.....	22. 36. 16.447	0.000
θ Aquilæ	20. 5. 56.284	0.000	μ Pegasi.....	22. 44. 58.953	
α^2 Capricorni.....	20. 12. 17.052	+ 0.001	λ Aquarii	22. 47. 11.293	0.000
β Capricorni.....	20. 15. 10.057		Fomalhaut	22. 51. 54.219	+ 0.048
ρ Capricorni	20. 22. 55.721	0.000	α Pegasi.....	22. 59. 34.755	0.000
ϵ Delphini.....	20. 28. 14.620	— 0.002	γ Piscium	23. 11. 46.379	— 0.001
α Delphini.....	20. 34. 48.405	0.000	κ Piscium	23. 21. 36.018	0.000
ϵ Aquarii	20. 42. 2.747	0.000	Bradley 3147	23. 27. 49.058	
μ Aquarii	20. 47. 2.640		ι Piscium	23. 34. 35.976	0.000
32 Vulpeculæ	20. 50. 7.621	— 0.001	δ Sculptoris	23. 43. 30.579	+ 0.029
θ Capricorni	21. 0. 6.068	0.000	ω Piscium	23. 53. 58.171	0.000
ζ Cygni	21. 8. 30.566	0.000	2 Ceti	23. 58. 24.725	

INVESTIGATION OF PERSONAL EQUATIONS.

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DETERMINATION OF THE PERSONAL EQUATIONS OF THE VARIOUS OBSERVERS
USING THE CHRONOGRAPHIC METHOD OF OBSERVING TRANSITS.

The Observers in order of seniority are :—

D, C, L, H, A C, B, H F, C D, R C, D E, W B, J, E B, S, R, W, H A, W S.

When a result depends on a single observation by one of the observers, half weight is given to it.
Such cases are denoted by an asterisk.

Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.	Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.
May 29	^h 2	C D	+ 0 ^s ·11	April 18	^h 2	B D	+ 0 ^s ·16
July 31	8	D C	+ 0·09*	,, 24	3	B D	+ 0·14
Nov. 10	7	D C	+ 0·37	May 27	0	B D	+ 0·13
				,, 30	6	B D	+ 0·14*
Jan. 19	1	D H	— 0·09	June 5	1	B D	+ 0·19
Mar. 19	3	D H	— 0·06	Sept. 28	8	B D	+ 0·06
,, 28	2	H D	— 0·09	Nov. 10	0	B D	+ 0·33
May 15	1	H D	— 0·15	Dec. 31	1	D B	+ 0·23*
July 13	4	D H	— 0·11	June 5	5	D C D	+ 0·09
Aug. 1	2	D H	— 0·10	Nov. 10	2	C D D	+ 0·26
,, 15	1	H D	— 0·11	May 2	1	D E D	+ 0·03
Sept. 26	10	D H	— 0·05*				
Jan. 9	6	A C D	— 0·02	Sept. 28	3	W B D	+ 0·12
April 1	6	A C D	+ 0·16	,, 30	2	W B D	— 0·04*
May 29	2	A C D	+ 0·18	Mar. 19	2	D J	+ 0·18
June 5	2	D A C	+ 0·23	Dec. 22	5	D J	+ 0·17
Sept. 28	6	D A C	+ 0·03*	Mar. 2	2	E B D	+ 0·08
,, 30	3	D A C	+ 0·01*	July 31	1	D E B	0·00
Dec. 22	5	A C D	+ 0·21	Sept. 30	2	E B D	— 0·06*
,, 31	7	A C D	+ 0·25*	Jan. 15	0	S D	0·00
Jan. 22	11	B D	+ 0·15	Mar. 4	10	S D	— 0·13
Mar. 2	4	D B	+ 0·09	,, 19	1	D S	0·00
				,, 28	2	D S	— 0·02

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OBSERVATIONS FOR PERSONAL EQUATIONS—continued.

Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.	Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.
May 30	^h 7	S D	— 0 ^s .08*	June 24	^h 4	C D C	— 0 ^s .18
June 5	1	S D	+ 0.08	July 6	6	C D C	— 0.20*
Aug. 1	0	S D	— 0.06	Sept. 29	8	C C D	— 0.17
Dec. 31	10	S D	— 0.08*	Nov. 3	2	C D C	— 0.05
				„ 10	9	C D C	— 0.11
Dec. 31	9	W S D	+ 0.20*	July 31	8	E B C	— 0.09*
Jan. 15	4	H A D	+ 0.08	Sept. 23	1	R C	— 0.31
Mar. 2	0	D H A	+ 0.12*	Oct. 18	1	R C	— 0.31
April 1	4	H A D	+ 0.15	June 29	3	C W	— 0.14
July 6	3	C H	— 0.41*	Oct. 30	5	W C	— 0.08
Nov. 29	6	H C	— 0.27*	Nov. 26	12	C W	— 0.03
May 29	0	A C C	+ 0.07	Sept. 23	4	W S C	— 0.24
July 9	2	C A C	+ 0.09	Nov. 5	8	W S C	— 0.03
Oct. 26	2	C A C	+ 0.04	Jan. 23	1	L H	— 0.14*
Nov. 5	9	A C C	+ 0.04	Feb. 2	6	L B	— 0.05
„ 26	5	C A C	+ 0.01	Feb. 3	1	W B L	0.00*
Dec. 18	2	C A C	+ 0.12	Feb. 3	1	L J	+ 0.06
June 29	4	C B	— 0.09	Jan. 23	1	L R	— 0.09*
Sept. 23	1	B C	— 0.23	Feb. 19	2	A C H	+ 0.24
„ 29	11	C B	+ 0.04	Mar. 12	2	A C H	+ 0.37
Oct. 21	5	B C	— 0.15	„ 23	4	A C H	+ 0.28*
„ 26	6	B C	+ 0.02	April 23	0	A C H	+ 0.19
„ 30	2	C B	— 0.12	May 4	5	A C H	+ 0.18
Nov. 10	7	B C	— 0.04	June 17	1	H A C	+ 0.29
„ 18	5	B C	0.00	„ 19	7	H A C	+ 0.26
„ 29	6	C B	0.00*				
June 29	3	H F C	— 0.27				
Oct. 30	7	H F C	— 0.26				

INVESTIGATION OF PERSONAL EQUATIONS.

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OBSERVATIONS FOR PERSONAL EQUATIONS—*continued.*

Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.	Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.
July 2	^h 3	A C H	+ 0 ^s .34	April 15	^h 0	H J	+ 0 ^s .31
„ 4	11	A C H	+ 0 ^s .20*	July 17	2	J H	+ 0 ^s .17*
Nov. 30	5	H A C	+ 0 ^s .28	June 1	7	E B H	+ 0 ^s .18*
Feb. 18	1	H B	+ 0 ^s .21	Mar. 19	3	S H	+ 0 ^s .06
Mar. 1	7	B H	+ 0 ^s .16	„ 28	4	H S	+ 0 ^s .07
„ 23	0	B H	+ 0 ^s .23	July 4	10	S H	+ 0 ^s .05
April 13	0	B H	+ 0 ^s .18	Aug. 1	2	S H	+ 0 ^s .04
Sept. 19	2	B H	+ 0 ^s .18	„ 11	2	S H	0 ^s .00
Oct. 5	9	H B	+ 0 ^s .24	Dec. 13	12	S H	- 0 ^s .06*
Nov. 4	7	B H	+ 0 ^s .28	Jan. 23	0	H R	+ 0 ^s .05
„ 29	12	H B	+ 0 ^s .27	Feb. 7	6	H R	+ 0 ^s .17*
April 17	3	H F H	+ 0 ^s .15	May 4	3	R H	- 0 ^s .01*
May 1	2	H H F	+ 0 ^s .07*	July 21	5	R H	+ 0 ^s .09
„ 4	9	H F H	+ 0 ^s .02	Dec. 13	8	R H	+ 0 ^s .09*
Nov. 30	10	H F H	+ 0 ^s .10	Jan. 29	1	W H	+ 0 ^s .22
June 3	3	H C D	+ 0 ^s .14	April 13	5	W H	+ 0 ^s .21*
July 4	9	C D H	+ 0 ^s .17*	June 3	7	W H	+ 0 ^s .11
„ 6	9	C D H	+ 0 ^s .21	July 2	1	W H	+ 0 ^s .32
Aug. 4	12	C D H	+ 0 ^s .17	Aug. 11	1	W H	+ 0 ^s .19
April 23	2	D E H	+ 0 ^s .05	April 13	2	H A H	+ 0 ^s .14
May 19	1	H D E	+ 0 ^s .14	„ 23	0	H H A	+ 0 ^s .19
May 1	0	H W B	+ 0 ^s .25	Sept. 19	1	H W S	+ 0 ^s .20
Oct. 4	8	W B H	+ 0 ^s .26	Nov. 30	7	W S H	+ 0 ^s .26
Nov. 21	7	W B H	+ 0 ^s .27	Jan. 20	4	A C B	- 0 ^s .17
Mar. 10	1	J H	+ 0 ^s .25	„ 24	7	A C B	- 0 ^s .05
„ 19	1	J H	+ 0 ^s .24	„ 28	1	A C B	- 0 ^s .15
„ 23	2	H J	+ 0 ^s .30				

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OBSERVATIONS FOR PERSONAL EQUATIONS—continued.

Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.	Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.
Feb. 17	^h 0	B A C	— 0 ^s .01	Mar. 9	^h 6	R C A C	— 0 ^s .01
Mar. 16	2	A C B	+ 0 ^s .04	Dec. 11	4	R C A C	— 0 ^s .24
„ 18	2	B A C	— 0 ^s .09				
„ 22	6	B A C	+ 0 ^s .01	Mar. 30	0	D E A C	— 0 ^s .10
„ 23	3	A C B	— 0 ^s .05*	April 23	2	D E A C	— 0 ^s .14
April 9	1	A C B	+ 0 ^s .08				
May 9	5	A C B	— 0 ^s .04	Jan. 8	10	W B A C	+ 0 ^s .14
„ 14	0	B A C	— 0 ^s .02	Feb. 21	1	W B A C	+ 0 ^s .08
„ 16	1	B A C	— 0 ^s .09	Aug. 26	4	A C W B	+ 0 ^s .01*
„ 18	0	B A C	— 0 ^s .02	Sept. 28	9	W B A C	+ 0 ^s .09*
June 5	2	B A C	— 0 ^s .04	„ 30	4	W B A C	+ 0 ^s .03
„ 11	4	A C B	— 0 ^s .05	Nov. 9	1	A C W B	— 0 ^s .02
„ 13	2	B A C	— 0 ^s .01				
„ 15	3	A C B	— 0 ^s .04	Mar. 3	9	J A C	+ 0 ^s .05
„ 28	4	B A C	— 0 ^s .05	„ 22	4	J A C	— 0 ^s .04
Sept. 3	0	B A C	— 0 ^s .04	„ 23	5	A C J	+ 0 ^s .02*
„ 9	4	B A C	— 0 ^s .06	April 30	6	J A C	— 0 ^s .01
Oct. 10	2	A C B	— 0 ^s .06	Dec. 22	10	A C J	— 0 ^s .04
„ 24	10	A C B	0 ^s .00				
„ 26	8	B A C	— 0 ^s .02	Mar. 30	2	E B A C	— 0 ^s .16
„ 29	7	B A C	— 0 ^s .09	Sept. 30	4	E B A C	— 0 ^s .07
Dec. 11	3	A C B	— 0 ^s .02				
„ 16	9	A C B	— 0 ^s .10	June 5	3	S A C	— 0 ^s .15
„ 31	8	A C B	— 0 ^s .02	July 4	1	A C S	— 0 ^s .15
Mar. 3	7	H F A C	— 0 ^s .07	„ 20	1	S A C	— 0 ^s .20
May 4	4	H F A C	— 0 ^s .16	Aug. 29	5	S A C	— 0 ^s .30
June 5	3	A C C D	— 0 ^s .14	Oct. 27	6	S A C	— 0 ^s .38
„ 28	3	C D A C	— 0 ^s .06	„ 29	4	S A C	— 0 ^s .34
July 4	2	A C C D	— 0 ^s .03	Dec. 15	10	S A C	— 0 ^s .37
„ 7	10	A C C D	— 0 ^s .13	„ 31	3	S A C	— 0 ^s .33
„ 14	5	C D A C	— 0 ^s .05				
Oct. 29	8	A C C D	— 0 ^s .02*				
Dec. 15	6	C D A C	— 0 ^s .22				

INVESTIGATION OF PERSONAL EQUATIONS.

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OBSERVATIONS FOR PERSONAL EQUATIONS—*continued.*

Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.	Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.
May 4	^h 2	A C R	— 0 ^s .19*	Sept. 8	^h 2	B C D	— 0 ^s .13
June 15	2	A C R	— 0 ^s .14	„ 16	1	C D B	— 0 ^s .11
Sept. 11	0	A C R	— 0 ^s .23	„ 28	10	C D B	— 0 ^s .04
Oct. 10	2	A C R	— 0 ^s .17	„ 29	2	C D B	— 0 ^s .21
April 2	7	W A C	— 0 ^s .02*	Oct. 22	1	B C D	— 0 ^s .06
May 4	7	W A C	— 0 ^s .16	Nov. 10	1	C D B	— 0 ^s .07
July 2	2	A C W	— 0 ^s .02	„ 29	12	B C D	— 0 ^s .07
Aug. 26	1	A C W	0 ^s .00	„ 30	9	C D B	— 0 ^s .11
„ 31	2	W A C	— 0 ^s .05	Oct. 28	5	R C B	— 0 ^s .14
Nov. 9	3	A C W	— 0 ^s .04	Dec. 11	8	R C B	— 0 ^s .22
„ 27	7	A C W	— 0 ^s .04	Mar. 27	1	B D E	— 0 ^s .11
April 1	2	A C H A	— 0 ^s .01	April 20	3	B W B	+ 0 ^s .07
„ 23	0	A C H A	0 ^s .00	May 3	2	B W B	+ 0 ^s .17
Oct. 29	4	W S A C	— 0 ^s .09	„ 26	1	B W B	+ 0 ^s .03
Nov. 5	2	A C W S	— 0 ^s .07	June 20	0	W B B	+ 0 ^s .04
„ 19	4	A C W S	— 0 ^s .08	Sept. 28	6	B W B	+ 0 ^s .06
„ 30	12	W S A C	— 0 ^s .02	Dec. 21	6	W B B	+ 0 ^s .03
Dec. 31	2	W S A C	— 0 ^s .05	Mar. 22	2	B J	— 0 ^s .05
June 14	1	B H F	+ 0 ^s .07	„ 23	2	B J	+ 0 ^s .07
„ 29	7	H F B	— 0 ^s .18	April 26	3	B J	+ 0 ^s .05
Oct. 30	9	H F B	— 0 ^s .14	May 26	0	J B	+ 0 ^s .06
Nov. 6	2	H F B	— 0 ^s .20	Aug. 27	9	J B	— 0 ^s .02
„ 30	4	B H F	— 0 ^s .14	Jan. 30	5	B E B	— 0 ^s .24
June 5	6	B C D	— 0 ^s .10	Feb. 5	0	E B B	+ 0 ^s .03*
„ 14	0	C D B	+ 0 ^s .04	Mar. 2	6	E B B	— 0 ^s .01
„ 16	2	C D B	— 0 ^s .12	April 16	2	B E B	— 0 ^s .05
„ 28	1	B C D	— 0 ^s .01				
Aug. 14	2	B C D	— 0 ^s .08				

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OBSERVATIONS FOR PERSONAL EQUATIONS—*continued.*

Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.	Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.
Aug. 10	^h 2	E B B	— 0 ^s .09	Aug. 20	^h 2	B W	— 0 ^s .04
Dec. 25	11	B E B	— 0 ^s .08	Sept. 5	4	B W	— 0 ^s .06
Feb. 11	5	B S	— 0 ^s .15	Oct. 23	1	B W	— 0 ^s .06
„ 24	1	B S	— 0 ^s .19	„ 30	7	W B	+ 0 ^s .04
Mar. 27	1	B S	— 0 ^s .18	Nov. 6	2	B W	— 0 ^s .05
April 20	3	B S	— 0 ^s .12	„ 30	1	B W	— 0 ^s .05
May 11	2	B S	— 0 ^s .15	Feb. 11	5	B H A	+ 0 ^s .08
„ 30	1	S B	— 0 ^s .22	Mar. 2	4	H A B	+ 0 ^s .03*
June 5	0	B S	— 0 ^s .11	April 13	2	H A B	— 0 ^s .04
Aug. 27	4	S B	— 0 ^s .31	„ 29	5	H A B	+ 0 ^s .03
Oct. 9	3	B S	— 0 ^s .17	Aug. 16	1	B H A	0 ^s .00
„ 23	0	S B	— 0 ^s .25	Oct. 23	0	H A B	0 ^s .00
„ 29	3	B S	— 0 ^s .25	Nov. 6	3	B H A	— 0 ^s .16
Nov. 6	2	B S	— 0 ^s .33	Sept. 16	5	B W S	+ 0 ^s .05
Dec. 12	2	B S	— 0 ^s .26	„ 18	3	W S B	0 ^s .00
„ 23	3	B S	— 0 ^s .20	„ 19	2	B W S	+ 0 ^s .02
„ 31	11	S B	— 0 ^s .31	„ 23	2	W S B	— 0 ^s .01
Mar. 6	7	R B	— 0 ^s .02	Oct. 29	3	B W S	0 ^s .00
June 6	6	R B	— 0 ^s .11*	Nov. 30	7	B W S	+ 0 ^s .02
„ 15	1	R B	— 0 ^s .10	Dec. 31	10	W S B	— 0 ^s .03
Sept. 23	1	B R	— 0 ^s .08	June 14	1	C D H F	— 0 ^s .03
Oct. 10	0	R B	— 0 ^s .11	Oct. 30	10	C D H F	+ 0 ^s .18*
„ 25	8	R B	— 0 ^s .01	Jan. 17	2	R C H F	+ 0 ^s .13
Nov. 16	2	B R	— 0 ^s .17	May 13	1	R C H F	+ 0 ^s .03
Dec. 12	6	B R	— 0 ^s .11	April 10	2	H F W B	+ 0 ^s .14
„ 30	10	R B	— 0 ^s .23*	May 1	2	W B H F	+ 0 ^s .18*
April 11	3	B W	— 0 ^s .05				
„ 13	5	W B	+ 0 ^s .03*				
„ 26	0	B W	— 0 ^s .06				
June 26	1	B W	— 0 ^s .06				
„ 29	1	W B	— 0 ^s .05				

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OBSERVATIONS FOR PERSONAL EQUATIONS—*continued.*

Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.	Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.
Mar. 3	^h 2	J H F	+ 0 ^s .12	July 27	^h 7	C D R	- 0 ^s .13
Oct. 27	2	H F E B	+ 0 ^s .11*	June 3	10	W C D	- 0 ^s .03*
Oct. 27	8	H F S	+ 0 ^s .03*	July 28	9	C D W	- 0 ^s .08
Nov. 6	4	H F S	- 0 ^s .13	Oct. 30	11	C D W	0 ^s .00*
May 4	6	H F R	- 0 ^s .03*	Dec. 7	1	C D W	+ 0 ^s .06
May 4	3	W H F	0 ^s .00	July 3	12	H A C D	+ 0 ^s .02*
June 29	6	H F W	+ 0 ^s .13	Aug. 28	8	H A C D	+ 0 ^s .08
Oct. 27	2	W H F	+ 0 ^s .17*	Sept. 16	6	C D W S	+ 0 ^s .16
„ 30	1	H F W	+ 0 ^s .18	„ 27	8	W S C D	- 0 ^s .01
Nov. 6	4	H F W	+ 0 ^s .15	Oct. 29	11	W S C D	- 0 ^s .07*
„ 30	3	W H F	+ 0 ^s .09	July 4	12	R C S	- 0 ^s .11
Aug. 22	4	H F H A	+ 0 ^s .14	April 28	3	W R C	0 ^s .00
Nov. 6	5	H F H A	+ 0 ^s .04	Feb. 6	2	D E W B	+ 0 ^s .14
Nov. 30	3	H F W S	+ 0 ^s .16	July 10	1	D E W B	+ 0 ^s .12
July 3	6	C D R C	- 0 ^s .03	Mar. 30	2	E B D E	- 0 ^s .06
Nov. 20	10	C D W B	+ 0 ^s .09	Mar. 27	0	S D E	- 0 ^s .07
Dec. 3	7	W B C D	+ 0 ^s .04	Mar. 24	3	W D E	+ 0 ^s .08
Aug. 28	6	E B C D	- 0 ^s .02	April 23	2	D E H A	+ 0 ^s .14
June 5	6	S C D	- 0 ^s .01	Feb. 3	2	W B J	+ 0 ^s .06*
July 3	11	S C D	- 0 ^s .09*	May 26	1	J W B	+ 0 ^s .03
„ 4	1	S C D	- 0 ^s .12	Sept. 30	0	E B W B	- 0 ^s .10
„ 28	8	S C D	- 0 ^s .17	April 20	0	S W B	- 0 ^s .19
Oct. 29	11	S C D	- 0 ^s .32*	Aug. 21	1	R W B	- 0 ^s .22
Nov. 12	8	C D S	- 0 ^s .12	Dec. 28	4	R W B	- 0 ^s .19
Dec. 15	4	S C D	- 0 ^s .15				

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OBSERVATIONS FOR PERSONAL EQUATIONS—concluded.

Day, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.	Date, 1896.	Interval between mean of Groups of Clock Stars.	Observers.	Excess of Clock Slow by Junior Observer.
Aug. 26	^h 4	W WB	— 0 ^s .01*	Jan. 15	^h 4	HA S	+ 0 ^s .08
Nov. 9	3	WB W	— 0 ^s .02	Feb. 4	1	HA S	+ 0 ^s .14
Mar. 19	1	S J	— 0 ^s .19	,, 11	1	S HA	+ 0 ^s .23
Aug. 27	5	J S	— 0 ^s .29	July 3	0	HA S	+ 0 ^s .11*
Jan. 10	1	J W	— 0 ^s .06*	Oct. 23	0	HA S	+ 0 ^s .25
April 26	3	W J	— 0 ^s .11	Nov. 6	1	S HA	+ 0 ^s .17
Oct. 27	6	EB S	— 0 ^s .08	Sept. 24	1	WS S	+ 0 ^s .28
Oct. 27	3	W EB	+ 0 ^s .06	Oct. 29	0	WS S	+ 0 ^s .25
Mar. 2	2	EB HA	+ 0 ^s .04*	Dec. 31	1	S WS	+ 0 ^s .28
Aug. 28	2	HA EB	+ 0 ^s .10	May 4	9	W R	+ 0 ^s .03*
Dec. 12	3	S R	+ 0 ^s .15	Sept. 23	3	WS R	+ 0 ^s .07
Jan. 1	4	S W	(— 0 ^s .03)	April 13	3	W HA	— 0 ^s .07*
May 8	4	W S	+ 0 ^s .11	Oct. 23	2	HA W	+ 0 ^s .06
Aug. 11	1	S W	+ 0 ^s .19	Nov. 6	1	W HA	— 0 ^s .11
Oct. 23	2	S W	+ 0 ^s .19	Nov. 30	6	W WS	+ 0 ^s .07
,, 27	9	W S	+ 0 ^s .14				
Nov. 6	1	W S	+ 0 ^s .28				

INVESTIGATION OF PERSONAL EQUATIONS.

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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 D.

$$\begin{aligned}
 5 (D - C) &= -1^{\circ}05 \\
 15 (D - H) &= +1^{\circ}47 \\
 13 (D - A C) &= -1^{\circ}81 \\
 18 (D - B) &= -2^{\circ}87 \\
 4 (D - C D) &= -0^{\circ}70 \\
 2 (D - D E) &= -0^{\circ}06 \\
 3 (D - W B) &= -0^{\circ}20 \\
 4 (D - J) &= -0^{\circ}70 \\
 5 (D - E B) &= -0^{\circ}10 \\
 14 (D - S) &= +0^{\circ}42 \\
 D - W S &= -0^{\circ}20 \\
 5 (D - H A) &= -0^{\circ}58
 \end{aligned}$$

For C.

$$\begin{aligned}
 5 (C - D) &= +1^{\circ}05 \\
 2 (C - H) &= +0^{\circ}68 \\
 12 (C - A C) &= -0^{\circ}74 \\
 17 (C - B) &= +1^{\circ}14 \\
 4 (C - H F) &= +1^{\circ}06 \\
 9 (C - C D) &= +1^{\circ}22 \\
 C - E B &= +0^{\circ}09 \\
 4 (C - R) &= +1^{\circ}24 \\
 6 (C - W) &= +0^{\circ}50 \\
 4 (C - W S) &= +0^{\circ}54
 \end{aligned}$$

For L.

$$\begin{aligned}
 L - H &= +0^{\circ}14 \\
 2 (L - B) &= +0^{\circ}10 \\
 L - W B &= 0^{\circ}00 \\
 2 (L - J) &= -0^{\circ}12 \\
 L - R &= +0^{\circ}09
 \end{aligned}$$

For H.

$$\begin{aligned}
 15 (H - D) &= -1^{\circ}47 \\
 2 (H - C) &= -0^{\circ}68 \\
 H - L &= -0^{\circ}14 \\
 18 (H - A C) &= -4^{\circ}78 \\
 16 (H - B) &= -3^{\circ}50 \\
 7 (H - H F) &= -0^{\circ}61 \\
 7 (H - C D) &= -1^{\circ}21
 \end{aligned}$$

For H—continued.

$$\begin{aligned}
 4 (H - D E) &= -0^{\circ}38 \\
 6 (H - W B) &= -1^{\circ}56 \\
 9 (H - J) &= -2^{\circ}37 \\
 H - E B &= -0^{\circ}18 \\
 11 (H - S) &= -0^{\circ}38 \\
 7 (H - R) &= -0^{\circ}53 \\
 9 (H - W) &= -1^{\circ}89 \\
 4 (H - H A) &= -0^{\circ}66 \\
 4 (H - W S) &= -0^{\circ}92
 \end{aligned}$$

For A C.

$$\begin{aligned}
 13 (A C - D) &= +1^{\circ}81 \\
 12 (A C - C) &= +0^{\circ}74 \\
 18 (A C - H) &= +4^{\circ}78 \\
 53 (A C - B) &= +2^{\circ}27 \\
 4 (A C - H F) &= +0^{\circ}46 \\
 13 (A C - C D) &= +1^{\circ}28 \\
 4 (A C - R C) &= +0^{\circ}50 \\
 4 (A C - D E) &= +0^{\circ}48 \\
 10 (A C - W B) &= -0^{\circ}56 \\
 9 (A C - J) &= +0^{\circ}06 \\
 4 (A C - E B) &= +0^{\circ}46 \\
 16 (A C - S) &= +4^{\circ}44 \\
 7 (A C - R) &= +1^{\circ}27 \\
 13 (A C - W) &= +0^{\circ}64 \\
 4 (A C - H A) &= +0^{\circ}02 \\
 5 (A C - W S) &= +0^{\circ}62
 \end{aligned}$$

For B.

$$\begin{aligned}
 18 (B - D) &= +2^{\circ}87 \\
 17 (B - C) &= -1^{\circ}14 \\
 2 (B - L) &= -0^{\circ}10 \\
 16 (B - H) &= +3^{\circ}50 \\
 53 (B - A C) &= -2^{\circ}27 \\
 10 (B - H F) &= +1^{\circ}18 \\
 26 (B - C D) &= +2^{\circ}14 \\
 4 (B - R C) &= +0^{\circ}72 \\
 2 (B - D E) &= +0^{\circ}22 \\
 12 (B - W B) &= -0^{\circ}80 \\
 10 (B - J) &= -0^{\circ}22 \\
 11 (B - E B) &= +0^{\circ}91
 \end{aligned}$$

For B—continued.

30 (B - S)	= + 6 ^s .40
16 (B - R)	= + 1 ^s .54
21 (B - W)	= + 0 ^s .85
13 (B - H A)	= + 0 ^s .15
7 (B - W S)	= - 0 ^s .10

For H F.

4 (H F - C)	= - 1 ^s .06
7 (H F - H)	= + 0 ^s .61
4 (H F - A C)	= - 0 ^s .46
10 (H F - B)	= - 1 ^s .18
3 (H F - C D)	= - 0 ^s .12
4 (H F - R C)	= - 0 ^s .32
3 (H F - W B)	= - 0 ^s .46
2 (H F - J)	= - 0 ^s .24
H F - E B	= - 0 ^s .11
3 (H F - S)	= + 0 ^s .23
H F - R	= + 0 ^s .03
11 (H F - W)	= - 1 ^s .27
4 (H F - H A)	= - 0 ^s .36
2 (H F - W S)	= - 0 ^s .32

For C D.

4 (C D - D)	= + 0 ^s .70
9 (C D - C)	= - 1 ^s .22
7 (C D - H)	= + 1 ^s .21
13 (C D - A C)	= - 1 ^s .28
26 (C D - B)	= - 2 ^s .14
3 (C D - H F)	= + 0 ^s .12
2 (C D - R C)	= + 0 ^s .06
4 (C D - W B)	= - 0 ^s .26
2 (C D - E B)	= + 0 ^s .04
12 (C D - S)	= + 1 ^s .55
2 (C D - R)	= + 0 ^s .26
6 (C D - W)	= + 0 ^s .07
4 (C D - H A)	= - 0 ^s .18
5 (C D - W S)	= - 0 ^s .23

For R C.

4 (R C - A C)	= - 0 ^s .50
4 (R C - B)	= - 0 ^s .72
4 (R C - H F)	= + 0 ^s .32

For R C—continued.

2 (R C - C D)	= - 0 ^s .06
2 (R C - S)	= + 0 ^s .22
2 (R C - W)	= 0 ^s .00

For D E.

2 (D E - D)	= + 0 ^s .06
4 (D E - H)	= + 0 ^s .38
4 (D E - A C)	= - 0 ^s .48
2 (D E - B)	= - 0 ^s .22
4 (D E - W B)	= - 0 ^s .52
2 (D E - E B)	= + 0 ^s .12
2 (D E - S)	= + 0 ^s .14
2 (D E - W)	= - 0 ^s .16
2 (D E - H A)	= - 0 ^s .28

For W B.

3 (W B - D)	= + 0 ^s .20
W B - L	= 0 ^s .00
6 (W B - H)	= + 1 ^s .56
10 (W B - A C)	= + 0 ^s .56
12 (W B - B)	= + 0 ^s .80
3 (W B - H F)	= + 0 ^s .46
4 (W B - C D)	= + 0 ^s .26
4 (W B - D E)	= + 0 ^s .52
3 (W B - J)	= - 0 ^s .12
2 (W B - E B)	= + 0 ^s .20
2 (W B - S)	= + 0 ^s .38
4 (W B - R)	= + 0 ^s .82
3 (W B - W)	= + 0 ^s .05

For J.

4 (J - D)	= + 0 ^s .70
2 (J - L)	= + 0 ^s .12
9 (J - H)	= + 2 ^s .37
9 (J - A C)	= - 0 ^s .06
10 (J - B)	= + 0 ^s .22
2 (J - H F)	= + 0 ^s .24
3 (J - W B)	= + 0 ^s .12
4 (J - S)	= + 0 ^s .94
3 (J - W)	= + 0 ^s .28

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For E B.

$$\begin{aligned}
 5 (E B - D) &= + 0.10 \\
 E B - C &= - 0.09 \\
 E B - H &= + 0.18 \\
 4 (E B - A C) &= - 0.46 \\
 11 (E B - B) &= - 0.91 \\
 E B - H F &= + 0.11 \\
 2 (E B - C D) &= - 0.04 \\
 2 (E B - D E) &= - 0.12 \\
 2 (E B - W B) &= - 0.20 \\
 2 (E B - S) &= + 0.16 \\
 2 (E B - W) &= - 0.12 \\
 3 (E B - H A) &= - 0.24
 \end{aligned}$$

For S.

$$\begin{aligned}
 14 (S - D) &= - 0.42 \\
 11 (S - H) &= + 0.38 \\
 16 (S - A C) &= - 4.44 \\
 30 (S - B) &= - 6.40 \\
 3 (S - H F) &= - 0.23 \\
 12 (S - C D) &= - 1.55 \\
 2 (S - R C) &= - 0.22 \\
 2 (S - D E) &= - 0.14 \\
 2 (S - W B) &= - 0.38 \\
 4 (S - J) &= - 0.94 \\
 2 (S - E B) &= - 0.16 \\
 2 (S - R) &= - 0.30 \\
 10 (S - W) &= - 1.82 \\
 11 (S - H A) &= - 1.85 \\
 6 (S - W S) &= - 1.62
 \end{aligned}$$

For R.

$$\begin{aligned}
 4 (R - C) &= - 1.24 \\
 R - L &= - 0.09 \\
 7 (R - H) &= + 0.53 \\
 7 (R - A C) &= - 1.27 \\
 16 (R - B) &= - 1.54 \\
 R - H F &= - 0.03 \\
 2 (R - C D) &= - 0.26 \\
 4 (R - W B) &= - 0.82 \\
 2 (R - S) &= + 0.30 \\
 R - W &= - 0.03 \\
 2 (R - W S) &= - 0.14
 \end{aligned}$$

For W.

$$\begin{aligned}
 6 (W - C) &= - 0.50 \\
 9 (W - H) &= + 1.89 \\
 13 (W - A C) &= - 0.64 \\
 21 (W - B) &= - 0.85 \\
 11 (W - H F) &= + 1.27 \\
 6 (W - C D) &= - 0.07 \\
 2 (W - R C) &= 0.00 \\
 2 (W - D E) &= + 0.16 \\
 3 (W - W B) &= - 0.05 \\
 3 (W - J) &= - 0.28 \\
 2 (W - E B) &= + 0.12 \\
 10 (W - S) &= + 1.82 \\
 W - R &= + 0.03 \\
 5 (W - H A) &= + 0.17 \\
 2 (W - W S) &= - 0.14
 \end{aligned}$$

For H A.

$$\begin{aligned}
 5 (H A - D) &= + 0.58 \\
 4 (H A - H) &= + 0.66 \\
 4 (H A - A C) &= - 0.02 \\
 13 (H A - B) &= - 0.15 \\
 4 (H A - H F) &= + 0.36 \\
 4 (H A - C D) &= + 0.18 \\
 2 (H A - D E) &= + 0.28 \\
 3 (H A - E B) &= + 0.24 \\
 11 (H A - S) &= + 1.85 \\
 5 (H A - W) &= - 0.17
 \end{aligned}$$

For W S.

$$\begin{aligned}
 W S - D &= + 0.20 \\
 4 (W S - C) &= - 0.54 \\
 4 (W S - H) &= + 0.92 \\
 5 (W S - A C) &= - 0.62 \\
 7 (W S - B) &= + 0.10 \\
 2 (W S - H F) &= + 0.32 \\
 5 (W S - C D) &= + 0.23 \\
 6 (W S - S) &= + 1.62 \\
 2 (W S - R) &= + 0.14 \\
 2 (W S - W) &= + 0.14
 \end{aligned}$$

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Now, since one of the quantities denoted by D, &c., must evidently remain indeterminate, we will refer all the rest to B as a standard; and, putting $B = 0$, the initials D, &c., will represent the values of "clock slow" which would be given by the observations of Mr. Dyson, &c., when that given by Mr. Bryant = 0.

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

89 D-5 C-15 H-13 A C-18 B-4 C D-2 D E-3 W B-4 J-5 E B-14 S -5 H A-5 W S	= - 6.38
64 C-5 D-2 H-12 A C-17 B-4 H F-9 C D-E B-4 R-6 W-4 W S	= + 6.78
7 L-H-2 B-W B-2 J-R	= + 0.21
121 H-15 D-2 C-L-18 A C-16 B-7 H F-7 C D-4 D E-6 W B-9 J-E B -11 S-7 R-9 W-4 H A-4 W S	= - 21.26
189 A C-13 D-12 C-18 H-53 B-4 H F-13 C D-4 R C-4 D E-10 W B -9 J-4 E B-16 S-7 R-13 W-4 H A-5 W S	= + 19.27
268 B-18 D-17 C-2 L-16 H-53 A C-10 H F-26 C D-4 R C-2 D E -12 W B-10 J-11 E B-30 S-16 R-21 W-13 H A-7 W S	= + 15.85
59 H F-4 C-7 H-4 A C-10 B-3 C D-4 R C-3 W B-2 J-E B-3 S-R -11 W-4 H A-2 W S	= - 5.03
99 C D-4 D-9 C-7 H-13 A C-26 B-3 H F-2 R C-4 W B-2 E B-12 S -2 R-6 W-4 H A-5 W S	= - 1.30
18 R C-4 A C-4 B-4 H F-2 C D-2 S-2 W	= - 0.74
24 D E-2 D-4 H-4 A C-2 B-4 W B-2 E B-2 S-2 W-2 H A	= - 0.96
57 W B-3 D-L-6 H-10 A C-12 B-3 H F-4 C D-4 D E-3 J-2 E B -2 S-4 R-3 W	= + 5.69
46 J-4 D-2 L-9 H-9 A C-10 B-2 H F-3 W B-4 S-3 W	= + 4.93
36 E B-5 D-C-H-4 A C-11 B-H F-2 C D-2 D E-2 W B-2 S-2 W -3 H A	= - 1.63
127 S-14 D-11 H-16 A C-30 B-3 H F-12 C D-2 R C-2 D E-2 W B-4 J -2 E B-2 R-10 W-11 H A-6 W S	= - 20.09
47 R-4 C-L-7 H-7 A C-16 B-H F-2 C D-4 W B-2 S-W-2 W S	= - 4.59
96 W-6 C-9 H-13 A C-21 B-11 H F-6 C D-2 R C-2 D E-3 W B-3 J -2 E B-10 S-R-5 H A-2 W S	= + 2.93
55 H A-5 D-4 H-4 A C-13 B-4 H F-4 C D-2 D E-3 E B-11 S-5 W	= + 3.81
38 W S-D-4 C-4 H-5 A C-7 B-2 H F-5 C D-6 S-2 R-2 W	= + 2.51

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Solving these equations by successive approximation, 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 of the corrections for personal equation for the several observers referred to B. :—

$B - D = + 0.14$	$B - CD = + 0.06$	$B - S = + 0.21$
$B - C = - 0.07$	$B - RC = + 0.09$	$B - R = + 0.13$
$B - L = 0.00$	$B - DE = + 0.10$	$B - W = + 0.03$
$B - H = + 0.23$	$B - WB = - 0.04$	$B - HA = + 0.02$
$B - AC = - 0.04$	$B - J = - 0.04$	$B - WS = 0.00$
$B - HF = + 0.13$	$B - EB = + 0.09$	

From 1885 March 14, it has been the practice for the observer with the Transit-circle to observe each night the transits of two clock-stars by the eye-and-ear method as well as by the chronographic method. The following table gives the comparison of the clock-errors deduced from these eye-and-ear transits with those deduced from the chronographic transits by the same observer, these latter being referred to the standard observer, Mr. Bryant, by applying the personal equations for chronographic transits found from the observations of 1896.

DETERMINATION OF THE PERSONAL EQUATIONS OF THE VARIOUS OBSERVERS
USING THE EYE AND EAR METHOD OF OBSERVING TRANSITS AS REFERRED
TO THE STANDARD OBSERVER USING THE CHRONOGRAPHIC METHOD.

Date of Observation, 1896.	Excess of Clock Slow by Eye and Ear Observer.	Date of Observation, 1896.	Excess of Clock Slow by Eye and Ear Observer.	Date of Observation, 1896.	Excess of Clock Slow by Eye and Ear Observer.
OBSERVER D.		OBSERVER H—cont.		OBSERVER H—cont.	
d h	s	d h	s	d h	s
Aug. 15. 8	+ 0.17	Mar. 19. 11	+ 0.31	July 6. 13	+ 0.53
		23. 9	+ 0.31	23. 12	+ 0.42
		31. 9	+ 0.35		
OBSERVER H.		April 13. 11	+ 0.26	Aug. 17. 9	+ 0.21
		17. 11	+ 0.27	25. 10	+ 0.39
		21. 11	+ 0.40	Sept. 19. 10	+ 0.38
		23. 10	+ 0.22	26. 16	+ 0.26
Jan. 19. 5	+ 0.24	May 1. 10	+ 0.39	Nov. 4. 9	+ 0.27
29. 7	+ 0.15	19. 9	+ 0.21	Dec. 17. 8	+ 0.23
Feb. 10. 9	+ 0.16	25. 11	+ 0.29		
18. 8	+ 0.23	June 19. 10	+ 0.24	Mean	+ 0.29
22. 11	+ 0.30				

GREENWICH OBSERVATIONS, 1896.

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OBSERVATIONS FOR PERSONAL EQUATIONS—*continued.*

Date of Observation, 1896.	Excess of Clock Slow by Eye and Ear Observer.	Date of Observation, 1896.	Excess of Clock Slow by Eye and Ear Observer.	Date of Observation, 1896.	Excess of Clock Slow by Eye and Ear Observer.
OBSERVER A C.		OBSERVER B—cont.		OBSERVER B—cont.	
Feb. 17. 6	+ 0'25	May 9. 16	+ 0'02	Nov. 3. 18	— 0'07
Mar. 30. 13	+ 0'15	11. 12	+ 0'01	6. 8	— 0'03
April 1. 9	+ 0'15	16. 8	+ 0'04	8. 19	+ 0'07
May 4. 11	+ 0'07	20. 15	+ 0'04	10. 4	— 0'05
16. 10	+ 0'03	24. 10	— 0'02	18. 16	+ 0'03
June 15. 9	+ 0'15	27. 8	+ 0'03	29. 19	— 0'06
July 11. 9	+ 0'11	28. 9	— 0'07	30. 9	— 0'05
Aug. 26. 11	+ 0'09	30. 10	+ 0'21	Dec. 6. 5	— 0'06
Sept. 3. 9	+ 0'14	31. 9	0'00	9. 20	+ 0'01
9. 13	— 0'03	June 5. 14	— 0'04	21. 18	+ 0'07
Oct. 20. 9	+ 0'29	6. 9	+ 0'04	23. 15	+ 0'04
26. 7	+ 0'10	11. 14	+ 0'12	24. 20	+ 0'01
Nov. 11. 10	+ 0'13	13. 13	— 0'03	31. 14	+ 0'04
Dec. 22. 10	+ 0'04	14. 12	+ 0'02	Mean	+ 0'02
Mean	+ 0'12	16. 8	+ 0'01	OBSERVER H F.	
OBSERVER B.		20. 14	— 0'04	April 10. 14	0'00
Jan. 14. 9	+ 0'06	26. 8	0'00	May 4. 10	0'00
22. 5	+ 0'05	28. 10	+ 0'06	June 29. 12	+ 0'22
24. 5	+ 0'11	29. 18	+ 0'04	Mean	+ 0'07
28. 8	+ 0'09	July 8. 10	+ 0'01	OBSERVER C D.	
30. 7	+ 0'08	Aug. 12. 11	— 0'03	June 12. 10	— 0'02
Feb. 2. 11	+ 0'03	14. 8	— 0'01	16. 3	+ 0'08
5. 8	+ 0'07	16. 7	— 0'04	24. 8	+ 0'02
11. 9	+ 0'04	20. 11	— 0'04	July 7. 14	— 0'04
17. 7	+ 0'01	27. 7	+ 0'01	27. 9	+ 0'06
18. 9	+ 0'06	Sept. 3. 6	— 0'01	28. 14	+ 0'05
24. 13	— 0'01	5. 10	— 0'01	Sept. 8. 10	+ 0'07
Mar. 16. 15	— 0'01	7. 9	+ 0'03	Oct. 22. 9	— 0'03
18. 10	+ 0'12	8. 9	+ 0'01	Nov. 3. 6	+ 0'05
23. 8	+ 0'06	16. 8	+ 0'04	12. 10	+ 0'06
25. 10	+ 0'06	18. 15	+ 0'03	20. 3	+ 0'09
27. 14	+ 0'01	19. 6	+ 0'02	Mean	+ 0'04
April 22. 14	+ 0'05	22. 7	+ 0'14		
		23. 5	+ 0'02		
		28. 5	— 0'01		
		29. 19	— 0'04		
		Oct. 5. 6	+ 0'01		
		9. 5	— 0'02		
		10. 7	— 0'02		
		23. 7	+ 0'01		
		24. 18	+ 0'02		
		28. 6	0'00		
		30. 17	+ 0'01		

EYE AND EAR PERSONAL EQUATIONS.

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OBSERVATIONS FOR PERSONAL EQUATIONS—concluded.

Date of Observation, 1896.	Excess of Clock Slow by Eye and Ear Observer.	Date of Observation, 1896.	Excess of Clock Slow by Eye and Ear Observer.	Date of Observation, 1896.	Excess of Clock Slow by Eye and Ear Observer.
OBSERVER D E.		OBSERVER R.		OBSERVER W.	
Feb. 6. 10	+ 0.15	July 27. 14	+ 0.19	Jan. 10. 5	+ 0.08
Mar. 24. 10	+ 0.16	Aug. 21. 10	+ 0.01	Mar. 24. 5	+ 0.19
27. 10	+ 0.10	Sept. 11. 9	+ 0.01	April 2. 11	+ 0.03
April 23. 8	+ 0.16	Oct. 25. 15	— 0.04	June 29. 10	+ 0.02
May 19. 12	+ 0.11	Nov. 16. 7	— 0.14	Sept. 5. 9	+ 0.12
Mean	+ 0.14	Mean	+ 0.01	Oct. 1. 17	+ 0.12
OBSERVER J.		OBSERVER H A.		Nov. 9. 9	+ 0.01
Mar. 29. 14	+ 0.19			30. 4	+ 0.10
Aug. 27. 11	+ 0.36			Mean	+ 0.08
Mean	+ 0.28			OBSERVER W S.	
OBSERVER E B.		Jan. 27. 5	+ 0.14	Sept. 19. 8	+ 0.35
June 1. 8	+ 0.13	Feb. 11. 10	+ 0.09	23. 5	+ 0.16
Aug. 28. 10	+ 0.05	April 1. 12	+ 0.23	24. 8	+ 0.08
Oct. 27. 12	— 0.03	Aug. 18. 11	+ 0.18	27. 9	+ 0.21
Mean	+ 0.05	Mean	+ 0.16	Oct. 29. 12	+ 0.23
				Mean	+ 0.21

Collecting these results together, the following are the values of the corrections for personal equation of the observers using the Eye and Ear method referred to the Standard Observer using the Galvanic method :—

$$\begin{aligned}
 B_0 - D &= -0.17 \\
 B_0 - H &= -0.29 \\
 B_0 - AC &= -0.12 \\
 B_0 - B &= -0.02 \\
 B_0 - HF &= -0.07 \\
 B_0 - CD &= -0.04 \\
 B_0 - DE &= -0.14
 \end{aligned}$$

$$\begin{aligned}
 B_0 - J &= -0.28 \\
 B_0 - EB &= -0.05 \\
 B_0 - R &= -0.01 \\
 B_0 - HA &= -0.16 \\
 B_0 - W &= -0.08 \\
 B_0 - WS &= -0.21
 \end{aligned}$$

[*Erratum* in the Introduction to the Greenwich Observations, 1895, p. cxxix. The signs of the quantities L — D, L — H, &c., are to be changed throughout.]

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. $1^{\circ} = 61^{\circ}.4$ 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.
0 ^o	0 ^r 052	36 ^o	0 ^r 057	72 ^o	0 ^r 054	108 ^o	0 ^r 059	144 ^o	0 ^r 084	180 ^o	0 ^r 053	216 ^o	0 ^r 041	252 ^o	0 ^r 047	288 ^o	0 ^r 054	324 ^o	0 ^r 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	063
20	056	56	070	92	078	128	086	164	067	200	039	236	049	272	063	308	084	344	069
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.

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DIVISION CORRECTION.

Applicable to Observations made with the six ordinary Microscopes.

(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°44	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 $270^\circ.30'$; under Microscope C, $210^\circ.30'$; under Microscope E, $150^\circ.30'$; under Microscope B, $90^\circ.30'$; under Microscope D, $30^\circ.30'$; and under Microscope F, $330^\circ.30'$.

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

For Nadir Point, the Pointer Reading being		$\left\{ \begin{array}{l} 179^{\circ} 35', \\ 179^{\circ} 40', \end{array} \right.$		the correction is	$\left\{ \begin{array}{l} + 0^{\circ} 37' \\ + 0^{\circ} 52' \end{array} \right.$
For Polaris	, ,	, ,	$\left\{ \begin{array}{l} 322^{\circ} 30', \\ 322^{\circ} 25', \\ 322^{\circ} 20', \end{array} \right.$	, ,	$\left\{ \begin{array}{l} + 0^{\circ} 69' \\ + 0^{\circ} 66' \\ + 0^{\circ} 66' \end{array} \right.$
For Polaris S.P.	, ,	, ,	$\left\{ \begin{array}{l} 319^{\circ} 45', \\ 319^{\circ} 50', \end{array} \right.$	, ,	$\left\{ \begin{array}{l} + 1^{\circ} 13' \\ + 1^{\circ} 04' \end{array} \right.$
For Cephei 51	, ,	, ,	$\left\{ \begin{array}{l} 323^{\circ} 50', \\ 323^{\circ} 55', \end{array} \right.$	, ,	$\left\{ \begin{array}{l} + 0^{\circ} 84' \\ + 0^{\circ} 83' \end{array} \right.$
For Cephei 51 S.P.	, ,	, ,	$\left\{ \begin{array}{l} 318^{\circ} 25', \\ 318^{\circ} 20', \\ 318^{\circ} 15', \end{array} \right.$	, ,	$\left\{ \begin{array}{l} + 0^{\circ} 67' \\ + 0^{\circ} 60' \\ + 0^{\circ} 63' \end{array} \right.$
For δ Ursæ Minoris	, ,	, ,	$\left\{ \begin{array}{l} 324^{\circ} 35', \\ 324^{\circ} 30', \\ 324^{\circ} 25', \end{array} \right.$	, ,	$\left\{ \begin{array}{l} + 0^{\circ} 72' \\ + 0^{\circ} 74' \\ + 0^{\circ} 79' \end{array} \right.$
For δ Ursæ Minoris S.P.	, ,	, ,	$\left\{ \begin{array}{l} 317^{\circ} 40', \\ 317^{\circ} 45', \end{array} \right.$	, ,	$\left\{ \begin{array}{l} + 0^{\circ} 75' \\ + 0^{\circ} 68' \end{array} \right.$
For λ Ursæ Minoris	, ,	, ,	$\left\{ \begin{array}{l} 322^{\circ} 10', \\ 322^{\circ} 5', \end{array} \right.$	, ,	$\left\{ \begin{array}{l} + 0^{\circ} 74' \\ + 0^{\circ} 70' \end{array} \right.$
For λ Ursæ Minoris S.P.	, ,	, ,	$\left\{ \begin{array}{l} 320^{\circ} 5', \\ 320^{\circ} 0', \end{array} \right.$	, ,	$\left\{ \begin{array}{l} + 1^{\circ} 08' \\ + 0^{\circ} 99' \end{array} \right.$

The Division under Microscope A is Pointer Reading — $89^{\circ} 30'$.

These corrections have been applied additively to the circle-readings whenever they were needed throughout the year 1896.

INVESTIGATION OF THE ERRORS OF THE MICROSCOPE-MICROMETER SCREWS OF THE TRANSIT-CIRCLE.

Successive intervals of about $1^{\text{rev.}}$ of each screw were compared by means of the South Collimator.

The South Collimator being set to $0^{\circ} 000$, the Transit-Circle was pointed on it and adjusted so that a division of the circle fell very nearly at the reading $9^{\circ} 000$ of each microscope, the interger 9 representing —1. The instrument was then clamped and the microscopes read, and six readings of the Transit-Circle micrometer were taken for

INVESTIGATION OF ERRORS OF THE MICROSCOPE-MICROMETER SCREWS. cxxxiii

coincidence with the South Collimator. The South Collimator was then set to $2^{\circ}500$, the interval corresponding nearly to one revolution of each microscope-micrometer, and the instrument pointed on it so that the reading of the telescope-micrometer was as nearly as possible the same, and the circle division before-mentioned fell very nearly at 0^{rev} . The microscopes and telescope-micrometer were then read as before, and the difference of readings of each microscope (when corrected for the small difference in setting as indicated by the change in reading of the telescope-micrometer) gave the value of the interval of that screw for the region $9^{\circ}-0^{\circ}$, corresponding to the standard interval on the South Collimator. Without unclamping the instrument, the South Collimator was now set back to $0^{\circ}000$ and a new set of six readings of the telescope-micrometer was taken, the microscopes having been read already. The South Collimator was set to $2^{\circ}500$ and the instrument unclamped and pointed on it as before, so that the intervals $0^{\circ}-1^{\circ}$ $1^{\circ}-2^{\circ}$, &c., of each screw were successively compared with the standard interval on the South Collimator.

RELATIVE VALUES OF SUCCESSIVE INTERVALS OF 1^{rev} OF THE MICROSCOPE-MICROMETER SCREWS.

1896 December 22—December 29.

			Observer.	
			Microscopes.	Telescope-Micrometer.
1896 December 22	(1 set)	$9-6$	D	T
December 22	(1 set)	$9-5$	D	T
December 23	(2 sets)	$9-5$	T	H F
December 24	(2 sets)	$9-5$	D	H F
December 28	(2 sets)	$9-5$	D	H F
December 28	(2 sets)	$9-5$	B	S
December 29	(2 sets)	$9-6$	D	S

$9^{\circ}-0^{\circ}$						$0^{\circ}-1^{\circ}$					
A	B	C	D	E	F	A	B	C	D	E	F
61 ^{''} 59	61 ^{''} 72	61 ^{''} 72	61 ^{''} 34	62 ^{''} 03	62 ^{''} 55	60 ^{''} 69	61 ^{''} 93	60 ^{''} 08	61 ^{''} 30	61 ^{''} 94	59 ^{''} 78
60 ^{''} 20	61 ^{''} 12	60 ^{''} 99	62 ^{''} 27	60 ^{''} 99	62 ^{''} 33	61 ^{''} 13	61 ^{''} 19	60 ^{''} 40	61 ^{''} 51	61 ^{''} 76	61 ^{''} 82
60 ^{''} 49	61 ^{''} 78	60 ^{''} 54	61 ^{''} 65	62 ^{''} 35	62 ^{''} 09	61 ^{''} 15	61 ^{''} 21	60 ^{''} 60	61 ^{''} 34	61 ^{''} 27	61 ^{''} 15
60 ^{''} 16	61 ^{''} 39	60 ^{''} 04	60 ^{''} 96	62 ^{''} 22	60 ^{''} 41	60 ^{''} 85	61 ^{''} 85	60 ^{''} 91	61 ^{''} 97	61 ^{''} 10	60 ^{''} 36
61 ^{''} 16	61 ^{''} 52	61 ^{''} 28	62 ^{''} 16	61 ^{''} 78	62 ^{''} 16	60 ^{''} 86	60 ^{''} 92	60 ^{''} 55	60 ^{''} 92	61 ^{''} 17	61 ^{''} 74
61 ^{''} 13	60 ^{''} 95	60 ^{''} 70	62 ^{''} 38	61 ^{''} 69	60 ^{''} 00	60 ^{''} 73	60 ^{''} 61	61 ^{''} 03	61 ^{''} 53	61 ^{''} 34	60 ^{''} 54
61 ^{''} 14	61 ^{''} 89	61 ^{''} 58	61 ^{''} 70	62 ^{''} 28	61 ^{''} 14	60 ^{''} 20	60 ^{''} 74	60 ^{''} 79	61 ^{''} 24	61 ^{''} 17	61 ^{''} 17
60 ^{''} 29	61 ^{''} 45	61 ^{''} 58	60 ^{''} 68	61 ^{''} 71	61 ^{''} 83	61 ^{''} 15	60 ^{''} 72	60 ^{''} 78	62 ^{''} 61	61 ^{''} 40	61 ^{''} 65
60 ^{''} 82	61 ^{''} 69	61 ^{''} 37	60 ^{''} 94	61 ^{''} 69	61 ^{''} 98	60 ^{''} 95	61 ^{''} 88	61 ^{''} 13	62 ^{''} 20	61 ^{''} 63	61 ^{''} 26
61 ^{''} 26	61 ^{''} 07	60 ^{''} 71	62 ^{''} 26	61 ^{''} 95	61 ^{''} 00	61 ^{''} 13	61 ^{''} 88	60 ^{''} 82	61 ^{''} 79	61 ^{''} 44	61 ^{''} 76
60 ^{''} 72	61 ^{''} 52	60 ^{''} 29	61 ^{''} 70	61 ^{''} 52	61 ^{''} 64	61 ^{''} 54	61 ^{''} 48	61 ^{''} 85	61 ^{''} 48	61 ^{''} 67	60 ^{''} 56
60 ^{''} 70	61 ^{''} 63	60 ^{''} 89	62 ^{''} 64	61 ^{''} 81	60 ^{''} 95	61 ^{''} 08	60 ^{''} 59	60 ^{''} 96	61 ^{''} 02	61 ^{''} 26	60 ^{''} 90
60 ^{''} 81	61 ^{''} 48	60 ^{''} 97	61 ^{''} 72	61 ^{''} 84	61 ^{''} 51	60 ^{''} 96	61 ^{''} 25	60 ^{''} 83	61 ^{''} 58	61 ^{''} 43	61 ^{''} 06

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RELATIVE VALUES OF SUCCESSIVE INTERVALS OF 1^{rev} OF THE MICROSCOPE-MICROMETER SCREWS—*concluded*.

A	B	C	D	E	F	A	B	C	D	E	F
$1^{\text{r}} - 2^{\text{r}}$						$2^{\text{r}} - 3^{\text{r}}$					
61°14	60°59	60°78	62°95	60°83	63°19	60°55	61°17	61°74	60°43	61°42	62°45
60°48	61°78	62°01	62°29	61°84	60°78	61°46	61°28	61°25	60°72	60°42	62°02
62°02	61°21	63°11	61°15	61°39	61°70	60°07	60°61	60°79	61°29	61°91	60°30
*(63°22)	(62°95)	(64°63)	(64°35)	(64°09)	(63°81)	60°78	61°02	61°14	60°90	60°65	61°70
60°41	61°08	61°64	62°29	62°20	61°14	61°80	62°19	61°37	61°80	60°81	60°87
61°07	62°52	61°50	61°62	61°38	62°78	60°99	61°86	61°61	61°74	61°11	61°61
60°68	61°48	61°30	61°92	61°48	61°36	61°19	61°32	61°63	61°98	61°50	61°88
60°39	61°44	61°07	62°13	61°25	61°82	60°96	61°65	61°58	61°07	61°49	61°67
60°26	60°02	60°68	60°68	60°88	60°88	61°39	60°46	61°26	61°45	61°39	60°51
60°57	60°51	62°30	60°64	61°74	60°26	61°05	61°17	60°07	61°93	61°80	60°73
60°22	61°13	61°32	62°34	62°09	61°56	61°18	60°87	61°12	61°31	60°99	61°37
60°57	61°52	61°14	62°16	61°52	61°77	61°30	60°74	60°62	61°05	61°42	61°36
60°71	61°21	61°53	61°83	61°51	61°57	61°06	61°20	61°18	61°31	61°24	61°37
$3^{\text{r}} - 4^{\text{r}}$						$4^{\text{r}} - 5^{\text{r}}$					
61°70	61°77	62°02	61°20	61°70	58°83	60°48	60°18	61°05	60°43	60°74	62°23
60°53	61°53	62°75	62°36	62°69	60°77	61°92	59°74	60°91	60°85	60°67	61°85
60°56	61°99	61°18	61°99	61°86	61°55	60°95	60°41	61°89	60°10	60°10	62°28
60°68	61°61	61°54	62°49	62°04	61°42	61°36	60°25	61°61	61°42	60°56	61°86
60°83	61°01	61°51	60°77	61°51	60°89	60°42	60°06	61°97	60°42	60°85	62°09
60°76	61°18	61°58	61°83	61°83	61°14	61°15	59°39	61°15	60°17	60°41	62°10
60°98	60°86	60°61	60°79	61°16	61°72	60°86	60°25	62°43	61°23	60°73	60°37
60°77	60°53	61°09	61°03	61°84	61°22	60°39	60°76	61°13	62°01	60°27	61°89
60°96	61°90	61°45	62°47	61°58	62°60	61°37	60°91	61°84	60°97	60°77	62°88
61°04	60°61	62°15	62°22	61°46	61°84	60°67	61°72	62°22	60°91	60°97	61°10
60°79	60°79	61°79	60°98	62°23	61°91	61°01	60°83	60°95	61°45	60°46	62°26
60°62	60°56	61°86	60°80	61°61	61°42	61°42	61°16	62°08	62°41	61°66	62°25
60°85	61°20	61°63	61°58	61°79	61°28	61°08	60°47	61°61	61°03	60°68	61°93
$5^{\text{r}} - 6^{\text{r}}$											
61°32	60°64	62°00	60°89	61°13	62°45	61°69	60°64	61°44	60°58	61°31	61°74
...	...	...	...	...	...	60°92	60°32	61°49	61°12	61°31	61°81
61°34	60°00	60°92	61°60	61°22	61°29	61°08	60°00	61°08	61°52	60°96	62°78
60°74	60°44	61°11	60°26	61°55	62°12	60°73	59°87	61°34	60°54	60°79	61°41
61°29	60°67	60°12	61°66	61°85	61°85	60°85	60°24	61°41	60°42	60°67	62°10
60°78	60°78	60°34	61°15	62°34	61°58						
61°13	60°52	60°58	60°82	60°95	62°58	61°08	60°37	61°08	60°96	61°28	61°97

* These discordances can be accounted for by assuming that the South Collimator microscope was left 0°·1 wrong.

INVESTIGATION OF ERRORS OF THE MICROSCOPE-MICROMETER SCREWS. cxxxv

The following are the values of successive intervals of 1^{rev} for the mean of the six microscopes :—

$9^{\text{r}}-0^{\text{r}}$	$0^{\text{r}}-1^{\text{r}}$	$1^{\text{r}}-2^{\text{r}}$	$2^{\text{r}}-3^{\text{r}}$	$3^{\text{r}}-4^{\text{r}}$	$4^{\text{r}}-5^{\text{r}}$	$5^{\text{r}}-6^{\text{r}}$	Mean $0^{\text{r}}-5^{\text{r}}$
$61''\cdot39$	$61''\cdot19$	$61''\cdot39$	$61''\cdot23$	$61''\cdot39$	$61''\cdot13$	$61''\cdot12$	$61''\cdot27$

The part of the screw in actual use is that from 0^{r} to 5^{r} : and the adopted value of 1^{rev} depends on the "Runs" deduced from measures of this interval. The corresponding quantity in the above measures is $61''\cdot27$.

The following are the apparent errors at different points of the screws, counting from the middle point $2^{\text{r}}\cdot5$, about which the observations are grouped on the average.

At	9^{r}	0^{r}	1^{r}	2^{r}	3^{r}	4^{r}	5^{r}	6^{r}
the error is	$-0''\cdot14$	$-0''\cdot02$	$-0''\cdot10$	$+0''\cdot02$	$-0''\cdot02$	$+0''\cdot10$	$-0''\cdot04$	$-0''\cdot19$

The corresponding quantities found in 1886, soon after the screws were mounted,

were	$-0''\cdot13$	$-0''\cdot07$	$+0''\cdot03$	$-0''\cdot06$	$+0''\cdot06$	$0''\cdot00$	$-0''\cdot06$	$+0''\cdot10$
and in 1893	$-0''\cdot29$	$-0''\cdot11$	$-0''\cdot15$	$+0''\cdot03$	$-0''\cdot03$	$0''\cdot00$	$-0''\cdot09$	$-0''\cdot11$

It has not been considered necessary to apply any corrections for these apparent errors.

If three of the screws had not been reversed these errors would have been at the present time $-0''\cdot57$, $-0''\cdot31$, $-0''\cdot10$, $+0''\cdot02$, $-0''\cdot02$, $+0''\cdot07$, $-0''\cdot36$, $-0''\cdot64$.

INVESTIGATION OF THE ERRORS OF THE ZENITH-DISTANCE MICROMETER SCREW OF THE TRANSIT-CIRCLE.

The value of 1^{rev} of this screw was determined in 1891; the screw was found to be sensibly uniform throughout the range at which it is generally used. A re-determination of the value of 1^{rev} of the screw and of its errors was made from 1896 November 26 to 1897 February 10.

These observations were of three kinds :—

A. Comparisons of 8^{revs} of the Screw with $5'$ of the Circle.

The lengths of the screw from 12^{r} to 20^{r} , 16^{r} to 24^{r} , and 20^{r} to 28^{r} , which are approximately $5'$, were measured on the circle, in three places, with the instrument directed on (1) the South Collimator, (2) the North Collimator, (3) the Nadir. The intervals between the divisions of the Circle were corrected for division-error.

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B. *Comparisons of successive lengths of the Screw with one another.*

The intervals of the screw 12^r to 16^r , 16^r to 20^r , 20^r to 24^r , 24^r to 28^r , were compared with a definite length on the South Collimator. The intervals 16^r to 18^r , 18^r to 20^r , 20^r to 22^r , 22^r to 24^r ; the intervals 16^r to 17^r , 17^r to 18^r , 18^r to 19^r , 19^r to 20^r , 20^r to 21^r , 21^r to 22^r , 22^r to 23^r , 23^r to 24^r ; and the intervals 19^r to $19^r.5$, $19^r.5$ to 20^r , 20^r to $20^r.5$, $20^r.5$ to 21^r were similarly compared with definite lengths on the South Collimator. The observations (A) in conjunction with the first series of (B) were used to determine corrections to the reading of the micrometer with the adopted value of $1^r = 37''.05$ at the points $12^r.000$, $16^r.000$, $24^r.000$, $28^r.000$, the correction at $20^r.000$ being taken as zero. The remaining observations of (B) were then used to determine the corrections to the adopted value of the screw for intermediate readings between $16^r.000$ and $24^r.000$.

C. *Comparisons with the Microscope-micrometers.*

The corrections to the micrometer (with the adopted value $1^{\text{rev.}} = 37''.05$) were obtained by observations of a point on one of the Collimators or of the Nadir, with the Zenith-Distance micrometer screw reading 16^r , 17^r , 18^r , 19^r , 20^r , 21^r , 22^r , 23^r , 24^r ; thus furnishing the correction in terms of the mean readings of the screws of the microscope-micrometers. As the errors of the mean of these screws are very small, this furnishes a good determination of the errors of the Zenith-Distance micrometer-screw.

A. *Comparisons of $8^{\text{revs.}}$ of the Screw with $5'$ of the Circle.*

The three divisions available for the purpose were arranged so as to give values for the intervals of $12^{\text{revs.}}$, $20^{\text{revs.}}$, and $28^{\text{revs.}}$, and also for $16^{\text{revs.}}$ to $24^{\text{revs.}}$, which are the parts of the screw most constantly in use.

The telescope-micrometer was made to read about $12^{\text{revs.}}$ or $16^{\text{revs.}}$, and the horizontal wire was set on one of the sides of the squares of the collimators, or on its own reflected image in the mercury, the instrument was then clamped, six readings of the telescope-micrometer were made and the microscopes read. Then the instrument was unclamped and moved so that the next $5'$ division, as viewed by the microscopes, gave almost exactly the same readings. The instrument was again clamped and a similar observation made; and then observations repeated by moving the instrument backwards and forwards, so that the micrometer read 12^r , 20^r , 28^r , 20^r , 12^r , 28^r , &c., successively.

Adopted value of $1^{\text{rev.}}$ of Zenith-Distance micrometer, $37''.05$.

- (1) Concluded Circle readings on the South Collimator of the divisions $89^\circ.40'$, $89^\circ.35'$, and $89^\circ.30'$, corresponding to reading of the telescope-micrometer at about $12^{\text{revs.}}$, $20^{\text{revs.}}$, and $28^{\text{revs.}}$.

ERRORS OF Z.D. MICROMETER SCREW OF TRANSIT-CIRCLE. cxxxvii

[These observations were made on 1897 January 18 and 19 by Mr. Dyson and Mr. Thackeray.]

12 ^{revs.}	20 ^{revs.}	28 ^{revs.}
$\begin{array}{r} \circ \quad / \quad '' \\ 89.49. \quad 5.79 \\ \quad \quad 6.40 \\ \quad \quad 5.53 \\ \quad \quad 6.61 \\ \quad \quad 6.98 \\ \quad \quad 6.88 \end{array}$	$\begin{array}{r} \circ \quad / \quad '' \\ 89.49. \quad 7.18 \\ \quad \quad 7.45 \\ \quad \quad 7.29 \\ \quad \quad 7.02 \\ \quad \quad 7.03 \\ \quad \quad 8.15 \\ \quad \quad 8.31 \\ \quad \quad 8.75 \\ \quad \quad 8.33 \\ \quad \quad 9.00 \end{array}$	$\begin{array}{r} \circ \quad / \quad '' \\ 89.49. \quad 6.06 \\ \quad \quad 5.82 \\ \quad \quad 5.58 \\ \quad \quad 7.53 \\ \quad \quad 7.28 \\ \quad \quad 7.74 \end{array}$
Mean 89.49. 6.37	89.49. 7.85	89.49. 6.67

Assuming the correction to the value of 20^{revs.} = 0".00, the Apparent Corrections to adopted value are :—

$$\begin{array}{ccc} '' & '' & '' \\ + 1.48 & 0.00 & + 1.18 \end{array}$$

- (2) Concluded Circle readings on the North Collimator of the divisions 269°. 40', 269°. 35', and 269°. 30', corresponding to readings of the telescope-micrometer at about 12^{revs.}, 20^{revs.}, and 28^{revs.}

[These observations were made on 1897 January 20 by Mr. Furner and Mr. Showell.]

12 ^{revs.}	20 ^{revs.}	28 ^{revs.}
$\begin{array}{r} \circ \quad / \quad '' \\ 269.49. \quad 11.35 \\ \quad \quad 11.87 \\ \quad \quad 11.77 \end{array}$	$\begin{array}{r} \circ \quad / \quad '' \\ 269.49. \quad 12.92 \\ \quad \quad 12.57 \\ \quad \quad 13.14 \\ \quad \quad 13.02 \\ \quad \quad 13.54 \end{array}$	$\begin{array}{r} \circ \quad / \quad '' \\ 269.49. \quad 11.34 \\ \quad \quad 12.00 \\ \quad \quad 12.22 \end{array}$
Mean 269.49. 11.66	269.49. 13.04	269.49. 11.85

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Assuming the correction to the value of $20^{\text{revs.}} = 0''.00$, the apparent corrections to adopted value are :—

"

+ 1'38

"

0'00

"

+ 1'19

(3.) Concluded Circle readings on the Nadir of the divisions $179.^{\circ}45'$, $179.^{\circ}40'$ and $179.^{\circ}35'$ corresponding to readings of the telescope-micrometer at about $12^{\text{revs.}}$, $20^{\text{revs.}}$ and $28^{\text{revs.}}$

[These observations were made on 1897 February 10 by Mr. Dyson, Mr. Thackeray and Mr. Furner.]

12 ^{revs.}	20 ^{revs.}	28 ^{revs.}
° ' " 179. 52. 35'88 36'12 35'74 35'81 35'86 35'72 36'74 36'56 36'68 36'78 36'42 36'30	° ' " 179. 52. 37'30 37'28 37'18 37'06 37'53 37'17 36'91 37'11 36'93 37'08 37'05 38'02 37'94 38'31 38'18 37'77 38'01 38'40 37'98 38'26 37'86 37'99	° ' " 179. 52. 36'05 36'42 35'96 36'05 35'84 36'13 36'76 36'85 36'74 36'89 36'90 37'04
Mean 179. 52. 36'22	179. 52. 37'61	179. 52. 36'47

Assuming the correction to the value of $20^{\text{revs.}} = 0''.00$, the apparent corrections to adopted value are :—

"

+ 1'39

"

0'00

"

+ 1'14

- (4) Concluded Circle readings on the North and South Collimators of the divisions $269^{\circ}.35'$ and $269^{\circ}.30'$, and $89^{\circ}.35'$ and $89^{\circ}.30'$, corresponding to readings of the telescope-micrometer, about $16^{\text{revs.}}$ and $24^{\text{revs.}}$

[The observations were made on 1897 January 20 by Mr. Furner and Mr. Showell.]

North Collimator.		South Collimator.	
$16^{\text{revs.}}$	$24^{\text{revs.}}$	$16^{\text{revs.}}$	$24^{\text{revs.}}$
$\begin{array}{r} \circ \quad / \quad " \\ 269. \ 35. \ 12.65 \\ \quad \quad 12.23 \\ \quad \quad 12.56 \\ \quad \quad 11.98 \\ \quad \quad 11.97 \end{array}$	$\begin{array}{r} " \\ 13.08 \\ 12.89 \\ 12.69 \\ 12.36 \\ 12.28 \end{array}$	$\begin{array}{r} \circ \quad / \quad " \\ 89. \ 35. \ 7.72 \\ \quad \quad 7.93 \\ \quad \quad 7.97 \\ \quad \quad 7.77 \\ \quad \quad 7.47 \end{array}$	$\begin{array}{r} " \\ 8.08 \\ 8.52 \\ 7.98 \\ 8.36 \\ 7.87 \end{array}$
Mean $269. \ 35. \ 12.28$	12.66	$89. \ 35. \ 7.57$	8.16

The difference of the corrections to the adopted values of the micrometer at 16^{r} and 24^{r} is—

+ $0''.38$ from observations of the North Collimator.

and

+ $0''.59$ from observations of the South Collimator

B. Comparisons of successive lengths of the Screw with one another.

Successive intervals of about $4^{\text{revs.}}$, $2^{\text{revs.}}$, $1^{\text{rev.}}$, and $0.5^{\text{rev.}}$ of the telescope-micrometer screw were measured by means of the South Collimator micrometer.

The South Collimator having been set to $0^{\text{r}}.000$, the Transit-circle telescope was pointed on it and clamped. Six readings in each case were then taken for coincidence of the horizontal wire with the middle of the side of the square. The South Collimator was then set to $6^{\text{r}}.000$ (the interval corresponding to about $4^{\text{revs.}}$ of the telescope-micrometer), and six readings were taken for coincidence.

These observations were repeated so as to measure each successive interval of about $4^{\text{revs.}}$ of the telescope-micrometer, corresponding to the same interval $6^{\text{r}}.000$ of the South Collimator micrometer.

Similar observations were made for measure of the successive intervals corresponding to $3^{\text{r}}.000$, $1^{\text{r}}.540$ and $0^{\text{r}}.770$ (2^{r} , 1^{r} , and 0.5^{r} nearly of telescope-micrometer) of the South Collimator micrometer.

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Adopted value of 1^{rev.} of telescope-micrometer = 37".05.

1897 JANUARY 26.

Readings of South Collimator Micrometer.	Mean Reading of Telescope-Micrometer.	Intervals.	Mean Reading of Telescope-Micrometer.	Intervals.	Mean Reading of Telescope-Micrometer.	Intervals.	Mean Reading of Telescope-Micrometer.	Intervals.
^r 0.000	^r 12.006	^r }	^r 12.018	^r }	^r 12.028	^r }	^r 12.021	^r }
6.000	15.923	3.917	15.946	3.928	15.952	3.924	15.947	3.926
0.000	16.000		15.992		15.960		16.047	
6.000	19.933	3.933	19.923	3.931	19.890	3.930	19.972	3.925
0.000	20.004		20.008		20.050		20.022	
6.000	23.915	3.911	23.910	3.902	23.952	3.902	23.927	3.905
0.000	24.008		24.004		23.978		24.042	
6.000	27.904	3.896	27.894	3.890	27.869	3.891	27.938	3.896
0.000	28.001		28.014		28.039		28.022	
6.000	24.109	3.892	24.117	3.897	24.140	3.899	24.128	3.894
0.000	24.000		24.030		24.178		24.040	
6.000	20.103	3.897	20.127	3.903	20.275	3.903	20.137	3.903
0.000	20.010		20.013		20.037		20.029	
6.000	16.075	3.935	16.077	3.936	16.098	3.939	16.092	3.937
0.000	15.994		16.005		16.118		16.050	
6.000	12.068	3.926	12.077	3.928	12.188	3.930	12.121	3.929
0.000								

1897 JANUARY 28 AND 29.

Readings of South Collimator Micrometer.	Mean reading of Telescope-Micrometer.	Intervals.	Readings of South Collimator Micrometer.	Mean reading of Telescope-Micrometer.	Intervals.
^r 0.000	^r 15.970	^r }	^r 3.000	^r 24.012	^r }
3.000	17.938	1.968	0.000	22.063	1.949
0.000	17.970		3.000	22.019	
3.000	19.938	1.968	0.000	20.062	1.957
0.000	19.951		3.000	20.022	
3.000	21.907	1.956	0.000	18.061	1.961
0.000	21.981		3.000	18.018	
3.000	23.931	1.950	0.000	16.048	1.970
0.000	23.921		3.000	15.998	
3.000	21.971	1.950	0.000	17.964	1.966
0.000	21.923		3.000	18.002	
3.000	19.965	1.958	0.000	19.966	1.964
0.000	19.941		3.000	19.995	
3.000	17.980	1.961	0.000	21.951	1.956
0.000	17.925		3.000	22.015	
3.000	15.954	1.971	0.000	23.962	1.947
0.000	16.018		3.000	23.982	
3.000	17.976	1.958	0.000	22.032	1.950
0.000	18.010		3.000	21.994	
3.000	19.977	1.967	0.000	20.042	1.952
0.000	19.993		3.000	20.005	
3.000	21.943	1.950	0.000	18.040	1.965
0.000	21.975		3.000	18.024	
3.000	23.924	1.949	0.000	16.056	1.968

ERRORS OF Z.D. MICROMETER SCREW OF TRANSIT-CIRCLE.

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1897 FEBRUARY 1.

Readings of South Collimator Micrometer.	Mean Reading of Telescope- Micrometer.	Intervals.	Mean Reading of Telescope- Micrometer.	Intervals.	Mean Reading of Telescope- Micrometer.	Intervals.	Mean Reading of Telescope- micrometer.	Intervals.
r	r	r	r	r	r	r	r	r
0.000	16.033	} 1.007	16.004	} 1.007	16.020	} 1.010	16.030	} 1.002
1.540	17.040		17.011		17.030		17.032	
0.000	17.028	} 1.003	17.004	} 1.007	17.020	} 1.010	17.031	} 1.002
1.540	18.031		18.011		18.030		18.033	
0.000	18.018	} 1.010	18.003	} 1.008	18.002	} 1.011	18.017	} 1.009
1.540	19.028		19.011		19.013		19.026	
0.000	19.033	} 1.007	19.007	} 1.011	19.012	} 1.011	19.030	} 1.009
1.540	20.040		20.018		20.023		20.039	
0.000	20.043	} 1.003	20.020	} 1.003	20.003	} 1.003	20.017	} 0.999
1.540	21.046		21.023		21.006		21.016	
0.000	21.013	} 1.003	21.025	} 0.999	21.006	} 1.004	21.023	} 1.003
1.540	22.016		22.024		22.010		22.026	
0.000	22.013	} 0.997	22.015	} 1.000	22.011	} 0.998	22.025	} 1.000
1.540	23.010		23.015		23.009		23.025	
0.000	23.017	} 1.004	23.015	} 0.999	23.007	} 1.003	23.002	} 0.999
1.540	24.021		24.014		24.010		24.001	
1.540	24.017	} 0.998	24.015	} 1.000	23.995	} 1.005	24.020	} 1.001
0.000	23.019		23.015		22.990		23.019	
1.540	23.022	} 1.000	23.024	} 1.004	23.004	} 0.999	23.035	} 0.999
0.000	22.022		22.020		22.005		22.036	
1.540	22.031	} 1.006	22.003	} 1.000	22.002	} 1.004	22.048	} 0.997
0.000	21.025		21.003		20.998		21.051	
1.540	21.010	} 1.004	21.005	} 1.008	21.022	} 1.003	21.021	} 1.001
0.000	20.006		19.997		20.019		20.020	
1.540	20.001	} 1.010	20.021	} 1.005	20.011	} 1.010	20.038	} 1.006
0.000	18.991		19.016		19.001		19.032	
1.540	19.031	} 1.009	19.013	} 1.011	19.014	} 1.014	19.052	} 1.009
0.000	18.022		18.002		18.000		18.043	
1.540	18.010	} 1.009	18.004	} 1.013	18.016	} 1.014	18.037	} 1.007
0.000	17.001		16.991		17.002		17.030	
1.540	17.024	} 1.008	17.011	} 1.013	17.022	} 1.018	17.049	} 1.007
0.000	16.016		15.998		16.004		16.042	

1897, FEBRUARY 2.

Readings of South Collimator Micrometer.	Mean reading of Telescope- Micrometer.	Intervals.	Mean reading of Telescope- Micrometer.	Intervals.	Mean reading of Telescope- Micrometer.	Intervals.
^r 0.000 0.770 0.000 0.770 0.000 0.770 0.000 0.770 0.000 0.770 0.000 0.770 0.000 0.770 0.000 0.770	^r 19.002 19.509 19.499 20.002 20.003 20.501 20.505 21.011 20.500 21.001 20.005 20.510 19.498 20.001 19.013 19.519	^r } 0.507 } 0.503 } 0.498 } 0.506 } 0.501 } 0.505 } 0.503 } 0.506	^r 19.002 19.502 19.505 20.008 20.014 20.513 20.518 21.016 20.518 21.018 20.003 20.503 19.519 20.024 19.006 19.512	^r } 0.500 } 0.503 } 0.499 } 0.498 } 0.500 } 0.500 } 0.505 } 0.506	^r 19.014 19.520 19.505 20.007 20.011 20.508 20.532 21.030 20.512 21.011 20.017 20.513 19.515 20.017 19.007 19.512	^r } 0.506 } 0.502 } 0.497 } 0.498 } 0.499 } 0.496 } 0.502 } 0.505

Intervals corresponding to 6^r.000 of South Collimator Micrometer (about 4^{rev.} of telescope-micrometer) :—

12 ^r — 16 ^r	16 ^r — 20 ^r	20 ^r — 24 ^r	24 ^r — 28 ^r
^r 3.917 3.926 3.928 3.928 3.924 3.930 3.926 3.929	^r 3.933 3.935 3.931 3.936 3.930 3.939 3.925 3.937	^r 3.911 3.897 3.902 3.903 3.902 3.903 3.905 3.903	^r 3.896 3.892 3.890 3.897 3.891 3.899 3.896 3.894
3.926	3.933	3.903	3.894

These quantities referred to the general mean 3^r.914 and converted into arc with the adopted value of 1^{rev.} = 37[″].05, assuming the correction at 20^r = 0[″].00, give the following apparent corrections :—

^r 12 ^r + 1 [″] .15	^r 16 ^r + 0 [″] .70	^r 20 ^r 0 [″] .00	^r 24 ^r + 0 [″] .41	^r 28 ^r + 1 [″] .15
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ERRORS OF Z.D. MICROMETER-SCREW OF TRANSIT-CIRCLE.

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Intervals corresponding to $3^{\text{r}}.000$ of South Collimator Micrometer (about $2^{\text{rev.}}$ of telescope-micrometer) :—

$16^{\text{r}} - 18^{\text{r}}$	$18^{\text{r}} - 20^{\text{r}}$	$20^{\text{r}} - 22^{\text{r}}$	$22^{\text{r}} - 24^{\text{r}}$
$1^{\text{r}}.968$ $1^{\text{r}}.971$ $1^{\text{r}}.958$ $1^{\text{r}}.970$ $1^{\text{r}}.966$ $1^{\text{r}}.968$	$1^{\text{r}}.968$ $1^{\text{r}}.961$ $1^{\text{r}}.967$ $1^{\text{r}}.961$ $1^{\text{r}}.964$ $1^{\text{r}}.965$	$1^{\text{r}}.956$ $1^{\text{r}}.958$ $1^{\text{r}}.950$ $1^{\text{r}}.957$ $1^{\text{r}}.956$ $1^{\text{r}}.952$	$1^{\text{r}}.950$ $1^{\text{r}}.950$ $1^{\text{r}}.949$ $1^{\text{r}}.949$ $1^{\text{r}}.947$ $1^{\text{r}}.950$
$1^{\text{r}}.967$	$1^{\text{r}}.964$	$1^{\text{r}}.955$	$1^{\text{r}}.949$

These quantities referred to the general mean $1^{\text{r}}.959$ and converted into arc with the adopted value of $1^{\text{rev.}} = 37''.05$, assuming the correction at $20^{\text{r}} = 0''.00$, give the following apparent corrections :—

16^{r}	18^{r}	20^{r}	22^{r}	24^{r}
—	—	—	—	—
+ $0''.48$	+ $0''.19$	$0''.00$	+ $0''.15$	+ $0''.52$

Intervals corresponding to $1^{\text{r}}.540$ of South Collimator micrometer (about $1^{\text{rev.}}$ of telescope-micrometer).

$16^{\text{r}} - 17^{\text{r}}$	$17^{\text{r}} - 18^{\text{r}}$	$18^{\text{r}} - 19^{\text{r}}$	$19^{\text{r}} - 20^{\text{r}}$	$20^{\text{r}} - 21^{\text{r}}$	$21^{\text{r}} - 22^{\text{r}}$	$22^{\text{r}} - 23^{\text{r}}$	$23^{\text{r}} - 24^{\text{r}}$
$1^{\text{r}}.007$ $1^{\text{r}}.008$ $1^{\text{r}}.007$ $1^{\text{r}}.013$ $1^{\text{r}}.010$ $1^{\text{r}}.018$ $1^{\text{r}}.002$ $1^{\text{r}}.007$	$1^{\text{r}}.003$ $1^{\text{r}}.009$ $1^{\text{r}}.007$ $1^{\text{r}}.013$ $1^{\text{r}}.010$ $1^{\text{r}}.014$ $1^{\text{r}}.002$ $1^{\text{r}}.007$	$1^{\text{r}}.010$ $1^{\text{r}}.009$ $1^{\text{r}}.008$ $1^{\text{r}}.011$ $1^{\text{r}}.011$ $1^{\text{r}}.014$ $1^{\text{r}}.009$ $1^{\text{r}}.009$	$1^{\text{r}}.007$ $1^{\text{r}}.010$ $1^{\text{r}}.011$ $1^{\text{r}}.005$ $1^{\text{r}}.011$ $1^{\text{r}}.010$ $1^{\text{r}}.009$ $1^{\text{r}}.006$	$1^{\text{r}}.003$ $1^{\text{r}}.004$ $1^{\text{r}}.003$ $1^{\text{r}}.008$ $1^{\text{r}}.003$ $1^{\text{r}}.003$ $0^{\text{r}}.999$ $1^{\text{r}}.001$	$1^{\text{r}}.003$ $1^{\text{r}}.006$ $0^{\text{r}}.999$ $1^{\text{r}}.000$ $1^{\text{r}}.004$ $1^{\text{r}}.004$ $1^{\text{r}}.003$ $0^{\text{r}}.997$	$0^{\text{r}}.997$ $1^{\text{r}}.000$ $1^{\text{r}}.000$ $1^{\text{r}}.004$ $0^{\text{r}}.998$ $0^{\text{r}}.999$ $1^{\text{r}}.000$ $0^{\text{r}}.999$	$1^{\text{r}}.004$ $0^{\text{r}}.998$ $0^{\text{r}}.999$ $1^{\text{r}}.000$ $1^{\text{r}}.003$ $1^{\text{r}}.005$ $0^{\text{r}}.999$ $1^{\text{r}}.001$
$1^{\text{r}}.009$	$1^{\text{r}}.008$	$1^{\text{r}}.010$	$1^{\text{r}}.009$	$1^{\text{r}}.003$	$1^{\text{r}}.002$	$1^{\text{r}}.000$	$1^{\text{r}}.001$

These quantities referred to the general mean $1^{\text{r}}.959$ and converted into arc with the adopted value of $1^{\text{rev.}} = 37''.05$, assuming the correction at $20^{\text{r}} = 0''.00$, give the following apparent corrections :—

16^{r}	17^{r}	18^{r}	19^{r}	20^{r}	21^{r}	22^{r}	23^{r}	24^{r}
—	—	—	—	—	—	—	—	—
+ $0''.59$	+ $0''.45$	+ $0''.33$	+ $0''.15$	$0''.00$	+ $0''.07$	+ $0''.19$	+ $0''.37$	+ $0''.52$
GREENWICH OBSERVATIONS, 1896.								u

Intervals corresponding to $0^{\text{r}}.770$ of South Collimator micrometer (about $0.5^{\text{rev.}}$ of telescope-micrometer).

$19^{\text{r}}.0 - 19^{\text{r}}.5$	$19^{\text{r}}.5 - 20^{\text{r}}.0$	$20^{\text{r}}.0 - 20^{\text{r}}.5$	$20^{\text{r}}.5 - 21^{\text{r}}$
r	r	r	r
0.507	0.503	0.498	0.506
0.506	0.503	0.505	0.501
0.500	0.503	0.499	0.498
0.506	0.505	0.500	0.500
0.506	0.502	0.497	0.498
0.505	0.502	0.496	0.499
0.505	0.503	0.499	0.500

These quantities referred to the general mean $0^{\text{r}}.502$ and converted into arc with the adopted value of $1^{\text{rev.}} = 37''.05$, assuming the correction at $20^{\text{r}} = .000''$, give the following apparent corrections :—

$19^{\text{r}}.0$	$19^{\text{r}}.5$	$20^{\text{r}}.0$	$20^{\text{r}}.5$	$21^{\text{r}}.0$
—	—	—	—	—
+ $0''.15$	+ $0''.04$	$0''.00$	+ $0''.11$	+ $0''.19$

C. Comparisons with the Microscope-micrometers.

The telescope-micrometer was made to read about $16^{\text{revs.}}$ and the horizontal wire was set on one of the sides of the square of the collimator or its own reflected image in the mercury, the instrument was then clamped, six readings of the telescope-micrometer made, and the microscopes read. Then the instrument was unclamped and the telescope-micrometer was moved as nearly as possible $1^{\text{rev.}}$, the horizontal wire was again set on one of the sides of the square of the collimator or its reflected image in the mercury, the instrument was clamped, and a similar observation made.

- (1.) Concluded Circle readings of the observation on the South Collimator at intervals of $1^{\text{rev.}}$ of the telescope-micrometer from $16^{\text{revs.}}$ to $25^{\text{revs.}}$

Adopted value of $1^{\text{rev.}}$ of the telescope-micrometer = $37''.05$.

The observations were made on 1897 January 16 and 26 by Mr. Furner, Mr. Witchell and Mr. Showell.

ERRORS OF Z.D. MICROMETER SCREW OF TRANSIT-CIRCLE.

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JANUARY 16^d. 0^h.

—	16 ^{revs.}	17 ^{revs.}	18 ^{revs.}	19 ^{revs.}	20 ^{revs.}	21 ^{revs.}	22 ^{revs.}	23 ^{revs.}	24 ^{revs.}	25 ^{revs.}
0 /	"	"	"	"	"	"	"	"	"	"
89. 49	3'35	3'80	3'90	4'31	4'39	4'36	3'86	4'04	3'71	4'01
	2'94	3'73	3'96	4'10	4'36	4'45	4'32	4'24	3'77	3'85
	3'34	3'55	3'92	4'01	4'30	4'25	4'44	3'92	3'73	3'67
	3'24	3'51	3'92	4'18	4'26	4'37	4'39	4'11	3'53	4'28
	3'19	3'91	3'90	4'34	4'35	4'12	4'35	3'78	3'50	3'82
Mean ...	3'21	3'70	3'92	4'19	4'33	4'31	4'27	4'02	3'65	3'93

Assuming the correction to the value of 20^{revs.} = 0".00, the apparent corrections to adopted value are :—

16 ^r	17 ^r	18 ^r	19 ^r	20 ^r	21 ^r	22 ^r	23 ^r	24 ^r	25 ^r
—	—	—	—	—	—	—	—	—	—
+ 1".12	+ 0".63	+ 0".41	+ 0".14	0".00	+ 0".02	+ 0".06	+ 0".31	+ 0".68	+ 0".40

JANUARY 26^d. 3^h.

—	16 ^{revs.}	17 ^{revs.}	18 ^{revs.}	19 ^{revs.}	20 ^{revs.}	21 ^{revs.}	22 ^{revs.}	23 ^{revs.}	24 ^{revs.}
0 /	"	"	"	"	"	"	"	"	"
89. 50	33'18	33'46	32'97	33'47	33'76	33'81	33'73	33'60	33'14
	32'79	33'02	32'98	33'18	33'37	33'66	33'66	33'16	33'22
Mean ...	32'99	33'24	32'98	33'33	33'57	33'74	33'70	33'38	33'18

Assuming the correction to the value of 20^{revs.} = 0".00, the apparent corrections to adopted value are—

16 ^r	17 ^r	18 ^r	19 ^r	20 ^r	21 ^r	22 ^r	23 ^r	24 ^r
—	—	—	—	—	—	—	—	—
+ 0".58	+ 0".33	+ 0".59	+ 0".24	0".00	— 0".17	— 0".13	+ 0".19	+ 0".39

(2) Concluded Circle readings of the observations of the Nadir at intervals of 1^{rev.} of the telescope-micrometer from 16^{revs.} to 24^{revs.}

Two sets of observations were made on 1897 January 21 and January 22 by Mr. Dyson and Mr. Thackeray, and by Mr. Rendell and Mr. Appleyard.

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Adopted value of 1^{rev.} of the telescope-micrometer = 37".05.

—	16 ^{revs.}	17 ^{revs.}	18 ^{revs.}	19 ^{revs.}	20 ^{revs.}	21 ^{revs.}	22 ^{revs.}	23 ^{revs.}	24 ^{revs.}
January 21. d. h. 179. 52	37".72	37".82	38".22	38".30	38".58	38".02	38".10	38".16	37".91
21. 23.	37".58	37".86	37".81	38".40	38".38	38".33	38".85	38".35	
	37".35	37".89	37".45	38".08	38".06	37".43	37".57	37".33	37".44
	36".65	36".98	37".32	37".39	37".86	37".51	37".23	37".63	
Mean ...	37".33	37".64	37".70	38".04	38".22	37".82	37".94	37".87	37".68

Assuming the correction to the value of 20^{revs.} = 0".00, the apparent corrections to adopted value are —

$$\begin{array}{cccccccc} \overline{16^r} & \overline{17^r} & \overline{18^r} & \overline{19^r} & \overline{20^r} & \overline{21^r} & \overline{22^r} & \overline{23^r} & \overline{24^r} \\ + 0''.89 & + 0''.58 & + 0''.52 & + 0''.18 & 0''.00 & + 0''.40 & + 0''.28 & + 0''.35 & + 0''.54 \end{array}$$

(3) Concluded Circle readings of the observations of the North Collimator at intervals of 1^{rev.} of the telescope-micrometer from 16^{revs.} to 24^{revs.}

These observations were made on 1897 January 26 and February 8 by Mr. Furner, Mr. Wittchell, and Mr. Showell.

Adopted value of 1^{rev.} of the telescope-micrometer = 37".05.

—	16 ^{revs.}	17 ^{revs.}	18 ^{revs.}	19 ^{revs.}	20 ^{revs.}	21 ^{revs.}	22 ^{revs.}	23 ^{revs.}	24 ^{revs.}
269° 50'	33".15	33".17	33".51	33".02	33".26	33".75	33".49	33".55	33".30
	32".76	32".85	33".43	33".31	33".20	33".32	33".32	33".45	33".55
Mean ...	32".96	33".01	33".47	33".17	33".23	33".54	33".41	33".50	33".43

Assuming the correction to the value of 20^{revs.} = 0".00, the apparent corrections to adopted value are :—

$$\begin{array}{cccccccc} \overline{16^r} & \overline{17^r} & \overline{18^r} & \overline{19^r} & \overline{20^r} & \overline{21^r} & \overline{22^r} & \overline{23^r} & \overline{24^r} \\ + 0''.27 & + 0''.22 & - 0''.24 & + 0''.06 & 0''.00 & - 0''.31 & - 0''.18 & - 0''.27 & - 0''.20 \end{array}$$

FEBRUARY 8^{d.} 3^{h.}

—	16 ^{revs.}	17 ^{revs.}	18 ^{revs.}	19 ^{revs.}	20 ^{revs.}	21 ^{revs.}	22 ^{revs.}	23 ^{revs.}	24 ^{revs.}
269° 49'	9".73	10".27	10".43	9".85	10".14	10".59	10".49	10".73	10".27
	9".71	9".76	10".03	10".06	10".10	10".38	10".06	10".39	10".00
	9".27	10".35	10".37	10".62	10".83	10".61	10".45	10".77	10".41
	9".22	9".60	9".62	9".57	10".20	10".13	10".06	9".17	10".11
Mean ...	9".48	10".00	10".11	10".03	10".32	10".43	10".27	10".27	10".20

Assuming the correction to the value of 20^{revs.} = 0".00, the apparent corrections to the adopted value are :—

$$\begin{array}{cccccccc} \overline{16^r} & \overline{17^r} & \overline{18^r} & \overline{19^r} & \overline{20^r} & \overline{21^r} & \overline{22^r} & \overline{23^r} & \overline{24^r} \\ + 0''.84 & + 0''.32 & + 0''.21 & + 0''.29 & 0''.00 & - 0''.11 & + 0''.05 & + 0''.05 & + 0''.12 \end{array}$$

CORRECTIONS TO ADOPTED READINGS OF TELESCOPE-MICROMETER SCREW. cxlvii

TABLE OF CORRECTIONS TO ADOPTED READINGS OF TELESCOPE-MICROMETER SCREW ON THE ASSUMPTION THAT THE SCREW IS UNIFORM AND $1^{\text{rev.}} = 37''_{05}$ DERIVED FROM PRECEDING RESULTS.

A.—FROM COMPARISONS OF 8 REVOLUTIONS OF THE SCREW WITH 5' OF THE CIRCLE.

—		12 ^{revs.}	20 ^{revs.}	28 ^{revs.}	16 ^{revs.} —24 ^{revs.}
January 18, 19	Observations of South Collimator ...	...	...	...	...
January 20	Observations of North Collimator ...	...	...	...	...
February 10	Observations of Nadir ...	...	...	...	...
	Mean	...	...	...	...
		+ 1'48 ₆	0'00 ₁₀	+ 1'18 ₆	+ 0'59 ₅
		+ 1'38 ₅	0'00 ₅	+ 1'19 ₃	+ 0'38 ₅
		+ 1'39 ₁₂	0'00 ₂₂	+ 1'14 ₁₂	...
		+ 1'41 ₂₁	0'00 ₃₇	+ 1'16 ₂₁	+ 0'48 ₁₀

B.—FROM COMPARISONS OF SUCCESSIVE LENGTHS OF THE SCREW WITH ONE ANOTHER.

—	12 ^{r.}	16 ^{r.}	17 ^{r.}	18 ^{r.}	19 ^{r.}	19 ^{r.} 5.	20 ^{r.}	20 ^{r.} 5.	21 ^{r.}	22 ^{r.}	23 ^{r.}	24 ^{r.}	28 ^{r.}
(1) 4 ^{revs.} of Tel.-mic. by means of S. Coll.	+ 1'15 ₈	+ 0'70 ₈	...	...	...	...	0'00 ₈	...	...	...	...	+ 0'41 ₈	+ 1'15 ₈
(2) 2 ^{revs.} of Tel.-mic. by means of S. Coll.	...	+ 0'48 ₆	...	+ 0'19 ₆	...	...	0'00 ₆	...	...	+ 0'15 ₆	...	+ 0'52 ₆	...
(3) 1 ^{rev.} of Tel.-mic. by means of S. Coll.	...	+ 0'59 ₈	+ 0'45 ₈	+ 0'33 ₈	+ 0'15 ₈	...	0'00 ₈	...	+ 0'07 ₈	+ 0'19 ₈	+ 0'37 ₈	+ 0'52 ₈	...
(4) 0 ^{rev.} 5 of Tel.-mic. by means of S. Coll.	...	...	...	...	+ 0'15 ₆	+ 0'04 ₆	0'00 ₆	+ 0'11 ₆	+ 0'19 ₆	...	...	...	...
Mean ...	+ 1'15 ₈	+ 0'60 ₂₂	+ 0'45 ₈	+ 0'27 ₁₄	+ 0'15 ₁₄	+ 0'04 ₆	0'00 ₈	+ 0'11 ₆	+ 0'12 ₁₄	+ 0'17 ₁₄	+ 0'37 ₈	+ 0'48 ₂₂	+ 1'15 ₈

TABLE OF CORRECTIONS TO ADOPTED READINGS OF TELESCOPE-MICROMETER SCREW—continued.

C.—FROM COMPARISONS WITH THE MICROSCOPE-MICROMETERS.

—		16 ^r .	17 ^r .	18 ^r .	19 ^r .	20 ^r .	21 ^r .	22 ^r .	23 ^r .	24 ^r .	25 ^r .
Jan. 16	Observations of South Collimator	+ 1 ^{.12} ₅	+ 0 ^{.63} ₅	+ 0 ^{.41} ₅	+ 0 ^{.14} ₅	0 ^{.00} ₅	+ 0 ^{.02} ₅	+ 0 ^{.06} ₅	+ 0 ^{.31} ₅	+ 0 ^{.68} ₅	" + 0 ^{.40} ₅
26	Observations of South Collimator	+ 0 ^{.58} ₂	+ 0 ^{.33} ₂	+ 0 ^{.59} ₂	+ 0 ^{.24} ₂	0 ^{.00} ₂	— 0 ^{.17} ₂	— 0 ^{.13} ₂	+ 0 ^{.19} ₂	+ 0 ^{.39} ₂	
Jan. 21-22	Observations of Nadir ..	+ 0 ^{.89} ₄	+ 0 ^{.58} ₄	+ 0 ^{.52} ₄	+ 0 ^{.18} ₄	0 ^{.00} ₄	+ 0 ^{.40} ₄	+ 0 ^{.28} ₄	+ 0 ^{.35} ₄	+ 0 ^{.54} ₄	
Jan. 26	Observations of North Collimator	+ 0 ^{.27} ₂	+ 0 ^{.22} ₂	— 0 ^{.24} ₂	+ 0 ^{.06} ₂	0 ^{.00} ₂	— 0 ^{.31} ₂	— 0 ^{.18} ₂	— 0 ^{.27} ₂	— 0 ^{.20} ₂	
Feb. 8	Observations of North Collimator	+ 0 ^{.84} ₄	+ 0 ^{.32} ₄	+ 0 ^{.21} ₄	+ 0 ^{.29} ₄	0 ^{.00} ₄	— 0 ^{.11} ₄	+ 0 ^{.05} ₄	+ 0 ^{.05} ₄	+ 0 ^{.12} ₄	
	Mean ...	+ 0 ^{.84} ₁₇	+ 0 ^{.46} ₁₇	+ 0 ^{.33} ₁₇	+ 0 ^{.19} ₁₇	0 ^{.00} ₁₇	+ 0 ^{.02} ₁₇	+ 0 ^{.06} ₁₇	+ 0 ^{.17} ₁₇	+ 0 ^{.38} ₁₇	+ 0 ^{.40} ₅

CORRECTIONS TO ADOPTED READINGS OF TELESCOPE-MICROMETER SCREW. cxlix

If C_{12} , C_{20} , C_{28} , &c., be the corrections to the adopted equivalents of the telescope-micrometer screw on the supposition that the screw is uniform and $1^{\text{rev.}} = 37''.05$, then assuming $C_{20} = 0$, we have—

$$\begin{array}{lcl} C_{12} = + 1''.41 & C_{28} = + 1''.16 & C_{16}-C_{24} = + 0''.48 \quad - \quad - \quad - \quad \text{from A} \\ \text{Also } \left. \begin{array}{l} C_{12} = + 1''.15 + 2x \\ C_{28} = + 1''.15 - 2x \end{array} \right\} & & \left. \begin{array}{l} C_{16} = + 0''.70 + x \\ C_{24} = + 0''.41 - x \end{array} \right\} \quad - \quad - \quad \text{from B (1)} \end{array}$$

where x is the correction to the adopted value of the interval on the collimator with which $12^{\text{r}}-16^{\text{r}}$, $16^{\text{r}}-20^{\text{r}}$, $20^{\text{r}}-24^{\text{r}}$, $24^{\text{r}}-28^{\text{r}}$, of the micrometer-screw were compared.

Giving the equations derived from A double weight, as they depend on more observations, we have the normal equations—

$$\begin{aligned} 3 C_{12} &= + 3''.97 + 2x \\ 3 C_{28} &= + 3''.47 - 2x \\ 3 C_{16} - 2 C_{24} &= + 1''.66 + x \\ 3 C_{24} - 2 C_{16} &= - 0''.55 - x \\ 10x - 2(C_{12} - C_{28}) - (C_{16} - C_{24}) &= - 0''.30 \end{aligned}$$

The solution of these equations gives—

$$\left. \begin{array}{l} x = + 0''.07 \\ C_{12} = + 1''.37 \\ C_{28} = + 1''.11 \\ C_{16} = + 0''.79 \\ C_{24} = + 0''.32 \end{array} \right\} \quad (i).$$

Similarly the second set of observations B (2) leads to the equations—

$$\left. \begin{array}{l} C_{16} = + 0''.48 + 2y \\ C_{24} = + 0''.52 - 2y \end{array} \right\} \quad \text{and} \quad \left. \begin{array}{l} C_{18} = + 0''.19 + y \\ C_{22} = + 0''.15 - y \end{array} \right\}$$

Using the values of C_{16} and C_{24} determined in (i) we obtain—

$$C_{16} = + 0''.74 \quad C_{18} = + 0''.32 \quad C_{22} = + 0''.02 \quad C_{24} = + 0''.26$$

The third set of equations B (3) similarly treated gives—

$$\begin{array}{llll} C_{16} = + 0''.79 & C_{17} = + 0''.60 & C_{18} = + 0''.43 & C_{19} = + 0''.20 \\ C_{21} = + 0''.02 & C_{22} = + 0''.09 & C_{23} = + 0''.22 & C_{24} = + 0''.32 \end{array}$$

Combining the determinations we have for the corrections C_{16} to C_{24} :—

	16 ^r	17 ^r	18 ^r	19 ^r	20 ^r	21 ^r	22 ^r	23 ^r	24 ^r	
	+0''.79	...	...	...	...	...	...	...	+0''.32	from A and B (1)
	+0''.74	...	+0''.32	...	...	...	+0''.02	...	+0''.26	from B (2), $\frac{1}{2}$ wt.
	+0''.79	+0''.60	+0''.43	+0''.20	...	+0''.02	+0''.09	+0''.22	+0''.32	from B (3), $\frac{1}{2}$ wt.
	+0''.84	+0''.46	+0''.33	+0''.19	...	+0''.02	+0''.06	+0''.17	+0''.38	from C.
Mean...	+0''.80	+0''.51	+0''.35	+0''.19	...	+0''.02	+0''.06	+0''.19	+0''.33	

c1 INTRODUCTION TO GREENWICH ASTRONOMICAL OBSERVATIONS, 1896.

The following table gives the resulting corrections to the readings of the micrometer screw from 11^r to 29^r , read off from a smoothed curve. The micrometer is never used beyond these limits and rarely outside 16^r to 24^r .

TABLE OF CORRECTIONS TO VALUES OF TELESCOPE-MICROMETER SCREW.

Revolution.	Correction.	Revolution.	Correction.
	"		"
11 $^{\circ}$ 0	+ 1 $^{\circ}$ 50	20 $^{\circ}$ 5	0 $^{\circ}$ 00
12 $^{\circ}$ 0	+ 1 $^{\circ}$ 39	21 $^{\circ}$ 0	+ 0 $^{\circ}$ 02
13 $^{\circ}$ 0	+ 1 $^{\circ}$ 25	21 $^{\circ}$ 5	+ 0 $^{\circ}$ 04
14 $^{\circ}$ 0	+ 1 $^{\circ}$ 13	22 $^{\circ}$ 0	+ 0 $^{\circ}$ 07
15 $^{\circ}$ 0	+ 0 $^{\circ}$ 98	22 $^{\circ}$ 5	+ 0 $^{\circ}$ 13
16 $^{\circ}$ 0	+ 0 $^{\circ}$ 80	23 $^{\circ}$ 0	+ 0 $^{\circ}$ 20
17 $^{\circ}$ 0	+ 0 $^{\circ}$ 52	24 $^{\circ}$ 0	+ 0 $^{\circ}$ 32
17 $^{\circ}$ 5	+ 0 $^{\circ}$ 45	25 $^{\circ}$ 0	+ 0 $^{\circ}$ 44
18 $^{\circ}$ 0	+ 0 $^{\circ}$ 35	26 $^{\circ}$ 0	+ 0 $^{\circ}$ 65
18 $^{\circ}$ 5	+ 0 $^{\circ}$ 25	27 $^{\circ}$ 0	+ 0 $^{\circ}$ 86
19 $^{\circ}$ 0	+ 0 $^{\circ}$ 16	28 $^{\circ}$ 0	+ 1 $^{\circ}$ 10
19 $^{\circ}$ 5	+ 0 $^{\circ}$ 10	29 $^{\circ}$ 0	+ 1 $^{\circ}$ 30
20 $^{\circ}$ 0	0 $^{\circ}$ 00		

These corrections have not been applied in the Zenith-Distances section, but have been applied to the results given in the Star Ledgers and Planetary Results in all cases where the correction amounted to $0''.1$. The correction to the adopted zenith point was first obtained for each day by applying the necessary corrections to the observations of Nadir and Reflexion Stars, and this was combined with the separate correction for the individual observations.

R—D INVESTIGATION.

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EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS
OF ZENITH DISTANCES WITH THE TRANSIT-CIRCLE, 1896, CORRECTED FOR
THE ERRORS OF THE TELESCOPE-MICROMETER SCREW.

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. R. A.	Approx. N. P. D.	R—D.	No. of Obs. R. and D.	Weight.	Star's Name.	Approx. R. A.	Approx. N. P. D.	R—D.	No. of Obs. R. and D.	Weight.
	h m	° ' "	"				h m	° ' "	"		
31 Camelopardi S.P.	5. 45	−30. 1	−1°58	1	1	Bradley 2796 S.P....	21. 17	−13. 4	+0°07	1	1
6 Ursæ Majoris S.P.	9. 6	−28. 1	+1°40	1	1	γ Cephei S.P.	23. 34	−13. 0	+0°21	3	3
α Ursæ Majoris S.P.	10. 57	−27. 7	+0°80	1	1	35 Draconis S.P. ...	17. 54	−13. 0	−0°37	1	1
α Cephei S.P.	21. 16	−27. 7	+0°35	1	1						
17 Camelopardi S.P.	5. 22	−27. 0	−0°63	2	2						
Groomb. 1806 S.P....	11. 32	−26. 7	−0°57	1	1						
						77 Draconis S.P. ...	21. 7	−12. 3	−0°83	1	1
19 Camelopardi S.P.	5. 27	−25. 9	−0°43	1	1	Groomb. 1151 S.P....	6. 25	−11. 9	+0°28	5	4
6 Ursæ Majoris S.P.	8. 48	−25. 0	−0°09	2	2	ρ Cephei S.P.	22. 29	−11. 7	−1°37	1	1
Groomb. 3739 S.P....	22. 14	−24. 4	−2°74	1	1	Cephei 47 S.P.	2. 52	−11. 0	−1°48	1	1
Groomb. 120 S.P....	0. 36	−24. 4	−0°82	1	1	Piazzi IV. 269 S.P..	5. 5	−10. 9	−2°09	1	1
Radcliffe 1516 S.P.	5. 32	−24. 4	−1°53	1	1	Piazzi VI. 75 S.P. ..	6. 28	−10. 3	−0°72	2	2
Bradley 1429 S.P....	10. 17	−23. 9	+0°70	1	1	Bradley 3067 S.P....	22. 59	−9. 8	−2°28	1	1
α Camelopardi S.P.	4. 44	−23. 8	−0°54	2	2	Lalande F. 4555 S.P.	23. 38	−9. 3	−1°22	1	1
						B.D. + 80° No. 34 S.P.	1. 8	−9. 0	+0°48	1	1
α Ursæ Majoris S.P.	8. 59	−22. 7	−0°19	2	2	Bradley 344 S.P. ...	2. 33	−9. 0	−0°47	1	1
42 Camelopardi S.P.	6. 40	−22. 3	−0°09	1	1	Bradley 1458 S.P....	10. 32	−9. 0	−0°69	1	1
55 Camelopardi S.P.	8. 0	−21. 2	+0°42	1	1	Bradley 1439 S.P....	10. 24	−9. 0	−0°59	1	1
4 Draconis S.P.	12. 26	−20. 2	−1°59	1	1	Groomb. 856 S.P....	4. 41	−9. 0	−0°35	3	3
Groomb. 3409 S.P....	21. 6	−19. 1	−2°67	1	1	Piazzi VI. 334 S.P..	7. 16	−8. 9	+0°14	2	2
						Piazzi VI. 285 S.P..	7. 3	−8. 6	−1°07	1	1
50 Cassiopeiæ S.P....	1. 54	−18. 1	−0°36	1	1	Piazzi IX. 37 S.P. ..	9. 21	−8. 2	−0°22	1	1
ψ ² Draconis S.P. ...	17. 57	−18. 0	−0°73	1	1	Bradley 48 S.P.	0. 32	−8. 1	−0°03	1	1
ψ ¹ Draconis S.P. ...	17. 44	−17. 8	−0°56	1	1						
γ Ursæ Minoris S.P.	15. 21	−17. 8	−0°73	1	1	Piazzi VI. 292 S.P....	7. 9	−7. 4	−1°68	2	2
40 Cassiopeiæ S.P. ...	1. 30	−17. 5	−1°40	1	1	Bradley 3038 S.P....	22. 48	−7. 4	+1°16	1	1
31 Cephei S.P.	22. 33	−16. 9	−0°97	1	1	Lalande F. 757 S.P.	5. 39	−7. 3	−0°80	2	2
79 Draconis S.P. ...	2. 51	−16. 8	−0°54	2	2	Bradley 3058 S.P. ...	22. 55	−6. 2	−1°03	1	1
τ Draconis S.P.	19. 17	−16. 8	−2°69	1	1	Bradley 1399 S.P....	10. 14	−5. 2	−0°54	1	1
Piazzi IX. 187 S.P..	9. 49	−16. 6	+0°17	2	2	Groomb. 956 S.P....	5. 33	−4. 7	+1°42	1	1
Bradley 282 S.P. ...	2. 3	−16. 5	+1°30	1	1	Groomb. 1418 S.P....	8. 24	−4. 6	−0°59	2	2
Bradley 3085 S.P....	23. 11	−16. 3	−1°58	2	2	Bradley 2993 S.P....	22. 22	−4. 4	−1°12	2	2
Piazzi VI. 254 S.P..	6. 49	−16. 2	−1°62	1	1	δ Ursæ Minoris S.P.	18. 6	−3. 4	−0°12	4	3
Bradley 417 S.P. ...	3. 0	−16. 0	−0°87	1	1	Groomb. 3548 S.P..	21. 21	−3. 4	−0°01	1	1
						Bradley 95 S.P.	0. 58	−3. 4	−0°98	1	1
π Cephei S.P.	23. 5	−15. 2	−1°90	1	1	Bradley 3147 S.P....	23. 28	−3. 3	−0°04	5	4
Piazzi XXIII. 218 S.P.	23. 47	−15. 0	−0°28	1	1	Cephei 51 S.P.	6. 51	−2. 8	−0°71	2	2
49 Cassiopeiæ S.P..	1. 55	−14. 4	+0°27	1	1	Groomb. 2283 S.P....	15. 11	−2. 4	−1°03	2	2
Bradley 1147 S.P....	8. 6	−13. 9	+0°30	2	2	Bradley 1672 S.P....	12. 14	−1. 7	+0°01	1	1
Bradley 1146 S.P....	7. 55	−13. 8	+0°24	1	1	Polaris S.P.	1. 20	−1. 3	+0°07	19	7
						Groomb. 1119 S.P....	7. 52	−1. 1	−0°33	4	3
						λ Ursæ Minoris S.P.	19. 29	−1. 0	−2°00	2	2

GREENWICH OBSERVATIONS, 1896.

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EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS
OF ZENITH DISTANCES WITH THE TRANSIT-CIRCLE, 1896—continued.

Star's Name.	Approx. R. A.	Approx. N. P. D.	R—D.	No. of Obs. R. and D.	Weight.	Star's Name.	Approx. R. A.	Approx. N. P. D.	R—D.	No. of Obs. R. and D.	Weight.
	h m	° ' "					h m	° ' "			
λ Ursæ Minoris.....	19. 29	1. 0	—0°06	6	4	10 Ursæ Minoris..	15. 6	15. 7	+0°07	1	1
Groombridge 1119..	7. 52	1. 1	+0°30	2	2	Groombridge 2719..	18. 48	16. 0	+0°10	1	1
Cephei 24	20. 2	1. 2	—0°74	1	1	Bradley 417.....	2. 59	16. 0	+1°03	1	1
Polaris	1. 20	1. 3	—0°01	9	5	79 Draconis.....	21. 52	16. 8	+0°94	2	2
Bradley 1672.....	12. 14	1. 7	—0°05	2	2	7 Draconis.....	19. 17	16. 8	+0°34	4	3
Groombridge 2283..	15. 11	2. 4	+0°30	4	3	Piazzi XIII. 109 ...	13. 23	17. 1	+1°09	1	1
Cephei 51	6. 51	2. 8	—0°71	4	3	16 Cephei	21. 58	17. 3	+0°08	4	3
Bradley 3147.....	23. 28	3. 2	+0°78	2	2	40 Cassiopeiæ	1. 29	17. 5	—0°30	1	1
δ Ursæ Minoris.....	18. 6	3. 4	+0°18	6	4	γ Ursæ Minoris.....	15. 21	17. 8	+0°40	1	1
Groombridge 3548..	21. 21	3. 4	+0°48	2	2	9 Ursæ Minoris.....	15. 0	17. 8	+1°28	1	1
Groombridge 642...	3. 32	3. 7	—0°55	1	1	ψ ¹ Draconis	17. 44	17. 8	—0°83	2	2
Bradley 2993.....	22. 21	4. 4	—0°21	2	2	50 Cassiopeiæ	1. 54	18. 1	+0°79	2	2
Bradley 1399.....	10. 14	5. 3	+1°21	2	2	Groombridge 2029..	13. 35	18. 2	—0°30	2	2
Bradley 3058.....	22. 55	6. 2	+0°59	1	1	Bradley 2934	22. 8	18. 4	+1°15	3	3
76 Draconis	20. 50	7. 8	+0°13	1	1	19 Lyrae	19. 8	58. 9	+0°67	1	1
ε Ursæ Minoris	16. 58	7. 8	—1°84	1	1	ρ Boötis	14. 27	59. 1	—0°61	1	1
Piazzi VI. 285	7. 5	8. 5	—1°10	1	1	32 Herculis.....	16. 29	59. 3	—0°37	1	1
75 Draconis	20. 35	8. 9	—0°13	1	1	7 Geminorum	7. 3	59. 6	—0°18	1	1
Bradley 1439.....	10. 24	9. 0	+0°61	1	1	ζ Cygni	21. 8	60. 2	—0°03	3	3
Lalande 2354.....	13. 42	9. 3	—0°63	1	1	τ Piscium.....	1. 5	60. 4	+0°81	1	1
Bradley 2749.....	20. 52	9. 8	+0°36	1	1	β Coronæ	15. 23	60. 5	—0°60	1	1
Lalande F. 2523.....	14. 36	9. 9	+0°16	1	1	ξ Herculis.....	17. 53	60. 7	—0°60	1	1
Groombridge 2066..	13. 50	10. 5	+0°18	1	1	α Trianguli	1. 47	60. 9	—0°22	3	3
Groombridge 2900..	19. 28	10. 6	+0°17	1	1	γ Comæ	12. 21	61. 1	+0°13	1	1
Groombridge 1735..	11. 2	11. 7	+0°64	2	2						
28 Cephei	22. 26	11. 7	—1°03	1	1						
Bradley 1508.....	10. 52	11. 7	+1°17	3	3						
Bradley 1634.....	12. 7	11. 8	—0°46	2	2						
Groombridge 1151..	6. 25	11. 9	—0°27	1	1	α Andromedæ	0. 2	61. 4	+0°18	1	1
ζ Ursæ Minoris.....	15. 48	11. 9	—0°21	1	1	β Comæ	13. 7	61. 6	+0°92	1	1
4 Ursæ Minoris	14. 9	11. 9	+0°41	3	3	Pollux	7. 38	61. 7	—0°58	1	1
						53 Geminorum	7. 8	61. 9	—0°74	1	1
						30 Comæ.....	12. 43	61. 9	+0°43	1	1
						ι Geminorum.....	7. 18	62. 0	—0°20	1	1
Groombridge 2391..	16. 48	12. 3	—1°32	1	1	9 Boötis	13. 52	62. 0	+0°31	1	1
θ Ursæ Minoris.....	15. 35	12. 3	+0°40	1	1	11 Boötis	13. 56	62. 1	+0°71	1	1
77 Draconis	21. 7	12. 3	—0°68	2	2	β Cygni	19. 26	62. 2	+0°06	1	1
Bradley 431	3. 5	12. 6	+0°61	1	1	32 Vulpeculæ.....	20. 49	62. 3	—0°09	2	2
Groombridge 2140..	14. 32	13. 0	—0°62	2	2	β Pegasi	22. 59	62. 4	—1°00	1	1
35 Draconis	17. 54	13. 0	+0°56	1	1	ε ² Boötis.....	14. 40	62. 5	—0°14	2	2
5 Ursæ Minoris.....	14. 28	13. 8	—0°34	3	3	ψ Boötis.....	14. 59	62. 6	+0°39	3	3
Bradley 1147.....	8. 6	13. 9	+0°39	1	1	α Coronæ	15. 30	62. 9	+0°87	1	1
Bradley 1650.....	12. 14	14. 2	+0°54	1	1	41 Arietis	2. 43	63. 1	+0°17	1	1
Piazzi IV. 112	4. 33	14. 2	+0°54	1	1	μ Leonis.....	9. 46	63. 5	+0°44	2	2
Piazzi XXIII. 218..	23. 47	15. 0	—1°03	1	1	λ Boötis	13. 41	63. 7	+0°70	1	1
β Ursæ Minoris.....	14. 51	15. 4	+0°61	3	3	λ Herculis.....	17. 26	63. 8	—0°06	1	1
73 Draconis	20. 33	15. 4	—0°67	1	1	3 Vulpeculæ	19. 18	63. 9	+1°09	1	1

R—D INVESTIGATION.

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EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS
OF ZENITH DISTANCES WITH THE TRANSIT-CIRCLE, 1896—continued.

Star's Name.	Approx. R. A.	Approx. N. P. D.	R—D.	No of Obs. R. and D.	Weight.	Star's Name.	Approx. R. A.	Approx. N. P. D.	R—D.	No of Obs. R. and D.	Weight.
	h m	° ' "	"				h m	° ' "	"		
d Boötis.....	14. 5	64. 4	+0°93	2	2	γ Geminorum	6. 32	73. 5	+0°92	1	1
ω Boötis.....	14. 57	64. 5	-0°33	2	2	51 Geminorum.....	7. 7	73. 6	+0°68	1	1
16 Pegasi	21. 48	64. 5	+0°06	4	3	ν Boötis	13. 44	73. 7	-0°09	2	2
ε Geminorum	6. 37	64. 7	+1°01	1	1	68 Geminorum.....	7. 27	73. 9	+0°28	1	1
67 Leonis	11. 3	64. 7	+0°68	1	1						
54 Leonis	10. 50	64. 7	-0°64	1	1						
κ Pegasi	21. 38	64. 8	+1°04	2	2						
11 Tauri.....	3. 34	65. 0	-0°09	1	1	14 Sagittæ.....	19. 58	74. 2	+0°45	1	1
ι Pegasi	22. 2	65. 1	+1°88	1	1	Bradley 2667.....	20. 34	74. 5	-0°48	2	2
30 Vulpeculæ	20. 47	65. 1	-0°78	2	2	15 Orionis.....	5. 3	74. 5	+1°34	1	1
ν Cancrī.....	8. 56	65. 1	+0°62	1	1	β Leonis	11. 41	74. 8	+0°42	1	1
α Vulpeculæ.....	19. 24	65. 5	+0°39	3	3	ν Orionis	6. 1	75. 2	+0°23	1	1
ε Leonis	9. 40	65. 7	+1°83	1	1	ι 29 Cancrī	8. 30	75. 4	+0°63	3	3
41 Leonis Minoris..	10. 38	66. 2	+0°12	1	1	α ¹ Herculis	17. 9	75. 5	+0°23	3	3
Piazzī XVIII. 100...	18. 26	66. 2	+0°42	2	2	37 Leonis	10. 10	75. 7	+0°94	1	1
Piazzī XVIII. 132...	18. 31	66. 4	+1°19	1	1	ζ Boötis	14. 36	75. 8	+0°16	2	2
34 Vulpeculæ	21. 16	66. 5	+1°28	1	1	α Ophiuchi	17. 30	77. 3	+0°31	4	3
						Piazzī XVII. 148...	17. 29	77. 4	-0°07	1	1
						Regulus	10. 2	77. 5	-0°46	2	2
1 Geminorum	5. 57	66. 7	-0°29	1	1	α Cancrī.....	8. 53	77. 7	+1°34	1	1
7 Arietis	1. 49	66. 9	+0°42	1	1	A Aquilæ	19. 7	77. 8	+0°57	1	1
α Arietis	2. 1	67. 0	-0°43	1	1						
1 Comæ	11. 56	67. 3	+0°92	1	1						
μ Geminorum	6. 17	67. 4	+1°65	2	2						
δ Geminorum	7. 14	67. 8	+1°58	1	1	b Aquilæ	19. 9	78. 2	+0°51	2	2
92 Leonis	11. 36	68. 0	+0°25	1	1	ε Virginis	12. 57	78. 5	+0°84	4	3
Δ ¹ Tauri.....	3. 58	68. 2	+0°01	1	1	ω Aquilæ	19. 13	78. 5	+0°85	2	2
109 Herculis.....	18. 19	68. 2	+0°29	4	3	58 Piscium	0. 41	78. 6	+0°65	1	1
β Herculis.....	16. 26	68. 3	-0°02	1	1	κ Cancrī.....	9. 3	78. 9	+0°63	2	2
1 Vulpeculæ.....	19. 11	68. 8	-0°01	1	1	l Leonis.....	10. 44	78. 9	+0°89	3	3
δ Leonis	11. 8	68. 9	+0°16	4	3	ε Delphini.....	20. 28	79. 0	+1°14	1	1
b Leonis	10. 55	69. 2	+0°21	1	1	δ Serpēntis	15. 29	79. 1	-1°23	1	1
β Arietis	1. 49	69. 7	-1°16	1	1	ρ Virginis	12. 36	79. 2	+0°75	1	1
ν Geminorum	6. 23	69. 7	+1°16	1	1	A Leonis	10. 2	79. 5	+1°05	1	1
						o Leonis.....	9. 36	79. 6	+2°87	1	1
Arcturus	14. 10	70. 2	+0°91	4	3	γ Aquilæ	19. 41	79. 6	+0°33	3	3
f Boötis	14. 22	70. 3	+0°04	2	2	γ Equulei	21. 6	80. 2	-0°66	1	1
ξ Boötis	14. 46	70. 4	+0°12	1	1	κ Delphini.....	20. 30	80. 2	+0°88	1	1
ω ¹ Tauri.....	4. 3	70. 6	+0°74	3	3	κ Ophiuchi	16. 53	80. 4	+0°65	1	1
γ Herculis.....	16. 18	70. 6	-0°03	1	1	ε Pegasi	21. 39	80. 6	+1°43	1	1
Piazzī XVII. 255...	17. 44	70. 7	+0°47	1	1	o Virginis	12. 0	80. 7	+0°42	1	1
η Boötis	13. 42	71. 1	-0°73	2	2	ξ Virginis	11. 40	81. 1	-0°76	1	1
5 Pegasi	21. 33	71. 1	+0°19	1	1	π ² Orionis	4. 45	81. 2	+1°12	1	1
g Geminorum	7. 39	71. 2	-0°76	1	1	o Piscium	1. 39	81. 3	+0°39	2	2
111 Herculis.....	18. 43	71. 9	+1°15	2	2	π Leonis	9. 54	81. 4	-0°15	4	3
71 Leonis	11. 16	72. 0	-1°46	1	1	31 Boötis	14. 36	81. 4	+1°86	1	1
τ Boötis	13. 42	72. 0	+0°40	5	4	α Aquilæ.....	19. 0	81. 4	+0°24	4	3
3 Comæ	12. 5	72. 6	+1°92	1	1	β Canis Minoris ...	7. 22	81. 5	-0°81	1	1
o Boötis	14. 40	72. 6	-0°31	1	1	k Herculis.....	16. 45	82. 6	+0°07	1	1
						α Orionis	5. 49	82. 6	+0°39	1	1

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EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, FOR OBSERVATIONS
OF ZENITH DISTANCES WITH THE TRANSIT-CIRCLE, 1896—concluded.

Star's Name.	Approx. R. A.	Approx. N. P. D.	R—D.	No. of Obs. R. and D.	Weight.	Star's Name.	Approx. R. A.	Approx. N. P. D.	R—D.	No. of Obs. R. and D.	Weight.
	h m	° ' "	"				h m	° ' "	"		
ε Piscium	0. 57	82. 6	+0°54	2	2	ο Aquarii	21. 58	92. 6	+0°50	1	1
π Virginis	11. 57	82. 8	+0°89	2	2	η Serpentis	18. 16	92. 9	+1°16	2	2
δ Piscium	0. 43	82. 9	+0°17	1	1						
ζ ¹ Piscium.....	1. 7	82. 9	+0°08	1	1	69 Aquilæ	20. 24	93. 2	—0°32	2	2
ζ ² Piscium.....	1. 7	82. 9	—0°03	1	1	ζ Serpentis	17. 53	93. 6	+1°17	1	1
						16 Libræ	14. 51	93. 9	—0°43	1	1
α Serpentis	15. 39	83. 2	+0°40	3	3	6 Aquilæ	18. 41	94. 7	+0°66	1	1
56 Leonis	10. 51	83. 2	+0°93	1	1	θ Virginis	13. 4	94. 9	+1°85	2	2
β Equulei	21. 10	83. 6	—0°44	2	2	Piazzi XVII. 99 ...	17. 21	94. 9	+1°20	2	2
ζ Hydræ	8. 49	83. 6	+1°05	3	3	3 Aquarii	18. 38	95. 4	+1°69	1	1
Procyon.....	7. 34	84. 5	+0°55	3	3	12 Aquilæ.....	18. 56	95. 8	—0°66	1	1
σ Aquilæ	19. 34	84. 8	+1°27	1	1	Bradley 2870.....	21. 53	95. 8	—1°27	1	1
α Equulei	21. 10	85. 1	+2°61	1	1						
ε Serpentis	15. 46	85. 2	+0°91	2	2	8 Sextantis	9. 47	97. 6	+0°73	2	2
β Ophiuchi	17. 38	85. 3	+0°98	3	3	Rigel	5. 9	98. 3	+1°75	1	1
σ Ophiuchi	17. 21	85. 7	+1°45	1	1	ψ Virginis	12. 48	98. 9	+1°95	1	1
δ Leonis.....	10. 55	85. 8	—0°80	1	1	2 Aquilæ	18. 36	99. 1	+1°51	1	1
ι Virginis	12. 50	86. 0	+0°31	1	1	ι Ceti	0. 14	99. 3	+0°76	1	1
α Ceti.....	2. 57	86. 3	+0°99	1	1	κ Orionis	5. 42	99. 7	+1°45	4	3
74 Ophiuchi	18. 4	86. 6	+0°27	1	1	ζ Ophiuchi	16. 31	100. 3	+0°74	2	2
δ Aquilæ	19. 20	87. 0	+0°86	1	1	Spica	13. 19	100. 6	+0°26	2	2
110 Virginis	14. 40	87. 5	+1°30	1	1	χ Ceti.....	1. 47	101. 1	+0°54	2	2
τ Virginis	13. 56	87. 9	+0°07	3	3	Piazzi I. 182	1. 44	101. 2	+0°84	1	1
						λ Hydræ	5. 2	101. 8	—1°30	1	1
ζ Virginis	13. 30	90. 0	—0°62	1	1						
ν Leonis.....	11. 31	90. 2	+0°61	2	2	γ ¹ Eridani.....	3. 53	103. 7	+1°42	1	1
α Aquarii	22. 0	90. 8	+0°89	1	1	μ Capricorni.....	21. 47	104. 0	+0°72	1	1
θ Aquilæ	20. 6	91. 1	—0°12	2	2	ι Aquarii	22. 0	104. 3	+1°73	1	1
α Hydræ	9. 22	91. 2	—0°25	1	1	γ Libræ	15. 30	104. 4	+1°20	1	1
71 Aquilæ.....	20. 33	91. 4	—0°09	2	2	Bradley 2313	18. 22	104. 6	+0°06	1	1
φ Virginis	14. 23	91. 7	+1°24	1	1	η Ophiuchi	17. 4	105. 5	+0°42	2	2

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, 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 $\frac{mn}{m^2e^2 + ne^2 + 2mne_0^2}$, or assuming $e_0^2 = \frac{1}{10}e^2$, which would make $e_0 = 0''.16$, the weight becomes $\frac{4mn}{m+n+\frac{1}{5}mn}$, which has been adopted. If $m = n$, as is usually the case, the weight becomes $\frac{20m}{10+m}$.

R—D INVESTIGATION.

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

Extent of Group, 1896.	Weight.	Mean N.P.D.	Mean Z.D. South.	Mean Value of R—D, cor- rected for Inclination of Verticals.	R—D computed by the Formula $+ 0''.112$ $+ 0''.734 \times$ $\sin Z.D.$	Apparent Error of Formula.
31 Camelopardi S.P. to Groomb. 1806 S.P.	7	-27. 8	-66. 3	- 0'.49	- 0'.56	- 0'.07
19 Camelopardi S.P. to α Camelopardi S.P.	9	-24. 5	-63. 0	- 0'.82	- 0'.54	+ 0'.28
σ^1 Ursæ Majoris S.P. to Groomb. 3409 S.P.	6	-21. 4	-59. 9	- 0'.86	- 0'.52	+ 0'.34
50 Cassiopeiæ S.P. to Bradley 417 S.P.	16	-17. 0	-55. 5	- 0'.91	- 0'.49	+ 0'.50
π Cephi S.P. to 35 Draconis S.P.	11	-13. 8	-52. 3	- 0'.20	- 0'.47	- 0'.27
77 Draconis S.P. to Bradley 48 S.P.	24	-10. 0	-48. 5	- 0'.57	- 0'.44	+ 0'.13
Piazzi VI. 292 S.P. to λ Ursæ Minoris.	38	- 3. 4	-41. 9	- 0'.55	- 0'.38	+ 0'.17
λ Ursæ Minoris to Bradley 3058	34	2. 6	-35. 9	0'.00	- 0'.32	- 0'.32
76 Draconis to 4 Ursæ Minoris	23	10. 7	-27. 8	- 0'.02	- 0'.23	- 0'.21
Groombridge 2391 to 73 Draconis.	19	13. 7	-24. 8	- 0'.16	- 0'.20	- 0'.04
10 Ursæ Minoris to Bradley 2934.	24	17. 4	-21. 1	+ 0'.34	- 0'.15	- 0'.49
19 Lyræ to γ Comæ	14	60. 2	+21. 7	- 0'.05	+ 0'.39	+ 0'.44
α Andromedæ to 3 Vulpeculæ	24	62. 5	+24. 0	+ 0'.24	+ 0'.42	+ 0'.18
δ Boötis to 34 Vulpeculæ	26	65. 2	+26. 7	+ 0'.52	+ 0'.45	- 0'.07
1 Geminorum to ν Geminorum.	20	68. 2	+29. 7	+ 0'.44	+ 0'.48	+ 0'.04
Arcturus to 68 Geminorum	29	71. 6	+33. 1	+ 0'.41	+ 0'.52	+ 0'.11
14 Sagittæ to A Aquilæ	23	76. 0	+37. 5	+ 0'.41	+ 0'.57	+ 0'.16
b Aquilæ to ζ^2 Piscium	47	80. 4	+41. 9	+ 0'.60	+ 0'.61	+ 0'.01
α Serpentis to τ Virginis	29	85. 1	+46. 6	+ 0'.78	+ 0'.65	- 0'.13
ζ Virginis to η Serpentis.	13	91. 3	+52. 8	+ 0'.51	+ 0'.70	+ 0'.19
69 Aquilæ to Bradley 2870	12	94. 6	+56. 1	+ 0'.68	+ 0'.73	+ 0'.05
8 Sextantis to χ Ceti	17	99. 8	+61. 3	+ 0'.99	+ 0'.76	- 0'.23
γ^1 Eridani to η Ophiuchi	7	104. 6	+66. 1	+ 1'.00	+ 0'.79	- 0'.21

In forming the mean values of R—D for groups in the last column but two 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—

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

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

For direct-observations

$$+ 0''.056 + 0''.367 \sin Z.D.$$

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For reflexion-observations

$$- 0''.056 - 0''.367 \sin Z.D. + 0''.16 \sin Z.D.$$

$$\text{or} \quad - 0''.056 - 0''.207 \sin Z.D.$$

For use, these formulæ have been tabulated as follows ; and the corrections have been applied to the mean results for 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, 1896.

N.P.D.	Corrections to Results of Direct- Observations.	Corrections to Results of Reflexion- Observations.
0	"	"
- 45	- 0'.31	+ 0'.15
40	0'.31	0'.15
30	0'.29	0'.14
20	0'.26	0'.12
- 10	0'.22	0'.10
0	0'.17	0'.07
+ 10	0'.12	0'.04
20	- 0'.06	+ 0'.01
30	0'.00	- 0'.03
40	+ 0'.07	0'.06
50	0'.13	0'.10
60	0'.19	0'.13
70	0'.25	0'.17
80	0'.30	0'.20
90	0'.35	0'.22
100	0'.38	0'.24
110	0'.41	0'.26
120	0'.42	0'.27
+ 125	+ 0'.43	- 0'.27

SPECIAL R—D INVESTIGATION.

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SECONDS OF DIFFERENCE OF N.P.D. OF PAIRS OF STARS, ONE BEING OBSERVED
BY REFLEXION AND THE OTHER DIRECTLY.

Date, 1896.	τ^2 Hydræ R. — ι Hydræ D.	τ^2 Hydræ D. — ι Hydræ R.	Date, 1896.	κ Serpentis R. — ι Serpentis D.	κ Serpentis D. — ι Serpentis R.
Mar. 23	"	"	June 18	"	"
27	...	18°08	19	...	32°27
28	20°92	...	20	34°18	...
	...	19°99	23	...	32°68
Apr. 10	20°64	...	25	36°12	...
15	20°51	...	26	...	33°75
17	...	19°29	29	32°80	...
18	19°41	...		...	31°40
20	...	17°91	July 6	...	32°17
21	20°45	...			
22	...	17°06			
Mean ...	20°49	18°47	Mean ...	34°37	32°45
Date, 1896.	6 Comæ R. — 3 Comæ D.	6 Comæ D. — 3 Comæ R.	Date, 1896.	κ Herculis R. — τ Herculis D.	κ Herculis D. — τ Herculis R.
Mar. 23	"	"	June 19	"	"
24	...	34°25	20	...	53°93
25	36°86	35°32	23	56°35	...
27	...	...	25	...	52°22
30	36°42	35°50	26	...	55°24
Apr. 1	...	35°39	29	53°79	...
18	...	35°47		...	53°70
21	...	34°37	July 6	54°77	...
23	34°50	...	9	...	52°69
May 1	37°67	...			
4	36°86	...			
Mean ...	36°46	35°05	Mean ...	54°97	53°56

SPECIAL REFLEXIONS—concluded.

Date, 1896.	2 Aquilæ R. — 1 Aquilæ D.	2 Aquilæ D. — 1 Aquilæ R.	Date, 1896.	Groomb. 3887 R. — Bradley 3038 D.	Groomb. 3887 D. — Bradley 3038 R.
July 17	"	"	Oct. 27	"	"
20	6.80	3.82		12.13	...
21	...	...			
24	...	5.43			
31	8.00	5.95	Nov. 2	13.66	...
Aug. 1	...	4.79	4	...	14.01
20	6.60	...	6	12.47	...
21	7.62	...	9	...	15.56
22	...	7.11	10	12.84	...
			30	...	14.81
Sept. 5	...	5.50			
Oct. 9	...	6.14	Dec. 4	13.35	...
10	8.31	...			
Mean ...	7.47	5.53	Mean ...	12.89	14.79
Date, 1896.	ω Aquilæ R. — ζ Aquilæ D.	ω Aquilæ D. — ζ Aquilæ R.	Date, 1896.	Piazzi XI. 43 S.P. R. — O.A. (N.) 11509 S.P. D.	Piazzi XI. 43 S.P. D. — O.A. (N.) 11509 S.P. R.
July 17	"	"	Oct. 27	"	"
21	3.96	...		13.01	...
	4.87	...			
Aug. 1	...	3.37	Nov. 2	...	13.12
11	...	3.46	4	10.07	...
12	4.43	...	5	...	10.69
13	...	2.51	6	14.90	...
14	3.93	...	9	...	13.08
17	...	1.54	10	11.62	...
20	...	2.69	30	...	11.11
22	...	3.03			
25	4.97	...			
Oct. 9	...	2.99	Dec. 4	12.30	...
10	5.62	...	22	12.83	...
Mean ...	4.63	2.80	Mean ...	12.40	12.00

SPECIAL R—D INVESTIGATION.

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VALUES OF z (R—D) DEDUCED FROM ABOVE OBSERVATIONS.

The Weight below is the number of complete sets of four observations.

Name of Star.	Approx. R. A.	Approx. N.P.D.	z (R—D.)	No. of Obs.	Wt.	Name of Star.	Approx. R. A.	Approx. N.P.D.	z (R—D.)	No. of Obs.	Wt.
	h m	°	"				h m	°	"		
P. XI. 43 S.P....	...	-25°1	+ 0°46	6		6 Comæ	...	74°5	+	5	
—O.A.(N)11509 S.P.	...	-21°2		4	4	— 3 Comæ	...	72°6	+ 1°41	5	5
Gr. 3887	...	9°2	- 1°90	5		ω Aquilæ	...	78°6	+ 1°83	6	
—Brad. 3038 ...	...	7°4		3	3	— ζ Aquilæ	...	76°3		7	6
κ Serpentis	...	71°5	+ 1°92	3		τ² Hydræ	...	90°7	+ 2°02	5	
—ι Serpentis	...	70°0		5	3	— ι Hydræ	...	90°7		5	5
κ Herculis	...	72°7	+ 1°41	3		2 Aquilæ	...	99°2	+ 1°94	5	
—r Herculis	...	71°9		5	3	— 1 Aquilæ	...	98°3		7	5

Results for R—D Discordance when the Reflexion and Direct observations were made on different nights compared with those taken in the ordinary manner, and with the values computed from the formulæ $+ 0''\cdot112 + 0''\cdot734 \sin Z.D.$

Approx. N.P.D.	Approx. Z.D. South.	R and D observation on different nights. R—D	Weight.	R observation immediately before D. R—D	From formula. R—D
°	°	"		"	"
- 23°2	- 61°7	+ 0°23	4	- 0°83	- 0°53
+ 8°3	- 30°2	- 0°95	3	- 0°07	- 0°28
+ 71°5	+ 33°0	+ 0°83	6	+ 0°41	+ 0°52
+ 73°6	+ 35°1	+ 0°71	5	+ 0°41	+ 0°55
+ 77°5	+ 39°0	+ 0°92	6	+ 0°60	+ 0°58
+ 90°7	+ 52°2	+ 1°01	5	+ 0°62	+ 0°70
+ 98°8	+ 60°3	+ 0°97	5	+ 0°90	+ 0°75

GREENWICH OBSERVATIONS, 1896.

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SIMULTANEOUS READINGS AT APPARENT NOON OF THE TRANSIT-CIRCLE EXTERIOR THERMOMETER, THE METEOROLOGICAL STANDARD THERMOMETER, AND THE THERMOMETER ON THE ROOF OF THE MAGNET HOUSE, IN THE YEAR 1896.

Date, 1896.	Exterior Thermom.	Excess of		Date, 1896.	Exterior Thermom.	Excess of	
		Meteoro-logical Standard.	Magnet House Thermom.			Meteoro-logical Standard.	Magnet House Thermom.
Jan. ^{d h m}	[°]	[°]	[°]	May ^{d h m}	[°]	[°]	[°]
13. 0. 9	42.0	- 2.0	+ 0.1	3. 23. 57	54.7	+ 6.1	+ 2.1
17. 0. 10	48.8	+ 1.0	+ 1.1	4. 23. 57	58.9	+ 5.3	+ 1.9
20. 0. 11	37.7	+ 1.1	+ 2.0	5. 23. 56	56.4	+ 0.4	+ 0.4
22. 0. 12	39.8	+ 1.1	+ 1.0	6. 23. 56	62.2	+ 0.4	+ 2.2
24. 0. 12	43.8	+ 1.5	+ 1.5	7. 23. 56	54.8	+ 4.1	+ 2.0
28. 0. 13	44.3	+ 1.1	+ 0.5	8. 23. 56	61.7	+ 4.0	+ 4.1
29. 0. 13	39.4	- 0.2	+ 0.2	9. 23. 56	66.4	+ 3.5	+ 4.2
30. 0. 13	35.8	+ 1.0	+ 0.3	10. 23. 56	65.9	+ 4.2	+ 3.9
Feb. ^{d h m}	[°]	[°]	[°]	11. 23. 56	68.2	+ 6.2	+ 5.1
2. 0. 14	36.7	+ 1.1	+ 1.9	12. 23. 56	60.0	+ 4.8	+ 1.8
3. 0. 14	39.6	+ 0.7	+ 1.6	13. 23. 56	66.1	+ 2.8	+ 2.7
8. 0. 14	50.6	+ 0.6	+ 1.5	14. 23. 56	67.1	+ 1.8	+ 2.5
9. 0. 14	50.6	+ 0.2	+ 1.1	15. 23. 56	55.8	+ 1.2	+ 1.0
10. 0. 14	46.9	+ 2.4	+ 1.4	16. 23. 56	63.3	+ 1.5	+ 1.1
12. 0. 14	50.0	+ 2.5	+ 2.0	17. 23. 56	71.8	+ 3.5	+ 3.3
13. 0. 14	45.9	+ 1.3	+ 2.1	18. 23. 56	59.2	+ 4.0	+ 1.4
17. 0. 14	39.8	+ 1.0	+ 2.0	23. 23. 57	58.4	+ 3.0	+ 1.1
22. 0. 14	39.8	+ 1.2	+ 2.2	27. 23. 57	61.9	+ 3.5	+ 1.9
23. 0. 14	37.3	+ 1.3	+ 2.3	28. 23. 57	66.7	+ 2.4	+ 1.9
24. 0. 13	37.3	+ 1.4	+ 2.8	30. 23. 58	61.8	+ 6.0	+ 4.0
27. 0. 13	39.1	+ 1.8	+ 1.8	31. 23. 58	69.8	+ 4.7	+ 3.0
Mar. ^{d h m}	[°]	[°]	[°]	June ^{d h m}	[°]	[°]	[°]
3. 0. 12	44.1	+ 1.0	+ 0.6	1. 23. 58	77.1	+ 3.5	+ 0.6
10. 0. 10	47.8	+ 1.6	+ 2.2	3. 23. 58	76.8	+ 3.3	+ 3.8
15. 0. 9	48.7	+ 1.3	+ 1.9	4. 23. 58	66.6	+ 0.5	+ 0.2
17. 0. 8	54.8	- 0.9	+ 0.1	6. 23. 59	63.6	- 0.3	- 1.0
19. 0. 8	42.9	+ 1.7	+ 3.0	10. 23. 59	66.8	+ 2.0	+ 2.0
22. 0. 7	59.4	+ 4.3	+ 3.5	12. 0. 0	74.7	+ 2.2	+ 3.2
23. 0. 6	57.7	+ 1.6	+ 1.5	13. 0. 0	77.2	+ 1.1	+ 1.9
24. 0. 6	58.4	+ 0.1	+ 1.4	14. 0. 0	71.7	+ 3.1	+ 2.9
25. 0. 6	56.8	+ 2.5	+ 2.0	15. 0. 0	76.1	+ 4.3	+ 1.8
26. 0. 6	49.7	+ 1.3	+ 0.5	16. 0. 1	80.3	+ 3.5	+ 2.0
27. 0. 5	46.1	+ 2.5	+ 1.2	18. 0. 1	68.9	+ 1.9	+ 0.9
30. 0. 4	44.6	+ 2.0	+ 1.0	19. 0. 1	69.0	+ 3.3	+ 2.3
31. 0. 4	43.5	+ 0.9	+ 0.5	21. 0. 2	67.2	- 0.6	- 0.5
Apr. ^{d h m}	[°]	[°]	[°]	22. 0. 2	67.9	+ 0.8	+ 0.5
2. 0. 3	45.2	+ 1.1	+ 0.8	23. 0. 2	71.8	- 1.0	0.0
13. 0. 0	47.0	+ 2.8	+ 1.0	26. 0. 3	60.4	+ 0.6	+ 1.4
15. 0. 0	47.2	+ 2.2	+ 1.2	28. 0. 3	73.2	+ 1.2	+ 1.2
16. 23. 59	52.8	+ 2.4	+ 0.4	29. 0. 3	64.2	+ 2.8	+ 1.7
18. 23. 59	57.3	+ 0.4	+ 0.7	30. 0. 3	69.6	+ 0.2	- 0.1
19. 23. 59	55.2	- 0.6	+ 1.4	July ^{d h m}	[°]	[°]	[°]
21. 23. 58	57.2	+ 1.8	+ 1.6	1. 0. 4	63.1	- 0.7	- 1.0
22. 23. 58	51.8	+ 0.3	+ 0.6	3. 0. 4	71.8	+ 0.1	0.0
23. 23. 58	52.9	+ 2.1	+ 1.9	4. 0. 4	68.7	+ 2.3	+ 0.9
27. 23. 57	58.4	+ 0.1	- 0.2	5. 0. 4	67.6	+ 2.7	+ 2.0
28. 23. 57	50.0	- 0.8	- 1.2	6. 0. 5	74.9	+ 7.0	+ 5.7
29. 23. 57	50.0	+ 4.3	+ 2.8	7. 0. 5	81.8	+ 1.5	+ 0.6
30. 23. 57	47.9	+ 4.4	+ 3.6	8. 0. 5	78.8	+ 3.5	+ 2.5

THERMOMETERS.

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SIMULTANEOUS READINGS AT APPARENT NOON OF THE TRANSIT-CIRCLE EXTERIOR THERMOMETER, THE METEOROLOGICAL STANDARD THERMOMETER, AND THE THERMOMETER ON THE ROOF OF THE MAGNET HOUSE IN THE YEAR 1896—concluded.

Date, 1896.	Exterior Thermom.	Excess of		Date, 1896.	Exterior Thermom.	Excess of	
		Meteoro-logical Standard.	Magnet House Thermom.			Meteoro-logical Standard.	Magnet House Thermom.
July	^d ^h ^m	[°]	[°]	Sept.	^d ^h ^m	[°]	[°]
9. o. 5	78.8	+ 3.3	+ 0.9	22. 23. 52	59.3	- 0.5	- 0.5
10. o. 5	72.5	+ 2.3	+ 1.7	23. 23. 52	56.1	+ 1.9	+ 1.3
11. o. 5	67.8	+ 2.0	+ 1.7	27. 23. 50	54.0	+ 1.0	+ 0.9
12. o. 5	72.6	+ 4.7	+ 3.7	28. 23. 50	56.4	+ 0.4	+ 1.1
13. o. 6	77.1	+ 5.6	+ 3.8	29. 23. 50	57.7	+ 3.7	+ 3.2
14. o. 6	79.9	+ 4.2	+ 3.2	30. 23. 49	54.9	- 2.0	0.0
15. o. 6	72.3	+ 4.5	+ 2.7				
17. o. 6	61.9	+ 3.5	+ 2.4				
18. o. 6	69.5	+ 2.3	+ 1.6	Oct.	4. 23. 48	51.8	+ 1.9
20. o. 6	81.8	- 0.2	+ 1.1	7. 23. 47	61.8	- 0.3	+ 0.1
21. o. 6	81.5	+ 4.3	+ 3.0	8. 23. 47	58.5	+ 2.6	+ 2.5
23. o. 6	71.4	+ 2.2	+ 1.6	9. 23. 47	56.9	+ 2.2	+ 1.7
24. o. 6	73.8	+ 2.8	+ 1.4	13. 23. 46	50.9	+ 1.6	+ 0.8
27. o. 6	66.7	+ 2.2	+ 1.9	14. 23. 46	56.4	+ 2.1	+ 1.4
28. o. 6	63.6	+ 6.2	+ 4.4	22. 23. 44	45.8	+ 2.4	+ 1.8
29. o. 6	69.9	+ 4.2	+ 2.6	26. 23. 44	45.4	+ 1.8	+ 1.4
31. o. 6	68.7	- 0.7	+ 0.9	27. 23. 44	43.1	+ 3.9	+ 3.9
				28. 23. 44	40.9	- 1.3	- 0.9
Aug.	^d ^h ^m	[°]	[°]	29. 23. 44	46.9	+ 1.1	+ 1.9
1. o. 6	67.8	+ 1.0	+ 0.6	30. 23. 44	43.5	+ 1.0	+ 0.3
3. o. 6	67.0	+ 2.8	- 0.2				
4. o. 6	64.0	+ 1.6	+ 0.8	Nov.	2. 23. 44	43.0	+ 2.0
6. o. 6	62.0	+ 4.0	+ 1.9	3. 23. 44	43.5	+ 2.0	+ 1.9
7. o. 5	64.1	+ 3.7	+ 0.7	4. 23. 44	43.9	+ 2.2	+ 1.3
10. o. 5	63.0	+ 2.8	+ 1.6	5. 23. 44	42.8	+ 2.0	+ 1.6
11. o. 5	66.2	+ 2.7	+ 2.2	8. 23. 44	42.8	+ 1.8	+ 0.8
12. o. 5	68.4	+ 2.3	+ 2.6	9. 23. 44	41.8	+ 1.1	+ 1.1
13. o. 5	71.6	0.0	+ 0.1	11. 23. 44	48.9	+ 0.8	+ 1.7
14. o. 4	69.1	+ 1.7	+ 0.8	12. 23. 45	47.4	+ 1.0	+ 1.7
15. o. 4	62.8	+ 1.0	+ 0.8	14. 23. 45	44.6	+ 0.7	+ 0.6
16. o. 4	65.4	+ 1.9	+ 2.0	15. 23. 45	46.7	+ 0.9	+ 1.5
17. o. 4	65.8	+ 0.4	+ 1.2	18. 23. 46	40.8	+ 1.6	+ 1.6
19. o. 3	65.6	- 0.3	+ 1.0	19. 23. 46	48.5	+ 0.4	+ 0.4
20. o. 3	65.3	+ 3.2	+ 2.7	26. 23. 48	40.3	+ 1.7	+ 1.7
21. o. 3	67.8	0.0	+ 2.1	28. 23. 49	36.9	+ 1.1	+ 1.5
22. o. 3	63.8	+ 2.3	+ 2.0	29. 23. 49	36.1	+ 1.7	+ 1.7
25. o. 2	66.0	+ 1.0	+ 1.6				
29. o. 1	63.0	+ 3.0	+ 3.4				
Sept.	^d ^h ^m	[°]	[°]	Dec.	^d ^h ^m	[°]	[°]
1. 23. 59	61.4	+ 1.5	+ 2.0	9. 23. 53	47.7	+ 1.1	+ 1.3
2. 23. 59	62.4	+ 0.5	+ 0.7	12. 23. 55	41.6	+ 1.5	+ 1.4
4. 23. 58	67.6	- 1.0	+ 0.3	14. 23. 56	38.8	+ 0.5	0.0
7. 23. 57	66.2	+ 0.8	+ 1.4	15. 23. 56	34.1	+ 1.7	+ 1.6
8. 23. 57	68.5	+ 1.3	+ 0.9	21. 23. 59	36.0	+ 1.8	+ 1.8
16. 23. 55	63.6	+ 2.4	+ 2.4	25. o. 1	41.8	+ 0.4	+ 0.6
18. 23. 54	59.2	+ 2.2	+ 1.6	27. o. 2	45.2	+ 0.3	+ 0.2
19. 23. 53	55.8	+ 0.5	+ 1.3	29. o. 3	35.0	+ 0.5	+ 0.8
20. 23. 53	57.8	+ 1.0	+ 0.7	31. o. 4	48.2	- 0.2	+ 0.1

MEANS OF SIMULTANEOUS READINGS AT APPARENT NOON OF THE TRANSIT-CIRCLE EXTERIOR THERMOMETER, AND EXCESS OF THE METEOROLOGICAL STANDARD AND MAGNET HOUSE THERMOMETER, ARRANGED IN MONTHS.

1896.	January.	February.	March.	April.	May.	June.
Exterior Thermometer	41° 5 ₈	42° 8 ₁₂	50° 3 ₁₃	52° 1 ₁₃	61° 4 ₂₁	70° 6 ₁₉
Excess of Meteor. Standard	+ 0° 6	+ 1° 3	+ 1° 5	+ 1° 3	+ 3° 5	+ 1° 9
Excess of Thermom. on Roof of Magnet House.....	+ 0° 8	+ 1° 9	+ 1° 5	+ 0° 9	+ 2° 5	+ 1° 4

1896.	July.	August.	September.	October.	November.	December.	Mean for Year.
Exterior Thermometer	72° 4 ₂₄	65° 7 ₁₉	60° 4 ₁₅	50° 5 ₁₂	43° 2 ₁₅	40° 9 ₉	54° 3
Excess of Meteor. Standard	+ 2° 9	+ 1° 8	+ 1° 1	+ 1° 3	+ 1° 5	+ 0° 8	+ 1° 6
Excess of Thermom. on Roof of Magnet House.....	+ 2° 1	+ 1° 5	+ 1° 2	+ 1° 3	+ 1° 3	+ 0° 9	+ 1° 4

EXCESS OF READINGS OF FRONT COURT THERMOMETER OVER THOSE OF THE TRANSIT-CIRCLE EXTERIOR THERMOMETER FOR EACH HOUR OF THE DAY, DEDUCED FROM SIMULTANEOUS READINGS.

(ASTRONOMICAL TIME.)

Month.	0 ^h (Noon).	1 ^h	2 ^h	3 ^h	4 ^h	5 ^h
1896.	0	0	0	0	0	0
July	+ 0° 4 ₁₃	...	...	...	- 0° 3 ₄	- 0° 8 ₁
August	+ 0° 3 ₂₄	...	- 0° 4 ₁	+ 0° 2 ₁	- 0° 5 ₃	- 0° 6 ₄
September	+ 0° 4 ₁₄	+ 0° 9 ₁₂	+ 0° 7 ₅	+ 1° 5 ₆	+ 0° 6 ₇	- 0° 1 ₈
October	+ 1° 0 ₂₂	+ 0° 7 ₁₆	+ 0° 4 ₄	+ 1° 0 ₁₁	+ 0° 4 ₁₆	+ 0° 5 ₁₄
November	+ 0° 6 ₂₄	0° 0 ₁₁	+ 0° 3 ₁₅	+ 0° 2 ₁₃	+ 0° 3 ₁₀	0° 0 ₁₂
December	+ 0° 3 ₁₁	+ 1° 0 ₁	+ 0° 0 ₅	+ 0° 1 ₆	+ 0° 2 ₈	+ 0° 4 ₁₀
Means ...	+ 0° 5	+ 0° 7	+ 0° 2	+ 0° 6	+ 0° 1	- 0° 1

THERMOMETERS.

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EXCESS OF READINGS OF FRONT COURT THERMOMETER OVER THOSE OF
THE TRANSIT-CIRCLE EXTERIOR THERMOMETER FOR EACH HOUR OF THE
DAY, DEDUCED FROM SIMULTANEOUS READINGS—*concluded.*

Month.	6 ^h	7 ^h	8 ^h	9 ^h	10 ^h	11 ^h
1896.	0	0	0	0	0	0
July	- 0.4 ₂	+ 0.5 ₆	+ 0.3 ₁₄	- 0.1 ₁₁	- 0.1 ₁₆	0.0 ₁₁
August	- 0.2 ₇	+ 0.3 ₁₁	- 0.1 ₂₉	- 0.1 ₂₇	- 0.1 ₃₅	0.0 ₃₄
September	+ 0.3 ₁₈	+ 0.3 ₂₅	+ 0.2 ₂₈	+ 0.1 ₂₂	0.0 ₂₄	0.0 ₂₀
October	+ 0.3 ₁₇	0.0 ₁₂	- 0.1 ₁₆	0.0 ₂₃	- 0.2 ₂₁	- 0.4 ₁₄
November	- 0.4 ₁₃	- 0.2 ₁₇	- 0.3 ₁₅	- 0.2 ₁₅	- 0.3 ₁₂	- 0.2 ₁₄
December	+ 0.2 ₁₀	0.0 ₉	+ 0.1 ₁₁	+ 0.1 ₁₀	- 0.1 ₁₂	- 0.1 ₁₂
Means ...	0.0	+ 0.2	0.0	0.0	- 0.1	- 0.1
Month.	12 ^h (Midnight)	13 ^h	14 ^h	15 ^h	16 ^h	17 ^h
1896.	0	0	0	0	0	0
July	- 0.3 ₇	- 0.2 ₅	- 0.5 ₄	- 0.4 ₃	...	...
August	- 0.1 ₂₈	- 0.1 ₁₄	- 0.2 ₇	- 0.4 ₄	- 0.1 ₂	- 0.7 ₁
September	- 0.1 ₂₂	- 0.1 ₁₆	- 0.3 ₉	- 0.3 ₆	- 0.1 ₂	- 0.2 ₂
October	0.0 ₁₆	+ 0.1 ₇	+ 0.1 ₁₀	- 0.2 ₆	+ 0.1 ₇	- 0.1 ₃
November	- 0.4 ₁₅	- 0.1 ₁₇	- 0.3 ₁₀	- 0.4 ₅	- 0.3 ₁₂	- 0.3 ₁₅
December	+ 0.1 ₈	0.0 ₆	+ 0.1 ₉	- 0.1 ₁₁	+ 0.1 ₉	0.0 ₁₀
Means ...	- 0.1	- 0.1	- 0.2	- 0.3	- 0.1	- 0.3
Month.	18 ^h	19 ^h	20 ^h	21 ^h	22 ^h	23 ^h
1896.	0	0	0	0	0	0
July	...	...	- 2.5 ₃	- 0.3 ₅	+ 1.7 ₃	+ 2.5 ₁
August	...	- 0.8 ₁	- 1.1 ₂	+ 0.6 ₄	+ 1.1 ₁	...
September	- 0.2 ₁	...	...	+ 0.5 ₅	+ 2.2 ₄	+ 0.9 ₁
October	- 0.7 ₁	- 0.3 ₁	+ 0.3 ₆	+ 0.6 ₁₀	+ 1.3 ₁₂	+ 1.2 ₇
November	- 0.2 ₁₄	0.0 ₈	- 0.3 ₇	- 0.1 ₁₁	+ 0.1 ₁₆	+ 0.6 ₉
December	+ 0.2 ₉	+ 0.1 ₈	+ 0.3 ₂	...	...	+ 0.4 ₁
Means ...	- 0.2	- 0.3	- 0.7	+ 0.3	+ 1.3	+ 1.1

INTRODUCTION TO GREENWICH ASTRONOMICAL OBSERVATIONS, 1896.

CORRECTION TO ASSUMED COLATITUDE, $38^{\circ}.31'.21''\cdot90$,

FROM OBSERVATIONS IN THE YEAR 1896.

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

Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations.			Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations.		
				Above Pole.	Below Pole.	Weight.					Above Pole.	Below Pole.	Weight.
	h m	° '	"					h m	° '	"			
Carrington 303.....	2. 28	0. 55	-0° 54	2	2	6	Bradley 3058.....	22. 55	6. 13	+0° 57	3	2	6
λ Ursæ Minoris.....	19. 27	1. 1	-0° 33	38	17	26	Carrington 2286 ...	15. 9	6. 16	-0° 45	3	1	4
Groombridge 1119..	7. 54	1. 3	-0° 09	12	17	21	Lalande F. (2) 46...	6. 58	6. 20	+0° 08	1	2	4
Radcliffe 56	0. 16	1. 7	-0° 46	3	2	7	Lalande F. 3268.....	19. 28	6. 44	+0° 40	1	2	4
Polaris	1. 21	1. 14	-0° 10	88	111	35	Carrington 1852 ...	12. 21	6. 45	+1° 17	2	2	6
Bradley 1672.....	12. 14	1. 43	-0° 53	17	9	20	Carrington 504.....	3. 33	6. 47	+1° 19	2	3	7
Groombridge 2065..	13. 28	1. 55	+0° 80	2	2	6	Lalande F. (2) 277..	21. 31	6. 53	+1° 18	1	1	3
Groombridge 175 ...	0. 59	2. 17	-0° 19	2	3	7	Carrington 60	0. 28	6. 57	-0° 31	3	1	4
Groombridge 2283..	15. 11	2. 22	+0° 10	20	7	18	Carrington 2037 ...	13. 22	6. 58	-1° 01	3	1	4
Carrington 2363 ...	15. 29	2. 36	-0° 43	3	2	7	Lalande F. 1933 ...	11. 38	7. 6	+0° 07	2	2	5
Cephei 51	6. 52	2. 47	-0° 07	23	41	28	Lalande F. 2811 ...	16. 24	7. 7	-0° 89	2	1	4
Carrington 1943 ...	12. 58	2. 47	+1° 46	1	1	3	Carrington 789.....	5. 35	7. 9	+1° 70	1	1½	3
Lalande F. 1479 ...	9. 43	2. 56	-1° 09	4	2	7	Carrington 203.....	1. 23	7. 11	-0° 59	2	2	5
Carrington 364.....	2. 36	3. 15	-1° 33	2	2	6	Lalande F. 3588 ...	20. 34	7. 10	+0° 25	1	1	3
Bradley 3147	23. 30	3. 15	+0° 32	13	21	23	Lalande F. 757.....	5. 39	7. 16	+1° 39	2	4	7
δ Ursæ Minoris.....	18. 6	3. 23	-0° 10	48	22	28	Carrington 3629 ...	23. 33	7. 22	+0° 47	3	2	6
Lalande F. 382-3...	2. 31	3. 24	+0° 36	2	2	6	Lalande F. (2) 29...	6. 36	7. 23	+1° 18	1	1	3
Groombridge 3548..	21. 20	3. 24	-0° 22	12	10	19	Bradley 3038	22. 47	7. 24	-0° 64	9	2	7
Bradley 95.....	0. 59	3. 25	-0° 63	3	2	6	Bradley 3203	23. 57	7. 36	+0° 21	3	2	6
Lalande F. 3178 ...	18. 48	3. 25	-0° 09	3	2	6	Carrington 2328 ...	15. 26	7. 39	+0° 16	1	2	4
Groombridge 2210..	14. 50	3. 37	-0° 65	1	2	4	Lalande F. 2018 ...	12. 7	7. 42	+2° 17	2	1	4
Groombridge 642 ...	3. 33	3. 40	+0° 35	2	2	6	Groombridge 1858..	12. 6	7. 43	+0° 95	3	2	6
Bradley 3194.....	23. 55	3. 52	+0° 67	2	2	6	Radcliffe 2790	11. 58	7. 44	+0° 02	2	1	4
Radcliffe 4489	19. 37	4. 8	+0° 27	2	1	4	Carrington 2865 ...	18. 53	7. 52	+0° 01	2	1	4
Lalande F. 693.....	4. 55	4. 11	-0° 57	4	1	4	Carrington 2502 ...	16. 37	7. 54	+0° 13	1	1	3
Carrington 218.....	1. 31	4. 15	+0° 93	4	2	7	Carrington 274.....	1. 50	7. 57	+1° 22	4	1	4
Bradley 2993.....	22. 21	4. 25	+0° 10	4	4	10	Carrington 2838 ...	18. 43	7. 58	+0° 61	1	1	3
Carrington 3232 ...	21. 7	4. 32	-0° 54	1	1	3	Carrington 2587 ...	17. 11	7. 58	-1° 37	1	1	3
Groombridge 2007..	13. 19	4. 42	+0° 33	3	2	6	Carrington 844.....	5. 58	8. 1	+0° 49	1	1	3
Lalande F. 1867-8..	11. 24	4. 43	-0° 49	1	3	5	Carrington 387.....	2. 39	8. 2	-0° 10	1	1	3
Groombridge 956 ...	5. 33	4. 44	+0° 10	1	2	4	Carrington 3486 ...	22. 43	8. 3	-0° 46	2	1	4
Lalande F. 2731-2..	15. 43	4. 50	-1° 47	1	1	3	Carrington 3686 ..	23. 54	8. 10	-0° 17	2	1	4
Radcliffe 2198	8. 47	4. 54	+0° 24	1	2	4	Carrington 2405 ..	15. 55	8. 13	-0° 10	2	1	4
Carrington 2170 ...	14. 22	4. 58	+0° 56	2	2	6	Carrington 577.....	4. 1	8. 17	+0° 46	1	3	4
Lalande F. 1094 ...	7. 40	5. 4	+0° 05	1	2	4	Lalande F. 1662 ...	10. 17	8. 17	+0° 90	2	2	5
Carrington 104.....	0. 45	5. 6	-0° 29	2	2	6	Groombridge 1782..	11. 25	8. 18	-0° 33	2	1	3
Lalande F. 4560 ...	23. 41	5. 6	+1° 02	4	1	4	Carrington 2725 ...	18. 3	8. 20	+0° 52	2	2	5
Carrington 2498 ...	16. 31	5. 13	+0° 01	1	2	4	Lalande F. 3613 ...	20. 42	8. 21	+0° 42	2	1	3
Bradley 1399.....	10. 15	5. 13	-0° 34	4	2	7	Groombridge 1778..	11. 23	8. 23	-0° 23	1	1	3
Carrington 643.....	4. 32	5. 19	-0° 57	2	2	6	Piazzi VI. 285	7. 6	8. 33	+0° 35	2	3	7
Groombridge 2213 ..	15. 2	5. 39	+0° 43	2	1	4	Lalande F. 4175 ...	22. 24	8. 35	-1° 04	3	1	4
Carrington 1296 ...	8. 56	5. 57	+0° 59	1	3	5	Piazzi II. 60	2. 23	8. 49	+0° 87	2	3	6
Carrington 124.....	0. 52	5. 57	-0° 55	3	2	6	Lalande F. 2690 ...	15. 36	8. 52	-0° 21	1	2	4
Groombridge 1879..	12. 16	6. 3	+0° 90	2	2	5	Lalande F. 713.....	5. 0	8. 54	-1° 82	2	2	5
Lalande F. 2963 ...	18. 10	6. 6	+1° 17	1	1	3	Carrington 2863 ...	18. 54	8. 54	-1° 64	1	1	3
Bradley 2832.....	21. 22	6. 11	+2° 03	3	2	6	Carrington 2171 ...	14. 27	8. 57	-0° 53	2	3	6

COLATITUDE INVESTIGATION.

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CORRECTION TO ASSUMED COLATITUDE—continued.

Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Ob- servations.		Weight.	Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Ob- servations.		Weight.
				Above Pole.	Below Pole.						Above Pole.	Below Pole.	
Bradley 1439.....	10. 25	8. 58	-0°18	2	3	6	Lalande F. 454.....	2. 45	15. 13	+1°74	2	2	5
B. D. + 80° No. 34..	1. 8	8. 59	+1°07	2	2	5	β Ursæ Minoris	14. 51	15. 25	+0°71	15	6	14
Groombridge 426...	1. 57	9. 1	+1°19	1	1	3	Groombridge 2413..	16. 59	15. 33	+0°25	1	2	4
Carrington 1447 ...	9. 48	9. 6	+1°08	1	2	4	10 Ursæ Minoris ...	15. 6	15. 43	+1°03	2	1	3
Lalande F. 1558 ...	9. 46	9. 8	-0°68	2	1	4	Groombridge 2930..	19. 38	15. 51	+1°32	1	1	3
Groombridge 1909..	12. 31	9. 11	+1°43	1	1	3	Bradley 417	3. 1	16. 0	+0°56	4	3	7
Lalande 39835	20. 23	9. 11	-1°29	2	1	3	Groombridge 2719..	18. 48	16. 2	-0°02	3	2	5
B. D. + 80° No. 254	8. 16	9. 17	-0°85	1	2	4	Piazzi IV. 207	4. 52	16. 5	+1°30	2	2	5
Lalande F. 659-60..	4. 18	9. 21	+0°23	3	2	6	Groombridge 307...	1. 21	16. 20	+1°66	1	2	4
Groombridge 779	4. 9	9. 25	-1°42	2	2	5	Groombridge 2337..	16. 16	16. 21	+0°18	1	2	4
Lalande 34641	18. 24	9. 27	+0°62	2	2	5	Groombridge 210...	0. 56	16. 22	+3°39	1	1	3
Lalande F. 2380 ...	13. 50	9. 34	+0°16	2	2	5	Piazzi IV. 204	4. 51	16. 23	-0°72	3	1	3
B. D. + 80° No. 17..	0. 37	9. 40	+1°18	1	2	4	Piazzi IX. 187	9. 49	16. 38	-1°03	2	4	7
18 Ursæ Minoris ...	15. 45	9. 41	-0°22	3	3	7	Oeltz. Arg. (N.) 5928	5. 28	16. 38	-0°71	2	4	7
Bradley 3067	22. 59	9. 47	+0°81	2	3	6	79 Draconis	21. 51	16. 47	-0°01	5	4	9
Groombridge 3814..	22. 27	9. 50	-1°28	3	1	4	7 Draconis	19. 17	16. 50	-0°26	12	2	6
Groombridge 4009..	23. 6	10. 0	+0°17	1	1	3	Groombridge 4040..	23. 14	16. 53	+0°97	3	3	6
Oeltz. Arg. (N.) 5896	5. 28	10. 26	-0°37	2	2	5	31 Cephei	22. 34	16. 54	+0°77	1	4	5
Groombridge 2363..	16. 26	10. 53	+0°07	3	2	6	Piazzi XIII. 109 ...	13. 23	17. 4	+0°70	2	1	3
Bradley 117	1. 3	10. 53	+1°26	1	3	4	B. D. + 72° No. 1071	22. 50	17. 5	-1°38	2½	2	5
B. D. + 79° No. 168	5. 5	10. 53	+0°63	2	2	5	16 Cephei	21. 58	17. 19	+0°80	8	1	3
Piazzi IV. 269	5. 5	10. 53	-0°21	1	2	4	40 Cassiopeiæ	1. 30	17. 29	+0°77	2	2	5
Lalande 33419	17. 56	11. 41	+0°88	3	2	6	Oeltz. Arg. (N.) 25964	23. 39	17. 31	+0°48	4	2	6
28 Cephei	22. 26	11. 45	-1°35	3	1	4	Groombridge 828...	4. 21	17. 42	+1°02	3	1	3
Groombridge 1151..	6. 24	11. 55	+0°65	2	9	9	Bradley 2252	17. 43	17. 47	+0°06	1	2	4
Groombridge 2382..	16. 40	12. 2	-0°01	2	2	5	7 Ursæ Minoris.....	15. 21	17. 48	+1°54	11	4	10
Piazzi IV. 317	5. 13	12. 7	+1°19	1	1	3	ψ¹ Draconis	17. 43	17. 48	-0°25	5	4	9
Groombridge 2391..	16. 48	12. 18	+1°42	3	1	4	ψ² Draconis	17. 56	17. 59	-0°40	2	2	4
77 Draconis	21. 8	12. 18	+0°38	4	4	9	50 Cassiopeiæ	1. 55	18. 5	+1°12	8	5	11
κ Cephei	20. 12	12. 36	+0°16	5	2	6	Oeltz. Arg. (N.) 14718	14. 31	18. 6	+0°65	2½	2	5
*	20. 12	12. 36	+1°04	4	2	6	Groombridge 3702..	22. 5	18. 8	+1°68	1	1	3
Bradley 431	3. 7	12. 39	+0°19	3	1	3	24 Cephei	22. 8	18. 10	+0°18	3	2	5
Groombridge 2140..	14. 32	12. 59	+0°04	5	1	4	Oeltz. Arg. (N.) 24224	22. 26	18. 17	+1°15	1	2	4
35 Draconis	17. 54	13. 1	+0°72	2	2	5	Groombridge 836...	4. 26	18. 19	+2°46	1	1	2
Bradley 1446	10. 26	13. 45	+0°26	1	2	4	12 Ursæ Minoris ...	15. 17	18. 25	+1°07	3	1	3
Groombridge 2128..	14. 27	12. 53	+0°45	1	2	4	Bradley 353	2. 32	18. 49	+1°73	2	3	6
5 Ursæ Minoris	14. 28	13. 50	-0°08	6	1	4	Oeltz. Arg. (N.) 2970	2. 33	18. 52	-0°02	2	3	6
Groombridge 3478..	21. 24	13. 54	-1°68	1	1	3	11 Cephei	21. 40	19. 10	-2°05	1	1	2
Bradley 1147	8. 6	13. 56	+0°89	3	4	8	Groombridge 2319..	16. 5	19. 28	-0°12	1	3	4
Oeltz. Arg. (N.) 15854	15. 57	14. 4	+0°08	2	2	5	Oeltz. Arg. (N.) 570-1	0. 33	19. 32	+1°00	2	2	5
Groombridge 3813..	22. 27	14. 18	-1°13	1	1	3	B. D. + 70° No. 35..	0. 34	19. 33	-0°80	2	2	5
B. D. + 75° No. 6...	0. 12	14. 26	-1°08	3	1	3	Oeltz. Arg. (N.) 11184	10. 47	19. 34	+1°59	1	2	4
Groombridge 3486..	21. 25	14. 29	+0°47	1	1	3	Groombridge 1697..	10. 47	19. 36	+1°14	3	3	6
Oeltz. Arg. (N.) 25287	23. 8	14. 32	+0°67	2	2	4	Groombridge 1713..	10. 52	19. 38	+2°43	1	2	4
Groombridge 2186..	14. 58	14. 39	-0°31	1	1	3	ε Draconis	19. 49	20. 0	+1°76	1	1	2
Groombridge 3384..	20. 57	14. 41	-1°92	1	1	3	Groombridge 3805..	22. 27	20. 6	+2°26	1	1	2
Radcliffe 3149	14. 5	14. 47	+0°49	2	2	5	Groombridge 3827..	22. 30	20. 10	+0°26	1	2	4
3 Ursæ Minoris	14. 6	14. 55	+0°89	2	1	3	Bradley 3125.....	23. 23	20. 13	+1°45	1	1	2
Piazzi XXIII. 218 ..	23. 48	15. 2	+0°48	2	4	7	4 Draconis.....	12. 26	20. 13	+1°92	1	2	4

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INTRODUCTION TO GREENWICH ASTRONOMICAL OBSERVATIONS, 1896.

CORRECTION TO ASSUMED COLATITUDE—*continued*.

Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations.		Weight.	Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations.		Weight.
				Above Pole.	Below Pole.						Above Pole.	Below Pole.	
	h m	o /	"					h m	o /	"			
Groombridge 3842..	22. 32	20. 18	+ 3'23	3	1	3	Piazzi XX. 42	20. 5	26. 36	+ 0'48	1	2	3
Groombridge 3806..	22. 28	20. 22	— 0'05	3	2	5	Groombridge 2899..	19. 33	26. 47	+ 0'04	4	2	5
Groomb. 3719 (1st Star)	22. 9	20. 23	+ 2'02	1	1	2	Groombridge 1210..	6. 38	26. 50	+ 0'20	1	2	3
Groomb. 3719 (2nd Star)	22. 9	20. 23	+ 1'64	3	1	3	ε Cassiopeiæ	1. 47	26. 50	+ 0'74	5	11	12
Groombridge 628...	3. 10	20. 39	+ 0'40	3	2	5	Piazzi XXI. 360 ...	21. 53	26. 52	+ 1'33	2	1	2
Piazzi X. 26	10. 13	20. 44	+ 0'35	3	2	5	Oeltz.Arg.(N.)11669	11. 14	27. 4	+ 1'19	3	1	2
A Draconis	16. 28	21. 0	— 1'46	1	1	2	Groombridge 341...	1. 30	27. 7	+ 0'27	1	1	2
Groombridge 1669..	10. 34	21. 1	+ 1'55	2	1	3	57 Camelopardi ...	8. 10	27. 10	— 1'30	1	1	2
Groombridge 4235..	0. 2	21. 30	— 0'65	1	2	4	Groombridge 3977..	23. 1	27. 19	— 1'12	2	1	2
Groombridge 1944..	12. 53	22. 12	— 0'03	1	3	4	θ Cephei	20. 29	27. 21	+ 0'14	1	1	2
Lalande F. 1812....	11. 3	22. 14	— 0'45	1	2	4	κ Cassiopeiæ	0. 27	27. 38	+ 1'20	2	1	2
Oeltz.Arg.(N.)11438	11. 2	22. 14	— 0'27	2	1½	4	α Ursæ Majoris.....	10. 57	27. 41	— 0'29	12	5	10
σ² Ursæ Majoris ...	9. 1	22. 27	— 1'12	1	2	4	Groombridge 3646..	21. 56	27. 44	+ 1'77	2	2	4
σ¹ Ursæ Majoris ...	8. 59	22. 43	— 0'46	2	4	4	α Cephei	21. 16	27. 51	— 0'42	10	3	7
Groombridge 3527..	21. 34	22. 14	— 1'57	1	1	2	Oeltz.Arg.(N.)18495	18. 36	27. 53	+ 0'62	1	2	3
Piazzi VIII. 137 ...	8. 39	22. 55	+ 0'86	2	3	5	21 Camelopardi	5. 31	28. 7	+ 1'85	2	1	2
Groombridge 365...	1. 37	22. 58	+ 0'94	1	1	2	c Ursæ Majoris.....	9. 6	28. 9	— 1'13	1	2	3
Lalande F. 404	2. 21	23. 2	+ 1'57	2	3	5	Oeltz.Arg.(N.)16188	16. 21	28. 19	— 0'30	2	2	4
Oeltz.Arg.(N.)2766	2. 21	23. 3	+ 0'82	2	4	6	η Cephei	20. 44	28. 34	+ 1'19	1	1	2
Bradley 332	2. 20	23. 4	— 0'11	3	8	10	Groombridge 3642..	21. 56	28. 50	+ 0'56	1	2	3
7-Yr. Cat. 1860 No. 154..	2. 21	23. 4	+ 0'89	3	2	5	o Ursæ Majoris.....	8. 22	28. 56	+ 1'15	6	1	3
7-Yr. Cat. 1860 No. 156..	2. 21	23. 4	+ 0'57	3	2	5	Piazzi VI. 310	7. 0	29. 5	— 1'04	1	2	3
Piazzi XIV. 260 ...	14. 57	23. 39	+ 0'90	1	2	3	Radcliffe 5555	22. 1	29. 8	— 0'60	2	1	2
Groomb. 3760 (2nd Star)	22. 18	23. 49	— 0'05	3	1	3	Groombridge 3682..	22. 1	29. 10	— 1'68	2	1	2
α Camelopardi	4. 44	23. 50	+ 0'45	1	6	5	Groombridge 1364..	7. 40	29. 27	— 0'96	1	1	2
B. D. + 66° No. 870	14. 45	24. 5	+ 0'73	3	1	3	γ Cassiopeiæ	0. 50	29. 51	— 0'73	11	2	5
Groombridge 192...	0. 52	24. 13	— 0'27	2	2	4	Radcliffe 3714	17. 24	29. 52	— 1'11	1	1	2
Groombridge 21 ...	0. 9	24. 14	+ 0'74	1	1	2	Radcliffe 285	0. 54	30. 7	+ 0'66	1	1	2
ι Cephei	22. 46	24. 20	— 0'23	1	1	2	B. D. + 59° No. 176	0. 58	30. 13	+ 0'28	1	2	3
Piazzi XVIII. 173..	18. 36	24. 36	— 0'35	3	2	5	Groombridge 99 ...	0. 31	30. 15	— 0'32	3	1	2
Groombridge 3354..	20. 53	24. 43	— 0'05	1	2	3	Oeltz. Arg. (N.) 603	0. 35	30. 15	— 0'58	3	1	2
Bradley 445	3. 8	24. 44	+ 0'72	3	2	5	Groombridge 108...	0. 33	30. 15	+ 0'61	1	2	3
Bradley 448	3. 11	24. 44	+ 0'20	3	2	5	Groombridge 104...	0. 32	30. 16	+ 0'63	1	2	3
Groombridge 3683..	22. 1	24. 55	— 1'11	1	1	2	Groombridge 95 ...	0. 30	30. 17	— 3'08	2	1	2
α Draconis.....	14. 2	25. 7	+ 0'67	8	1	3	Groombridge 320...	1. 23	30. 17	+ 0'53	1	2	3
γ Draconis.....	16. 40	25. 13	— 1'25	2	1	3	Groombridge 3230..	20. 29	30. 17	— 0'97	1	1	2
π Ursæ Majoris.....	8. 31	25. 19	— 2'40	3	1	3	Groombridge 189...	0. 51	30. 19	— 0'24	3	2	4
Piazzi XV. 136.....	15. 29	25. 26	— 1'62	1	2	3	Piazzi III. 51.....	3. 21	30. 25	— 0'51	3	1	2
32 Cassiopeiæ	1. 5	25. 32	+ 0'35	1	2	3	Groombridge 315...	1. 22	30. 30	— 1'37	1	2	3
Piazzi O. 312	1. 6	25. 32	+ 0'71	2	1	3	Oeltz.Arg.(N.)23360	22. 1	30. 36	+ 0'03	2	1½	3
6 Cephei	21. 17	25. 34	+ 0'07	2	3	5	Piazzi XXI. 401 ...	22. 1	30. 38	— 0'20	1	2	3
65 Draconis	20. 1	25. 39	+ 0'12	1	1	2	Lalande 7984	4. 14	30. 38	— 0'30	1	1	2
19 Camelopardi	5. 27	25. 55	— 0'58	2	2	4	Groombridge 2608..	18. 30	30. 39	— 0'11	1	2	3
Groombridge 23 ...	0. 9	26. 0	+ 0'72	1	1	2	Lalande 799	0. 28	30. 40	— 1'17	2	1	2
Piazzi I. 230.....	1. 57	26. 6	+ 0'93	3	2	4	Oeltz.Arg.(N.)23355	22. 1	30. 40	+ 1'15	2	2	4
B. D. + 63° No. 305	2. 6	26. 8	+ 1'07	3	2	4	ι Draconis	15. 23	30. 40	— 0'20	6	1	2
Piazzi XXI. 142 ...	21. 20	26. 13	+ 1'61	1	2	3	15 Cephei	22. 1	30. 41	— 0'08	1	2	3
B. D. + 63° No. 1922	22. 59	26. 20	+ 0'46	2	1	2	Groombridge 3945..	22. 54	30. 44	+ 1'09	1	1	2
10 Cassiopeiæ	0. 1	26. 23	+ 0'82	1	5	5	12 Camelopardi	4. 57	31. 7	— 1'43	2	2	4

COLATITUDE INVESTIGATION.

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CORRECTION TO ASSUMED COLATITUDE—continued.

Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Ob- servations.		Weight.	Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Ob- servations.		Weight.
				Above Pole.	Below Pole.						Above Pole.	Below Pole.	
	h m	o /	"					h m	o /	"			
θ Draconis.....	16. 0	31. 9	+ 0.76	1	1	2	19 Lynceis	7. 14	34. 31	- 0.21	1	1	2
ι Camelopardi	4. 57	31. 10	- 0.78	2	3	5	Oeltz. Arg. (N.) 3195	2. 43	34. 32	+ 0.07	2	2	3
2 Cassiopeiae	23. 5	31. 14	+ 1.04	4	2	4	η Persei	2. 43	34. 32	- 0.80	6	2	4
Groombridge 4000..	23. 5	31. 17	+ 0.58	1	1	2	Groombridge 1333..	7. 30	34. 34	+ 1.14	1	1	2
Groombridge 909...	4. 56	31. 17	+ 0.06	1	1	2	Oeltz. Arg. (N.) 3187	2. 42	34. 35	+ 0.67	3	2	4
*.....	12. 17	31. 20	- 1.93	2	1	2	Groombridge 3176..	20. 21	34. 54	+ 2.28	1	1	2
β Cassiopeiae.....	0. 4	31. 25	+ 1.23	6	4	7	Groombridge 3162..	20. 20	34. 58	- 1.92	1	1	2
Groombridge 4116..	23. 35	31. 36	+ 3.16	1	1	2	Oeltz. Arg. (N.) 10371	9. 50	35. 1	+ 0.71	2	1	3
Radcliffe 3513	16. 7	31. 47	- 0.61	3	1	2	Lalande 4258	2. 14	35. 4	+ 1.72	3	1	2
Groombridge 4112..	23. 34	31. 50	- 1.77	1	1	2	Groombridge 3387..	21. 1	35. 11	- 1.40	1	1	2
Groombridge 4110..	23. 34	31. 55	- 0.03	3	2	4	Groombridge 2907..	19. 36	35. 16	+ 0.55	1	1	2
Piazzi XXIII 100...	23. 25	32. 1	- 0.71	2	1	2	Piazzi X. 257	11. 5	35. 17	- 1.68	3	2	4
ζ Cephei	22. 7	32. 19	- 2.08	3	1	2	Piazzi X. 246	11. 3	35. 17	- 2.22	1	2	3
Groombridge 3885..	22. 41	32. 28	- 0.28	1	1	2	Groombridge 3965..	22. 58	35. 19	+ 1.04	1	2	3
Oeltz. Arg. (N.) 1043	0. 58	32. 37	+ 1.44	3	1	2	Piazzi X. 247	11. 4	35. 20	- 0.53	2	2	3
Groombridge 1787..	11. 24	32. 41	- 1.83	1	1	2	21 Ursæ Maj. (1st Star)	9. 18	35. 32	+ 0.35	1	1	2
Groombridge 1791..	11. 25	32. 41	- 3.00	1	1	2	21 Ursæ Maj. (2nd Star)	9. 18	35. 32	+ 0.38	1	2	3
Lalande 7721	4. 6	32. 48	+ 1.03	2	1	2	Groomb. 135 (1st Star)	0. 40	35. 35	- 0.43	1	2	3
Oeltz. Arg. (N.) 22571	21. 34	32. 53	+ 2.16	2	1	2	μ Cassiopeiae.....	1. 1	35. 35	+ 0.20	1	2	3
Groombridge 3526..	21. 35	32. 54	+ 2.32	1	1	2	Groombridge 1044..	5. 51	35. 37	- 0.30	1	2	3
Oeltz. Arg. (N.) 22563-4	21. 33	32. 58	+ 0.44	2	1	2	Groombridge 3886..	22. 42	35. 41	+ 0.81	1	1	2
Oeltz. Arg. (N.) 22641	21. 36	32. 59	+ 1.14	1	1	2	Lalande 19985	10. 14	35. 42	+ 0.26	2	2	3
Groombridge 3536..	21. 36	32. 59	+ 1.76	1	1	2	Lalande 19950	10. 12	35. 43	- 1.27	1	2	3
Oeltz. Arg. (N.) 22648	21. 36	32. 59	+ 2.25	1	1	2	γ Ursæ Majoris.....	11. 48	35. 44	- 0.68	18	4	7
Groombridge 3513..	21. 33	33. 0	- 3.14	1	1	2	Groombridge 3582..	21. 46	36. 6	+ 0.19	1	2	3
Groombridge 3510..	21. 33	33. 0	- 2.22	1	2	3	Groombridge 3587..	21. 46	36. 15	+ 0.66	1	2	3
β Ursæ Majoris.....	10. 56	33. 4	- 0.51	12	2	4	Piazzi VIII. 78.....	8. 25	36. 32	+ 0.03	1	2	3
Groombridge 2945..	19. 46	33. 10	- 1.32	1	1	2	Groombridge 967..	5. 21	36. 39	- 0.14	3	1	2
Groombridge 1109..	6. 8	33. 14	+ 1.06	2	2	4	Radcliffe 2647	11. 10	36. 39	+ 0.97	1	1	2
Piazzi II. 36	2. 12	33. 19	+ 1.52	1	1	2	ζ Cassiopeiae	0. 31	36. 40	+ 0.20	2	2	3
Bradley 316	2. 12	33. 21	+ 2.51	1	1	2	Groombridge 2816..	19. 16	36. 44	- 1.86	1	2	3
ε Cephei.....	22. 11	33. 28	- 0.46	1	2	3	Groombridge 2302..	15. 59	36. 48	- 0.56	2	2	3
ε Ursæ Majoris.....	12. 49	33. 29	- 1.27	9	1	2	κ Cygni	19. 14	36. 49	- 0.88	3	1	2
Groombridge 3382..	21. 1	33. 29	- 0.20	1	1	2	γ Persei	2. 57	36. 54	- 1.56	2	1	2
Groombridge 2211..	15. 11	33. 30	- 3.03	1	1	2	Bradley 3084.....	23. 12	37. 21	+ 0.25	3	2	3
Groombridge 2209..	15. 10	33. 34	+ 0.69	1	1	2	Groomb. 1173 (N. Star)	6. 26	37. 28	+ 1.40	1	1	2
20 Camelopardi	5. 29	33. 35	- 0.71	1	1	2	Groombridge 3235..	22. 31	37. 32	- 0.46	2	2	3
Groombridge 3833..	22. 30	33. 41	- 1.22	1	1	2	Groombridge 3232..	20. 31	37. 33	- 0.97	2	2	3
B. F. 522	4. 13	33. 45	+ 0.27	3	1	2	τ Persei	2. 47	37. 40	+ 0.54	5	1	2
Groombridge 3445..	21. 18	33. 54	- 0.77	1	1	2	Groombridge 1115..	6. 8	37. 47	+ 0.49	1	2	3
Groombridge 3693..	22. 4	33. 56	- 0.65	1	2	3	Groombridge 1896..	12. 25	37. 50	+ 1.11	1	1	2
Groombridge 3440..	21. 17	33. 57	+ 0.77	1	1	2	θ Ursæ Majoris.....	9. 26	37. 51	+ 0.78	4	1	2
Oeltz. Arg. (N.) 23462	22. 3	34. 0	+ 1.22	2	2	4	7 Canum Venaticum	12. 25	37. 53	- 1.64	1	1	2
α Cassiopeiae.....	0. 35	34. 2	- 0.03	6	8	11	Groombridge 3425..	21. 13	37. 57	+ 2.44	1	2	3
Groombridge 1330..	7. 28	34. 1	0.00	1	1	2	Groombridge 3430..	21. 15	37. 58	+ 1.02	1	2	3
Groombridge 2374..	16. 41	34. 7	- 0.46	2	1	2	Groombridge 2877..	22. 40	38. 2	- 0.07	1	2	3
Groombridge 3071..	20. 7	34. 17	+ 0.21	1	1	2	Groombridge 3708..	22. 8	38. 5	- 1.38	2	2	3
Oeltz. Arg. (N.) 23923	22. 17	34. 25	- 0.05	2	1	2	Groombridge 618...	3. 4	38. 14	+ 1.60	1	2	3
Bradley 1054	7. 14	34. 31	+ 0.12	1	1	2	35 Camelopardi ...	5. 56	38. 25	+ 0.28	1	2	3

GREENWICH OBSERVATIONS, 1896.

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CORRECTION TO ASSUMED COLATITUDE—concluded.

Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations.		Weight.	Star's Name.	Approximate R.A.	Approximate N.P.D.	Excess of N.P.D. above Pole.	No. of Observations.		Weight.
				Above Pole.	Below Pole.						Above Pole.	Below Pole.	
	h m	o /	"					h m	o /	"			
β Cygni	19. 27	38. 29	— 0.74	3	2	3	α Persei	3. 17	40. 31	+ 0.32	6	2	3
γ Draconis.....	17. 55	38. 30	— 2.08	8	1	2	Groombridge 2815..	19. 15	40. 37	— 0.73	4	2	2
Groombridge 1024..	5. 43	38. 31	+ 0.07	1	1	2	χ Ursæ Majoris.....	11. 41	41. 39	— 2.05	6	2	2
Groombridge 3500..	21. 30	38. 46	+ 0.66	1	2	3	ζ Andromedæ.....	1. 31	41. 54	+ 0.86	4	1	1
Groombridge 3290..	20. 44	39. 37	+ 0.79	1	1	1	ψ Persei.....	3. 29	42. 9	— 1.91	4	1	1
Oeltz. Arg. (N.) 9494	8. 54	39. 48	+ 0.04	2	1	1	δ Persei	3. 36	42. 33	— 0.98	3	1	1
54 Andromedæ.....	1. 37	39. 50	— 0.65	6	3	4	Capella	5. 9	44. 6	+ 0.27	15	2	2
Groombridge 1494..	8. 54	39. 51	+ 1.66	1	2	2	λ Ursæ Majoris.....	10. 11	46. 34	— 0.24	6	2	1
η Ursæ Majoris.....	13. 43	40. 10	— 0.03	11	2	3	μ Ursæ Majoris.....	10. 16	47. 59	— 4.92	9	1	0
Oeltz. Arg. (N.) 18164	18. 19	40. 28	+ 0.35	3	1	1							

The weights used in the above table are determined by use of the "Probable Errors of the Greenwich Observations in Zenith Distance," given by Mr. Stone in the *Monthly Notices of the Royal Astronomical Society* for 1869 June, 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 $\frac{2 n n_1}{n_1 e^2 + n e_1^2 + 2 n n_1 e_0^2}$; or assuming $e_0^2 = \frac{1}{10} e^2$, which would make $e_0 = 0''.16$, the weight becomes $\frac{2 n n_1}{n_1 e^2 + n e_1^2 + \frac{1}{5} n n_1 e^2}$, which has been adopted in the investigation.

If z be the correction to the assumed colatitude $38^\circ. 31'. 21''.90$, $2z$ + the algebraic sum of determinations ought to be equal to 0. Combining the whole with the weights above attached to them, $2z = -0''.151$, or $z = -0''.076$. The colatitude determined from the observations of 1896 is therefore $38^\circ. 31'. 21''.82$.