GREENWICH
ASTRONOMICAL OBSERVATIONS,
1847.

INTRODUCTION.

I. *Personal Establishment and Arrangements.*

During the year 1847, the establishment of Assistants in the Astronomical department of the Observatory consisted of the following persons:—The Rev. Robert Main, M.A, First Assistant; Mr. John Henry, Mr. Thomas Ellis, Mr. William Rogerson, Mr. Edwin Dunkin, and Mr. Hugh Breen, jun. The addition of Mr. Breen was in consequence of the erection of the Altitude and Azimuth Instrument, for making chiefly extra-meridional observations of the Moon, which came into use this year. Mr. Dunkin was put in charge of this instrument, and Mr. Breen was withdrawn from the Magnetical and Meteorological department to supply the necessary assistance in the Astronomical department, the appointment of another observer having been sanctioned by the Lords Commissioners of the Admiralty.

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

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

Mr. Henry, assisted by Mr. Rogerson, conducts the observations with the Transit instrument; the reduction of the observations with that instrument; the rating of the clocks; the comparisons of the chronometers belonging to the Royal Navy, or on trial for purchase by the Government; and the dropping of the Signal Ball every day. Their initials, attached as signatures to the observations made by them, are H. and R.

Mr. Ellis, assisted by Mr. Breen, and occasionally by Mr. Rogerson, makes observations with Troughton's Mural Circle, the Zenith Sector, and the Equatoreals, and reduces those observations. The initials are E., H.B., and R.

Mr. Dunkin, assisted by Mr. Breen, makes observations with the Altitude and Azimuth Instrument, and reduces those observations. Their initials are D. and H.B.

The persons who have occasionally observed with the Meridional Instruments, during the absence or illness of any of the Assistants, are:

1. The Assistants attached to the Magnetical department of the Observatory — Mr. Glaisher, Mr. Downs, Mr. Lovelace, and Mr. Humphreys. Their initials are G., T. D., L., and G. H.

2. Mr. William Ellis, who was employed in the computations connected with the Greenwich Lunar Reductions.

The Observations, &c., are prepared for press, and the proof-sheets read, by the Assistants who are regularly attached to the respective departments.

The whole of these works are under the immediate direction of the Astronomer Royal, who is responsible for every part. Correspondence relating to the affairs of the Observatory, not transacted by the Astronomer Royal himself, is managed by the First Assistant, but only at the command of the Astronomer Royal.

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

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; and the two Mural Quadrants, mounted on their piers; the Quadrant on the Western pier being now included in the safe or fire-proof room of the Observatory. The Zenith Sector of Bradley and Maskelyne was removed to the Cape of Good Hope in the year 1837, to be used in the survey carrying on by Mr. Maclear for the verification and extension of La Caille's Arc, and for the mapping of a part of the Cape Colony. The fixed telescope, used by Mr. Pond for investigating the parallax of α Aquilæ, is still attached to the West side of the circle pier, and, it is believed, fit for service, though it has not been used for several years. The corresponding telescope, for investigating the parallax of α Cygni, which was attached to the Western Quadrant pier, has been taken down, and deposited in the Octagon Room of the Observatory.

The instruments now in use are the following:—

The Transit instrument, constructed by Troughton, and erected in the year 1816.

The length of the telescope is about 10 feet, and the clear aperture of the object-glass 5 inches; the length of the axis (between the extremities of the pivots) 4 feet. The telescope is directed to a given N. P. D. by means of circles carried by the eye-end of the telescope, whose moveable index is a spirit-level. The pivots of the axis of the Transit are of steel, fixed in 1825, and fresh turned in 1832; and the severest level-examinations have never detected any want of perfect circularity of form. They continue in excellent condition. The seven vertical wires inserted in 1836 continued in use, without alteration, from that time to November, 1846, when one was found broken. The eye-piece has also two vertical micrometer-wires at a small interval, carried by one micrometer, and moved by it horizontally. Two fixed horizontal wires serve to define the middle of the field, and the object observed is usually placed between them.

Two Mural Circles, of 6 feet diameter, constructed, one by Troughton, the other by Jones.

The Circle by Troughton has for some years been used alone, as, after a long trial of the use of both instruments simultaneously, I have come to the conclusion that, except in cases when it is necessary to observe an unusually large number of stars, nothing is gained in point of convenience or accuracy by the use of both. In the year 1839, the Circle by Jones, which was in use to that time, was sent to the Cape of Good Hope, for the use of the Observatory near Cape Town, and a considerable interval elapsed before the damaged Circle (also by Jones), which was sent home by Mr. Maclear, was made ready for use. It is now fully adjusted, yet I have not felt it necessary to recur to the use of two Circles. Each Circle is read by six microscopes; the telescope of each is supported at the middle by a spindle passing through the axis of the circle, and is clamped at its ends to the limb; and the diameter of the object-glass of the telescope of each is 4 inches; in the eyepiece of each are five vertical wires, and a single horizontal wire carried by a micrometer.

The Altitude and Azimuth Instrument.

The Altitude and Azimuth Instrument was constructed with the sanction of the Lords Commissioners of the Treasury and the Lords Commissioners of the Admiralty, in consequence of a Resolution of the Board of Visitors, which expressed their approval of the suggestion made to them by the Astronomer Royal at the Meeting of 1843, Nov. 10, representing the importance of devoting an instrument of this class, constructed on principles of extraordinary firmness, to the extension of the observations of the Moon. The Address and Explanation of the Astronomer Royal, developing these considerations, is attached to the Volume of Greenwich Astronomical Observations for 1843.

The assent of the Government to the preparation of this instrument was granted with little delay; the erection of the building was immediately commenced; and steps were taken in concert with Messrs. Ransome and May, Engineers, of Ipswich (who undertook the fabrication of the massive parts), and with Messrs. Troughton and Simms, Opticians, of London (who managed the delicate parts and adjustments generally, the graduations, the levels, and the optical and micrometrical parts of the telescope and microscopes), for constructing the instrument in accordance with the principles explained in the Address and Explanation. In very trifling points of detail only was the smallest deviation made from the forms described in that Explanation. The engineers' part of the work is, perhaps, superior in general accuracy to anything that had been effected by engineers before that time; and the graduations, and the micrometrical and optical parts, fully maintain the character of the unrivalled workmanship of Messrs. Troughton and Simms.

An accident in the engineers' work delayed the completion of the instrument a very considerable time. It was, however, finished in the spring of 1847; a short time was employed in examining the graduations and levels, in preparing auxiliary tables for the reduction of the observations, and in making trial observations; and the instrument was used for the first time in actual observation of the Moon on 1847, May 16, the first observation being made by Mr. Hugh Breen, jun. This observation is as good as any of those which follow it.

The further history of the instrument will be given at the end of the Description.

DESCRIPTION OF THE ALTITUDE AND AZIMUTH INSTRUMENT.

At the commencement of this Work is given a general perspective view of the instrument, to which the reader is referred for an understanding of the aspect of the instrument and the relation of its principal parts. The details are contained in Plates I., II., III., IV., to which the following explanations refer in every point.

It is proper to premise that the foundation of the instrument is a three-rayed pier of brickwork, unconnected with the surrounding building, &c.: that upon the three rays of this pier are laid the radial arms of the iron triangle which is the basis of the support of the upper pivot of the instrument, and that upon its center is placed a smaller pier that supports the fixed circle in which turns the lower part of the instrument: that the remaining parts of the frame supporting the upper pivot are in triangular arrangement, and possess very great firmness: and that in all the moving parts of the instrument the fundamental principles of construction have been:—to form as many parts as possible in one cast of metal,—to use no small screws in the union of parts,—and to leave no power of adjustment in any part; it being intended that the observations shall be so arranged that every instrumental error shall be deduced from the ordinary observations, and that numerical corrections shall be applied in the reduction of the observations.

In every part of the diagrams the same letters refer to the same parts.

Figure 1, Plate I., is a horizontal plan of the brick pier and the iron basis of the support of the upper pivot.

A is the central part of the pier, which is triangular.

B, B, B, the three rays of the pier. These are covered by blocks of Portland stone 4½ inches thick, which are continued inwards till they meet at the center. The height of the surface of this stone above the foundation is about 26 feet. The stones are channelled, and the radial arms D of the lower iron triangle are laid in the channels.

C, the upper cylindrical pier, covering the center of A, and covering also the center of the iron radial arms. Its top is a block of Portland stone, 1 foot thick. C is the support of the lower fixed circle of the instrument.

D, D, D, the radial arms of the lower iron triangle, 1½ inch square, resting in the stone channels.

E, E, E, the three sides of the lower iron triangle, 1½ inch square. They are welded to the radial arms D; and they have no support except at their extremities.

F, F, &c., the places of attachment of the rising bars of the side-triangles. Screw-bolts project horizontally from the sides of E E E, being welded to E E E; and upon these the eyes at the bottoms of the rising bars are forced by powerful nuts. The radial arms D, the sides E of the triangle, and the screw-bolts at F, form, by welding, one piece of metal.

G, G, &c., portions of the rising arms of the side-triangles, as projected on the horizontal plan. The lower triangle is entirely below the floor and floor-joists of the observing-room.

Figure 2 is an elevation of one of the three side-triangles.

F, the attachment of the eye at the bottom of the rising bar G, shewn more clearly in figure 2*a*.

G, G, the rising bars, which are round, 1½ inch in diameter. They are welded together at the top, and at the place of their meeting a hole is pierced for the passage of the screw-bolt which is welded to the upper triangle.

H (see also figure 2*b*), a screw-bolt welded to the upper triangle, passing through the hole at the union of the arms G, where the screw H is drawn by a powerful nut.

I, I, portions of the sides of the upper triangle, which are round iron bars, 1½ inch in diameter.

K, a fork, welded to the upper triangle, in which one of the upper radial bars rests.

L, a nut upon the end of the radial bar, which is cut with a screw.

The arms G G pass through holes in the floor of the room without touching it.

Figure 3 is the horizontal plan of the upper triangle with its radial bars and the upper Y for the rotation in azimuth.

G, G, &c., are portions of the rising bars, as projected on the horizontal plan.

H, H, H, the screws on the arms which project horizontally from and are welded with the angles of the upper triangle, passing through holes at the unions of the bars G G, &c., and drawn by powerful nuts.

I, I, I, the three sides of the triangle, welded in one piece.

K (see figure 3*a*), a fork which projects upwards from, and is welded with, each angle of the upper triangle. The sides I, the screws H, and the forks K, form, by welding, one piece of metal.

M, M, M, the three radial bars of the upper triangle, which are round, and 1 inch in diameter. They are welded together at the center, where they meet, and their ends are cut into screws. Each of these ends rests in a fork K, and carries two nuts, L, L, one exterior to K and one interior to it. By these nuts the fork K is firmly embraced, and the rod is prevented from sliding endways in it.

N is the upper Y, in which the upper pivot of the azimuthal motion turns. The triangular part of N is welded to M; the pivot is forced horizontally into the triangular part by a vertical plate which is screwed by bolts and nuts, and in which the spring of metal insures a firm and constant contact with the upper pivot. The three bars M and the triangular part N of the Y form, by welding, one piece of metal.

The Y was placed nearly in its proper position by the use of the pairs of nuts L L (every strain of these nuts producing a flexure of some part of the radial bars M), and then all the nuts L were made tight and the Y was left without further adjustment.

Figure 4 is a perspective view of all the parts described in figures 1, 2, 3; the floor being supposed to be removed, and no part of the instrument mounted except the lower fixed circle. The reader will remark that, in the perspective, the lower triangle is represented as viewed from above, and the upper triangle as viewed from below: and thus it will be seen that the sides of one of these triangles correspond to the angles of the other. The general arrangement of the rods represents the edges or arrêtes of a slightly irregular octahedron.

The azimuthal position of the triangles is not arbitrary. There was, however, only one reason to determine the selection of position, namely, that that position ought to be preferred in which the bars of the frame would least interrupt the telescope in the view of the Moon (the interruption of the view of a star being unimportant, as the observation might be deferred, or another star might be taken). The single bars offer no material interruption to the telescope; the only part which deserves consideration is the angle of the upper triangle, where five bars unite, and where there are also a fork, nuts, &c. Now it was obvious that, if the frame were so placed that one of these angles should be exactly South; then the two remaining angles would be in positions in which the Moon could never pass them; and the southern angle, though it would undoubtedly interrupt the sight of the Moon, would do so in a position of the Moon which is not favourable to observations with this instrument, and in which she would infallibly be observed with the meridional instruments. That position was therefore adopted for the frame; and every arrangement of the building, staircase, &c., was made in subordination to this choice.

The support for the upper pivot is exceedingly firm and steady; it requires no precise adjustment of the length of the bars (which would take perfectly firm bearing if the lengths of one or of several were erroneous, even to the amount of one or two feet), and is therefore made at small expense; and I would propose it for adoption in any other similar case. In the detail of workmanship I would propose as an improvement, that the three radial bars of the lower triangle should not be united at the center, or should be omitted entirely; and that the three angles of the lower triangle should be widened into broad thick plates, each admitting of a vertical hole in each side, through which the points of the rods G should pass: these points having screws cut upon them, and the rods G being drawn down by nuts below the horizontal triangle.

Figure 5 is a plan of the lower fixed circle, as viewed from above.

O, O, O, are the three cast-iron blocks, weighing 36 lbs. each, in which three spokes of of the circle rest. These are solid blocks, having projections below which enter into the stone capping of the central pier and are fixed there with plaster of Paris, and whose tops are cut each with a furrow to receive the spoke of the circle. A very little consideration will shew that there is but one position in which three given spokes can rest in three given furrows. These blocks have no adjustment whatever, and their furrows were cut to the proper depth by filing. The circle being dropped into them, the horizontality of its graduated limb was examined by means of a spirit level. When it was discovered which side was too high, the circle was raised, the furrows nearest to the high part were filed, and the circle was lowered and again examined in the same manner, till it was brought sufficiently near to horizontality.

P, P, P, are three of the spokes of the circle, resting in the furrows.

Q is the dove-tail furrow turned in the circle, for the insertion of the band of silver upon which the graduations are cut. The divisions are to every 5′: the numeration of the divisions is in a continuous series from 0° to 360°, in the direction N., E., S., W., N.

The spokes, the cylindrical ring, and the flat circle, are of rather hard gun-metal, cast in one piece. The weight of this cast is 441 lbs.

R is a circle with interior toothed-wheel (in which act the pinions X X, figure 8, for slow motion in azimuth), screwed upon the solid cast circle. To avoid confusion, the teeth are not represented in figure *5*: but in figure *5 a* they are represented in full size.

Figure 6 is a plan of the lower fixed circle as seen from the lower side: it requires no explanation.

Figure 7 is a vertical section of the lower fixed circle. The teeth of the toothed wheel R are shewn in view; and two of the blocks O are also seen, one of which exhibits its furrow as viewed obliquely. The perforation at the center of the circle is for the bearing of the lower pivot of the revolving frame and for the counterpoise machinery, which will be explained in reference to figure 9.

In the case of constructing another instrument for the same purpose, it would be well to consider whether the graduated limb could not be carried by a circle entirely unconnected with those parts which carry the bearing of the pivot of the vertical axis and the toothed wheel for slow motion. When the instrument is turned by the toothed pinion X, there is no sensible tendency to turn the fixed circle: but when the instrument is turned by hand there is a tendency to turn the fixed circle and graduated limb, equivalent to the friction of the pivot upon its bearing. An arrangement such as I propose would perhaps be practically difficult.

Figure 8 is a horizontal plan of the lower part, or base-plate, of the frame revolving in azimuth, as viewed from below.

S, S, &c., are the vertical ribs, of cast-iron.

T, T, T, T, are the four micrometer-microscopes by which the graduations of the circle

Q are read. The tubes of these microscopes are of iron, cast in the same flow of metal with the rest of the base-plate, and forming one piece of metal with it. They were cast solid and afterwards bored. The bored cylinders were bushed with brass (by a process which gives an almost metallic connexion with the iron), and in these brass linings were cut the screws for attachment of the object-glasses and the eye-tubes. The cases, &c., of the micrometers are attached by small screws in the usual way: but the piece which supports the pressure of the micrometer-screw, and upon which the accuracy of the micrometer depends, is cast in the same flow with the rest. The microscopes are marked **a**, **b**, **c**, **d**, in the order of the graduations of the lower fixed circle: **a** being at the observer's right hand when the graduated face of the vertical circle is Right.

V is the pointer-microscope, or microscope for reading the integer graduations of the circle Q. It is a plain microscope with cross-wires in its field of view: it is screwed to the edge of the base-plate. The only part of it seen in this view is its reflector.

W, W, are the two clamps (of which one only is used at a time) for taking hold of the projection of the circle to which R is screwed.

X, X, are the two toothed pinions (of which only one is used at a time, the other being withdrawn longitudinally) which act in the teeth of R, and by which a moderately-slow motion in azimuth is given to the instrument. It will be remarked, that there is no apparatus for very-slow motion, as by screws. The observations being made entirely by the observation of the time of transit over the wires in the field (whatever be the direction of the telescope, and whatever be the direction of the star's motion), no very-slow motion in azimuth is needed for an observation in azimuth; but a moderately-slow motion in azimuth is needed for an observation in zenith-distance, in order that the vertical transit may always be observed on the middle of the horizontal wires.

Y, Y, are reflectors, two on each side, by which the light of a lamp β in figure 22, which is thrown downwards by a reflector ϵ in figure 22, is turned horizontally to illuminate the reflectors of the microscopes T, T, T, T. In each system Y of reflectors, the two reflectors are inclined opposite ways, one to throw the light upon the right-hand microscope, the other to throw it on the left-hand microscope.

The weight of the base-plate, &c., is 340 lbs.

Figure 9 is a vertical section through the base-plate in its longest direction, and through the lower fixed circle, to shew the machinery of the counterpoise for relieving the vertical pressure of the lower pivot: and shewing also one of the levels parallel to the axis of the vertical circle.

Z is the counterpoise.

a, the lever on which it immediately acts.

b, the hook which serves as fulcrum for **a**.

c, the connecting rod, which is drawn upwards by **a**.

d, the hook which serves as fulcrum for **e**.

e, the lower lever by which the slider **f** is thrust upwards. This slider has a small hard steel cylinder at its top, acting against a similar cylinder inserted in the spherical pivot **g**: the ends of these cylinders where they are in contact are nearly flat, thus allowing the spherical pivot to remain in contact with the internal cone **h**. The slider **f** has a collar of leather to retain the oil.

g, the spherical pivot, of gun-metal, which takes bearing upwards in a socket in the base-plate, and downwards in a cone **h** of harder gun-metal in the lower fixed circle. It has a projection upwards to the top of the base-plate, for keeping it steady. The channel bored through it is for oiling the bearing of **g** upon **h**.

i, **i**, the flanges at the bottoms of the vertical cheeks. The dotted upright lines shew the section of the vertical cheeks (see figure 10), and other dotted lines shew the holes through which the ends of the level-bar pass (see z, figures 22 and 23).

j, **j**, the level-bar. This is a bar of cast-iron, one inch square, widened at one end in order to admit of two bearing-points (between which the screw passes), and having at the other end only one bearing-point, or rather narrow ring surrounding the screw. These points take bearing upon the flanges **i i** of the vertical cheeks; and the bar is held down by pretty strong screws. The support of the bar is made to depend on the external flanges of the vertical cheeks, because the level which it carries is intended to give information as to the position of the horizontal axis, whose bearings are on the external side of the vertical cheeks.

k, **k**, two brass Y's attached to the bar **j j**, in which the glass tube of the level rests, and into which it is pressed by light springs above.

l, **l**, two stops for preventing end-motion of the level: one of them is furnished with a spring.

m, the glass shade, covering the level and its scale. The numeration of the divisions of the level-scale proceeds in a continuous series of numbers from that end which is nearest the vertical cheek carrying the microscopes (figure 11) to that end which is nearest the vertical cheek carrying the clamping circle and toothed wheel (figure 12).

It must be remarked, that there are upon the base-plate two similar levels parallel to the axis of the vertical circle. The holes in the vertical cheeks through which they pass are seen at **z z** in figures 11, 12, and 23. No part of these levels or level-bars has any adjusting-screw, the adjustment having been effected by filing. The level which is nearest to the observer when the face of the vertical circle is right is marked **e**, **f**: the other **g**, **h**.

Figure 10 is a section, in the same direction as the section of figure 9, through one of the cast-iron vertical cheeks (namely, that which carries the microscopes).

n is the inner flat plate of the cheek, which is not continuous, very large parts being removed, as shewn in figures 11 and 12.

o is the exterior semi-cylindrical plate of the cheek, which is continuous, except that it is pierced with one hole for the pivot of the vertical circle, and with the holes for the level-bars **j j**.

p is the upper flange, by which the cheek is bolted to the upper plate.

q, **q**, are the brackets which carry the levels that are parallel to the plane of the vertical circle.

r is the bracket which carries the Y for the horizontal pivot. It appears here interrupted, the section passing through the large hole (see figure 14) through which the screw-bolt of the Y passes.

s is the Y for the horizontal pivot, of gun-metal, resting upon the bracket **r**, with a piece of lead between them. Its lower part passes through the hole of **r**, and is cut with a screw-thread, upon which is a powerful nut, by which **s** is drawn with great force into contact with **r**. There is no power of adjusting either of the Y's: they have been adjusted by filing.

t is the pivot of the vertical circle.

v, a counterpoise.

w, a lever, upon which **v** immediately acts.

x, a wheel-frame, supported by the other end of **w**.

y, a friction-wheel, turning in the frame **x** and supporting the pivot **t**.

Figure 11 is an elevation of the inner flat plate of that vertical cheek which carries the microscopes.

o, **o**, **o**, **o**, **o**, are portions of the external semi-cylindrical plate seen through the large openings of the inner plate.

z, **z**, are the holes through which the level bars **jj** pass.

a is the hole in the semi-cylindrical plate through which the pivot of the vertical circle passes.

b, *b*, *b*, *b*, are the four micrometer-microscopes. The description of T, T, T, T, figure 8, applies in every respect to *b*, *b*, *b*, *b*. The microscopes are marked A, B, C, D, in the order of the graduations of the Vertical Circle (see figure 18, below), A being the upper microscope which is nearest to the observer when the graduated face of the vertical circle is Right.

c is the pointer-microscope, for reading the integer divisions. Its reflector only is seen in this view: it is screwed upon the iron cheek.

The vertical cheek, the microscopes, the brackets which carry the levels, and the bracket which carries the Y for the pivot of the vertical axis, are all in one cast of metal. The weight of this cheek is 429 lbs.

Figure 12 is an elevation of the inner flat plate of the other vertical cheek.

d is the clamping-ring, for the clamp of the vertical circle.

e is a toothed wheel, in which acts the pinion *n* (figure 18), carried by the vertical circle.

d and *e* are upon a plate of gun-metal which is screwed to the iron plate.

The weight of this cheek is 421 lbs.

Figure 13 is a horizontal section, on a larger scale, through one side of the toothed wheel and clamping ring of figure 12, in the direction of a horizontal diameter of the toothed wheel. The ends of the teeth of the wheel *e* are seen in perspective here: their points or ridges being seen in figure 12.

Figure 14 is a horizontal section of the vertical cheek which carries the microscopes and the levels parallel to the plane of the vertical circle; with view (from above) of the lower pair of microscopes and lower level. The levels parallel to the plane of the vertical circle are of the ordinary English construction, the glass tube being fitted into a tube of thin brass by the insertion of plaster of Paris. The ends of the brass tube are connected with more solid pieces of brass, and these are screwed down to the brackets **q q**, the bearing being at one end upon two points between which the pressing-screw acts, and at the other end upon a thin ring surrounding the screw. There is no screw-adjustment; the adjustment was made by filing. The numeration of the level-scales is in a continuous series of numbers proceeding from right to left. The scale of the lower level (here shewn) is marked E, F: that of the upper level G, H. In front of the level is seen the glass shade, intended principally to protect the level from the heat of the lamp β in figure 22. I propose at some time to change this construction of levels for the German construction (in which the glass tube rests in Y's) adopted in the levels upon the base-plate shewn in figure 9. The latter levels were at first constructed on the English form, and, being very long, shewed very strikingly the defects of that construction, not only by the instability of their readings, but also by the changes in the value of the scale-divisions: and it was there found absolutely necessary to change the construction for the superior German construction. Hitherto no absolute necessity for the change of construction of the other levels has been felt; but it will doubtless be prudent to make the change.

The form of the ends of the microscopes (which is the same as for the microscopes T, figure 8) may also be seen. A thin tube of brass, lined with white plaster, and so long as very nearly to touch the divided limb (leaving the smallest possible interval) surrounds the microscope and is screwed to it: in one side of it is a hole for the admission of light;

and within it is a reflector of the usual form, but covered with white plaster. The effect of this construction is, that, when sufficient illumination is used, the divisions are seen as dark strokes upon a light ground, without any appearance of specular reflexion and without any bright lines at their edges. The idea of this mounting of the illuminators was borrowed from instruments which I saw in Germany.

I will make one more remark common to all the microscopes of this instrument The only adjustment which has been possible in the mounting of the object-glasses is, to put them in focus, without attempting to give any definite values to the divisions of the microscope-micrometers. The values of these divisions are therefore determined by trial, and they are (as might be expected) different for the different microscopes, and have no near relation to the ordinary sexagesimal divisions.

Figure 15 is a front view, on a larger scale, of one of the brackets supporting a Y with the Y, the nut that draws it downwards, and the pivot. In the center of the pivot is a small plate carrying a fine dot, to be observed by the micrometer-microscope *z* (figure 22), for ascertaining the movements and consequently the form of the pivot. On the unperforated pivot, this plate is carried by the piece of metal which closes the pivot: on the perforated pivot, it is carried by a piece of glass which closes the pivot.

Figure 16 is a view from above of the cast-iron upper plate of the revolving frame.

f, *f*, &c., are the ribs diverging from the center.

g, the flange, which is bolted to the flange **p**, of the vertical cheeks, figure 10.

h, *h*, two cast-iron ribs (in the same cast of metal) upon which the upper levels are mounted.

i i, *i i*, two levels, similar in construction to that shewn in figure 14. The numeration of their scales proceeds continuously from the end next the vertical cheek which carries the microscopes to the other end. The level which is nearest to the observer when the graduated face of the vertical circle is Right is marked **i, k**; the other is marked **l, m**.

j, *j*, the roofed glass shades over the levels.

k, the upper pivot, of gun-metal, which turns in the Y marked N, figures 3 and 4.

Figure 17 is a section through the upper plate, in its longest direction. It exhibits the method of fixing the upper pivot.

The weight of the upper plate and pivot is 189 lbs.

Figure 18 is a side-view of the gun-metal vertical circle and telescope, on the side opposite to that which carries the divided limb.

l, *l*, &c., are curved spokes of the circle.

m is the clamp, which takes hold of the ring *d*, figures 12 and 13.

n is the toothed pinion which acts in the toothed wheel *e*, figures 12 and 13. This toothed pinion is intended to give a moderately-slow motion to the vertical circle; it is used for the observation of transits in azimuth across the vertical wires, to insure that the transits take place across the middle of the wires. There is no very-slow motion in zenith-distance.

o, the object end of the telescope, in the same cast of gun-metal with the greater portion of the circle. The object-glass is screwed into this.

p, the eye end, in the same cast of metal. The intermediate part of the telescope is a tube of thin brass.

q, the eye-piece, of brass, screwed into *p*.

r, a projecting plate, with a small eye-hole, and *s* a projecting ring with a larger hole. These two holes constitute the finder of the telescope.

It does not appear necessary to give a view of the other side of the circle, as it contains nothing peculiar except the graduated limb. The divisions are to every 5′: the numeration proceeds from 0° to 360°, in the order opposite to that of a watch-dial.

Figure 19 is a view of the vertical circle in the plane of the circle, the object-glass being in view.

t is the drum or intermediate part of the circle.

Figure 20 is a view of the eye-end, on a larger scale.

u is a rapid screw, by which the first slider is carried horizontally across the wires.

v is a pinion mounted in the first slider and acting in a rack attached to the second slider, by which the second slider is carried vertically over the wires.

w, the eye-piece, carried by the second slider. The parallel lines across it represent the groove in which dark glasses for observations of the Sun can be placed.

The system of wires in the eye-piece consists of six horizontal wires at intervals of 2′ very nearly, and of six vertical wires at intervals of 4′ very nearly.

Figure 21 is a section of the vertical circle through its pivots, shewing the connection of the two sides. The whole vertical circle, except the clamp, the pinion-mounting, the optical parts, the intermediate tube, and the finder, is formed in two casts. One cast comprehends the drum, the groove for the silver on which the divisions are cut, the spokes and pivot on one side, the object-end of the telescope, and the eye-end of the telescope. The other cast comprehends the spokes and pivot on the other side. The two sides are connected by powerful screws. The weight of the vertical circle is 401 lbs.

The weights above given are those of the castings, unfurnished with the instrument-maker's fittings. The weight of the latter (micrometers, levels, eye-pieces, &c.) is 210 lbs.

Figure 22 is a general elevation of the instrument complete, viewed in the plane of the vertical circle.

x, x, x, are glass shades protecting the levels which are parallel to the plane of the vertical circle. Their positions have been determined by the considerations that the levels are exposed to the radiation from the lamp β, and also to the occasional radiation from a hand-lamp which is necessarily held above the levels.

y, y, are two large projecting pieces of brass, for carrying two microscopes z.

z is one of the micrometer-microscopes for examination of the point on the pivot (figure 15). Microscopes are adapted to both the pieces y, y, but that on the side on which the lamp is placed is usually removed, to allow the light of the lamp to enter the perforated pivot. The microscope can be placed with its micrometer-head horizontal or vertical: and it is used first in the former position, to ascertain the horizontal movements of the point on the pivot as the vertical circle is placed in different positions; and then in the latter position, to ascertain the vertical movements of the point on the pivot as the vertical circle is placed in different positions.

α, α, α, are three rods supporting the lamp β.

The regulator of the illumination is omitted in this view.

Figure 23 is a general elevation of the instrument, viewed on the side of the graduated limb of the vertical circle.

γ is the regulator of illumination, turning upon a screw fixed in the wheel-frame **x**.

δ is a slender rod, sliding in two small pieces screwed to the brackets **q q**, with a pin which acts in the lower end of the lever carrying the regulator γ.

ϵ is a set of three reflectors on each side. The two smaller reflect the light of the lamp to the microscopes b, b, and abundantly illuminate the divisions under them. The larger reflects the light downwards to the two reflectors Y which illuminate the divisions under the microscopes T, T: when the reflectors are well polished this light is sufficient; at other times the assistance of a hand-lamp is desirable.

The woodcut at the commencement of the volume (for which the work is indebted to the proprietors of the *Illustrated London News*) represents the instrument as in use. The step-ladder, it will be seen, turns in a circle round the central pier. It has been found convenient to attach to the revolving frame two boards, whose edges are in a plane parallel to the plane of the vertical circle; the eye being directed along these to view the object, the instrument is placed very nearly in the proper azimuth; and then the telescope is directed accurately by the ring-finder *r s*. These boards are omitted in the views.

The dome is cylindrical, with double sides, between which the air can pass freely, and with sliding shutters. Its clear inner diameter is 10 feet.

The following is a history of the examinations and changes of the instrument made from its erection to the end of 1847. They are not given exactly in the order in which they were made.

I. Examination of the Graduations of the Horizontal Circle.

On various days from March 19 to April 20, Messrs. Dunkin and H. Breen were employed in the successive steps of this examination. The logical order is as follows:—First, it was assumed that, as no absolute assurance of the non-displacement of the center of the revolving frame could be given, there was no possibility of discovering the relation of the errors of two opposite divisions, whether fundamental (as 0° and 180°) or derivative: and therefore all our process through the larger arcs must consist in an examination of the relation of diameters; and we might assume the errors of both 0° and 180° to be zero, and might attribute the errors of other diameters equally to their terminal graduations: but in the subdivision of small arcs we might satisfy ourselves with examining one end of a diameter at a time, using for the terminal errors those found as above mentioned. Next (α), the errors of the diameter 90°—270° were found, and attributed equally to the two divisions 90° and 270°. Then (β), the errors of the diameters 45°—225°, 135°—315°, were found in like manner by bisecting the angles made by the last mentioned diameters, and were attributed equally to their opposite divisions. Then (γ), all the angles included between the diameters inclined 90° were bisected by a similar diametral process, and thus the errors of all the diameters inclined 15° were found. Then (δ), the arcs of 15° were trisected, not using the diametral process: and thus the error at every division of 5° was found.

(α). The four microscopes **a**, **b**, **c**, **d**, were read; **a** being placed first over 0°, then over 90°, then over 180°, then over 270°. This operation (of 16 readings) was repeated 20 times. The readings with **a** over 0° and **a** over 180° were grouped together and their means taken; similarly with **a** over 90° and **a** over 270°. In the former case, $\frac{\mathbf{b}+\mathbf{d}}{2} - \frac{\mathbf{a}+\mathbf{c}}{2}$ was found $= +\,4''\cdot53$; in the latter, $\frac{\mathbf{b}+\mathbf{d}}{2} - \frac{\mathbf{a}+\mathbf{c}}{2} = +\,2''\cdot13$. Half the excess of the former above the latter is the error due to the graduations 90° and 270°, and is freed from the errors of position of the microscopes. Hence, error of reading of division 90° = error of reading of division 270° $= +\,1''\cdot20$.

(β). Two microscopes p and q were clamped to the base-plate in positions advanced 45° beyond **a** and **c** respectively, and **a**, **c**, p, q, were read, **a** being placed at 0°, 45°, 180°, 225°, for one diameter, and at 90°, 135°, 270°, 315°, for the other. Each complete set was repeated ten times. The excess of $\frac{p+q}{2} - \frac{\mathbf{a}+\mathbf{c}}{2}$ when **a** was upon 0°, above the same quantity when **a** was upon 45°, was + 2″·29; hence the error (in reading) of the diameter 45° — 225° above the mean of the two primary diameters is + 1″·15, or its absolute error + 1″·75. The excess of $\frac{p+q}{2} - \frac{\mathbf{a}+\mathbf{c}}{2}$ when **a** was upon 90°, above the same quantity when **a** was upon 135°, was + 0″·40: hence the relative error of the diameter 135°—315° was + 0″·20, and its absolute error + 0″·80.

(γ). The microscopes p and q were clamped to the base-plate in positions advanced 30° beyond **a** and **c** respectively, and then by three steps of 30° each an arc of 90° was covered. These arcs were begun successively at 0° and 180°, at 90° and 270°, at 45° and 225°, and at 135° and 315°. Each complete set was repeated ten times. The value of $E = \frac{p+q}{2} - \frac{\mathbf{a}+\mathbf{c}}{2}$ being ascertained for each diameter at an interval of 30°, and the mean of three successive values being taken, and the excess of each individual E over the mean of the three being found; then (supposing the arc to begin at 0°) the first excess is the relative error of the diameter 30° — 210°, and the first excess + second excess is the relative error of the diameter 60° — 240°. To obtain the absolute errors, there must be added to the first of these $\frac{2}{3}$ of the error of the diameter 0° — 180° and $\frac{1}{3}$ of the error of the diameter 90° — 270°; and to the second of them $\frac{1}{3}$ of the error of the diameter 0°—180° and $\frac{2}{3}$ of the error of the diameter 90° — 270°. In this way were found the following numbers :—

Diameter.	Relative Error.	Absolute Error.
° °	″	″
30 — 210	— 0·70	— 0·30
60 — 240	— 0·94	— 0·14
120 — 300	+ 0·21	+ 1·01
150 — 330	— 0·17	+ 0·23
75 — 255	+ 0·29	+ 1·73
105 — 285	+ 0·22	+ 1·33
165 — 345	+ 0·36	+ 1·47
195 — 15	— 0·45	+ 0·99

(δ). Two microscopes r and s, whose construction admitted of their being brought within 5°, were clamped upon the base-plate at an interval of 5°, and by three steps of this arc an arc of 15° was covered. This was repeated five times for each arc. The process is in every respect the same as under (γ), except that diameters were not used, and therefore there was no taking of means in opposite positions or for opposite microscopes. The results are as follows :—

Division.	Relative Error.	Absolute Error.
°	″	″
5	— 0·53	— 0·20
10	— 0·22	+ 0·44

Division.	Relative Error.	Absolute Error.
°	″	″
20	+ 0·04	+ 0·60
25	+ 1·33	+ 1·46
35	+ 0·75	+ 1·13
40	+ 0·88	+ 1·95
50	− 0·39	+ 0·73
55	+ 0·35	+ 0·84
65	0·00	+ 0·49
70	+ 0·39	+ 1·49
80	− 0·49	+ 1·06
85	− 0·71	+ 0·67
95	+ 0·09	+ 1·33
100	+ 0·08	+ 1·37
110	+ 0·43	+ 1·66
115	− 0·16	+ 0·95
125	+ 0·29	+ 1·23
130	+ 0·42	+ 1·29
140	− 0·61	0·00
145	− 0·38	+ 0·04
155	− 0·18	+ 0·46
160	+ 0·52	+ 1·58
170	− 0·25	+ 0·73
175	+ 0·44	+ 0·93
185	− 0·63	− 0·30
190	+ 0·43	+ 1·09
200	− 0·35	+ 0·21
205	+ 0·42	+ 0·55
215	+ 0·15	+ 0·53
220	+ 0·09	+ 1·16
230	+ 0·55	+ 1·67
235	+ 0·49	+ 0·98
245	+ 0·43	+ 0·92
250	+ 0·14	+ 1·24
260	+ 0·14	+ 1·69
265	+ 0·26	+ 1·64
275	+ 0·29	+ 1·53
280	+ 0·47	+ 1·76
290	− 0·64	+ 0·59
295	− 1·43	− 0·32
305	− 0·14	+ 0·80
310	− 0·03	+ 0·84
320	+ 0·94	+ 1·55

Division.	Relative Error.	Absolute Error.
°	″	″
325	+ 0·32	+ 0·74
335	− 0·54	+ 0·10
340	+ 0·43	+ 1·49
350	− 0·43	+ 0·55
355	− 0·06	+ 0·43

Remarking now that, by the process of reading the four microscopes, **a**, **b**, **c**, **d**, in all cases, the actual result of the error on the estimated position of the instrument will be the mean of the four errors for divisions 90° apart, we get the following Errors of Circle Reading.

Division under **a**.				Error.	Division under **a**.				Error.
°	°	°	°	″	°	°	°	°	″
0,	90,	180,	270,	+ 0·60	45,	135,	225,	315,	+ 1·27
5,	95,	185,	275,	+ 0·59	50,	140,	230,	320,	+ 0·99
10,	100,	190,	280,	+ 1·17	55,	145,	235,	325,	+ 0·65
15,	105,	195,	285,	+ 1·16	60,	150,	240,	330,	+ 0·05
20,	110,	200,	290,	+ 0·76	65,	155,	245,	335,	+ 0·49
25,	115,	205,	295,	+ 0·66	70,	160,	250,	340,	+ 1·45
30,	120,	210,	300,	+ 0·35	75,	165,	255,	345,	+ 1·60
35,	125,	215,	305,	+ 0·92	80,	170,	260,	350,	+ 1·01
40,	130,	220,	310,	+ 1·31	85,	175,	265,	355,	+ 0·92

It appeared that these apparent errors were not sufficiently large or sufficiently certain to require systematic correction in the Reduction of the Observations.

A microscope had been prepared for examination of every division, consisting of two optical arrangements in one barrel, at the interval of 1° very nearly (by which it was intended to quinquesect the arcs of 5°), and of two sets of wires carried by one micrometer-screw, at the interval of 5′ very nearly (by which it was intended to measure the interval from each division to the next). But, remarking that the circle was divided by the Dividing Engine, in which (from the nature of the screw-motion by which the circle is carried under the cutter) it is almost certain that the errors of division will very nearly follow a continuous law, and remarking the smallness of the errors at every 5°, it did not appear desirable to go through this laborious process.

II. Examination of the Graduations of the Vertical Circle.

At different times, from March 15 to April 12, Mr. Dunkin and Mr. H. Breen were occupied with the examinations of the graduations of the Vertical Circle. The process of observation and calculation was precisely similar to that for the Horizontal Circle, and (changing merely the figures expressing the equivalents of the micrometer-readings) the very same words will apply without any alteration. It appears therefore unnecessary to give the details, and sufficient to give the ultimate result.

Errors of Circle Reading in the mean of the four microscopes, for the Vertical Circle.

Division under A.				Error.	Division under A.				Error.
°	°	°	°	″	°	°	°	°	″
0,	90,	180,	270,	— 0·69	45,	135,	225,	315,	— 0·98
5,	95,	185,	275,	— 0·43	50,	140,	230,	320,	— 1·48
10,	100,	190,	280,	— 0·76	55,	145,	235,	325,	— 1·60
15,	105,	195,	285,	— 1·32	60,	150,	240,	330,	— 1·22
20,	110,	200,	290,	— 1·54	65,	155,	245,	335,	— 0·63
25,	115.	205,	295,	— 1·35	70,	160,	250,	340,	— 0·60
30,	120,	210,	300,	— 0·69	75,	165,	255,	345,	— 1·05
35,	125,	215,	305,	— 1·02	80,	170,	260,	350,	— 1·26
40,	130,	220,	310,	— 0·44	85,	175,	265,	355,	— 1·10

For the same reasons which applied to the Horizontal Circle, the examination of the errors of the smaller divisions was not continued; and no correction is systematically applied for these errors.

III. Examination of the form of the Pivots of the Vertical Circle.

Two sets of examinations have been made; the latter which was made on 1848, January 6 and 7, by Mr. Dunkin, is selected for detailed description.

(*a*) Examination of the Pivot opposite to the Graduated Face. The microscope for viewing the dot on the pivot was turned so that its micrometer moved in a truly horizontal direction, its wire being vertical. The observer read the micrometer when the wire touched the left edge, when it bisected the dot, and when it touched the right edge. The circle was turned so that the divisions under the pointer were successively *5°*, *15°*, *25°*, &c., to *355°*, then *355°*, *345°*, &c., to *5°*, and the means of the six readings for each position under the pointer were taken. The readings increase as the micrometer-wire moves to the right. The following are the mean readings, expressed in terms of the micrometer revolution :—

Pointer.	Reading.	Pointer.	Reading.	Pointer.	Reading.	Pointer.	Reading.
°	r	°	r	°	r	°	r
5	1·695	95	0·738	185	2·856	275	3·837
15	1·401	105	0·828	195	3·142	285	3·733
25	1·150	115	0·970	205	3·381	295	3·574
35	0·986	125	1·185	215	3·592	305	3·357
45	0·806	135	1·406	225	3·784	315	3·121
55	0·720	145	1·695	235	3·894	325	2·847
65	0·657	155	1·982	245	3·953	335	2·560
75	0·631	165	2·258	255	3·974	345	2·275
85	0·651	175	2·548	265	3·917	355	1·980

In order to take into account the effect of excentricity of the dot, it is assumed that these readings can be expressed by the formula

$$a' + b'.\ \sin \text{ pointer-reading} + c'.\ \cos \text{ pointer-reading} + z',$$

a' being a constant of the micrometer, and b' and c' being rectangular co-ordinates determining the excentricity of the dot, and z' being a residual irregularity, which in the first instance is neglected. Determining a' by taking the mean of all the readings, b' by comparing the group from 5° to 175° with that from 185° to 355°, and c' by comparing that from 275° to 85° with that from 95° to 265°, we find

$$a' = 2^{\mathrm{r}}{\cdot}280,\quad b' = -37^{\mathrm{r}}{\cdot}468 \times \frac{\sin 5^\circ}{2},\quad c' = -10^{\mathrm{r}}{\cdot}122 \times \frac{\sin 5^\circ}{2}.$$

The microscope was then turned so that the micrometer moved in a truly vertical direction, the readings increasing as the wire was carried downwards; and the following mean readings were found in the same way:—

Pointer.	Reading.	Pointer.	Reading.	Pointer.	Reading.	Pointer.	Reading.
°	r	°	r	°	r	°	r
5	0·526	95	2·849	185	3·729	275	1·447
15	0·709	105	3·085	195	3·558	285	1·196
25	0·918	115	3·301	205	3·354	295	0·988
35	1·147	125	3·487	215	3·112	305	0·789
45	1·414	135	3·661	225	2·868	315	0·599
55	1·716	145	3·765	235	2·580	325	0·462
65	1·997	155	3·826	245	2·318	335	0·410
75	2·287	165	3·834	255	2·004	345	0·402
85	2·590	175	3·811	265	1·730	355	0·464

Assuming that these readings can be expressed by the formula

$$a'' + b''.\ \cos \text{ pointer-reading} - c''.\ \sin \text{ pointer-reading} + z''$$

the following values were found in the same manner as before:

$$a'' = 2^{\mathrm{r}}{\cdot}137,\quad b'' = -36^{\mathrm{r}}{\cdot}813 \times \frac{\sin 5^\circ}{2},\quad c'' = -12^{\mathrm{r}}{\cdot}911 \times \frac{\sin 5^\circ}{2}.$$

Now if our operations of every kind had been perfectly correct, since the excentricity which gives rise to the constants b'' and c'' is the same which gives rise to the constants b' and c', we may consider the values found for b' and b'' as two different determinations of the true constant b, and similarly for c. Adopting the mean, we have as the expression for the horizontal measure

$$2^{\mathrm{r}}{\cdot}280 - 1^{\mathrm{r}}{\cdot}618\ .\ \sin \text{ pointer-reading} - 0^{\mathrm{r}}{\cdot}502\ .\ \cos \text{ pointer-reading} + z'.$$

and for the vertical measure

$$2^{\mathrm{r}}{\cdot}137 - 1^{\mathrm{r}}{\cdot}618\ .\ \cos \text{ pointer-reading} + 0^{\mathrm{r}}{\cdot}502\ .\ \sin \text{ pointer-reading} + z''.$$

Computing the values of these formulæ for the pointer-readings 5°, 15°, &c., and comparing them with the quantities measured, we find the following values for the residual errors z', z'':

Pointer Reading.	z'	z''	Pointer Reading.	z'	z''	Pointer Reading.	z'	z''	Pointer Reading.	z'	z''
°	r	r	°	r	r	°	r	r	°	r	r
5	+ ·056	− ·042	95	+ ·027	+ ·063	185	− ·064	+ ·025	275	− ·011	− ·050
15	+ ·024	+ ·006	105	− ·018	+ ·046	195	− ·041	− ·013	285	+ ·019	− ·038
25	+ ·008	+ ·035	115	− ·056	+ ·026	205	− ·036	− ·037	295	+ ·041	− ·011
35	+ ·047	+ ·048	125	− ·056	+ ·011	215	− ·028	− ·062	305	+ ·039	− ·007
45	+ ·025	+ ·066	135	− ·084	+ ·026	225	+ ·005	− ·059	315	+ ·053	− ·083
55	+ ·035	+ ·095	145	− ·069	+ ·015	235	000	− ·072	325	+ ·051	− ·061
65	+ ·056	+ ·088	155	− ·069	+ ·011	245	− ·004	− ·046	335	+ ·052	− ·048
75	+ ·044	+ ·086	165	− ·087	+ ·005	255	+ ·002	− ·068	345	+ ·061	− ·042
85	+ ·028	+ ·093	175	− ·091	+ ·019	265	− ·019	− ·046	355	+ ·061	− ·016

These are the irregularities in the motion of a point the nearest possible to the center of the pivot, depending upon nothing but the irregularity of form of the pivots and the errors of observation. The law of the irregularities (as well as that of the discordance between b' and b'', c' and c'') would seem to shew that the two positions of the micrometer were not exactly at right angles; this assumption with a proper amount of error of position would reduce z' and z'' almost to zero.

(β). Proceeding in exactly the same manner with the pivot on the same side as the graduated face, the horizontal measures increasing to the right, and the vertical measures increasing upwards, we get the following residual errors:

Pointer Reading.	z'	z''	Pointer Reading.	z'	z''	Pointer Reading.	z'	z''	Pointer Reading.	z'	z''
°	r	r	°	r	r	°	r	r	°	r	r
5	− ·009	− ·022	95	+ ·017	+ ·014	185	+ ·008	+ ·045	275	+ ·016	− ·002
15	− ·010	− ·032	105	+ ·027	+ ·001	195	+ ·003	+ ·040	285	− ·025	− ·006
25	+ ·012	− ·017	115	+ ·046	− ·005	205	− ·005	+ ·014	295	− ·014	− ·008
35	+ ·002	− ·020	125	+ ·038	− ·007	215	− ·009	+ ·008	305	− ·001	− ·005
45	+ ·005	− ·014	135	+ ·033	− ·007	225	− ·023	+ ·009	315	− ·002	+ ·006
55	+ ·014	− ·023	145	− ·002	− ·028	235	− ·044	− ·010	325	000	+ ·018
65	+ ·014	− ·015	155	− ·009	+ ·009	245	− ·009	− ·003	335	− ·007	− ·003
75	+ ·013	− ·006	165	− ·009	+ ·029	255	+ ·002	− ·009	345	000	− ·011
85	− ·004	+ ·015	175	+ ·004	+ ·065	265	− ·008	− ·013	355	− ·028	− ·012

It was found by trial of the microscopes on the limb of the horizontal circle (radius 18 inches), that, in the mean of the two, $6^{r}{\cdot}206 = 5'$. Hence in respect to the movement of the horizontal axis of the vertical circle, whose length is 38·75 inches, $1^{r} = 22''{\cdot}45$ nearly. The greatest apparent error in the position of the axis (which will be the sum of the corresponding values of z' for the horizontal error or of z'' for the vertical error) is $z' + z'$ for pointer-reading 165°, and amounts to $0^{r}{\cdot}096$, or $2''{\cdot}1$. The amount of the vertical errors (which are more important) is considerably less. On the whole it has appeared unnecessary and unsafe to attempt to make any correction to the observations for this possible cause of error.

In 1847, May, an examination conducted in exactly the same way indicated smaller errors.

IV. Determinations of the values of the level-scales, and changes of the levels.

On 1847, March 12 and 13, the levels were taken off the instrument and were placed upon a level-prover, lent by Mr. Simms, whose scale was determined by our own measures. The results for the values of one division were

	″
For $E-F$	1·1996
$G-H$	1·1395
$e-f$	1·1802
$g-h$	0·9020
$i-k$	0·9857
$l-m$	0·9346

These values were used for a time in the reduction of the observations. On comparing however the changes in the position of the vertical axis shewn by the levels $e-f$, $g-h$, $i-k$, $l-m$, in rapid reversion of the instrument, it was found that their indications were so different as to shew that the curvatures of the glass tubes of the levels when mounted on the instrument were different from what they were when placed on the level-prover. To obviate this, on May 28, blocks of wood were placed on the telescope of Troughton's circle, and the levels were screwed upon these as nearly as possible in the same manner as when mounted on the instrument. The results for the values of one division were now as follows:

	″
For $E-F$	1·1797
$G-H$	1·0040
$e-f$	1·1037
$g-h$	0·7040
$i-k$	1·1864
$l-m$	1·1350

The reductions of the observations which had been made with the former values of the level divisions were at once recomputed with these values. The values thus found for $E-F$ and $G-H$ have still been retained; and those for $e-f$, $g-h$, $i-k$, $l-m$, were retained to 1847, November 10.

The levels up to this time were made on the common English construction, the glass tubes being fixed by plaster in brass tubes; and to the ends of these brass tubes were attached more solid pieces of brass, which were screwed down, with a flat bearing, to the supporting parts of the instrument. It was found, however, in the months of May and June, that the levels, especially the longest $e-f$, $g-h$, were perpetually changing their zero, and that this zero was altered by forcing the attaching screws. On June 10, therefore, the bearings of all the levels were altered in such a way that one of the solid brass ends rested upon two points, midway between which the pressing screw acted, and the other upon one point, or rather upon a small ring surrounding the pressing screw: and from this time the anomalies which I have mentioned disappeared.

Still it was evident that the levels *e*—*f*, *g*—*h*, were too infirm to be trusted; and the observations made during a journey on the continent having suggested the advantages which would be derived from the adoption of the German construction, on Nov. 14 new levels were mounted in the place of *e*—*f*, *g*—*h*, in the form which is explained in the description above.

Mr. Simms having expressed his confidence in the correctness of his values of the scales of the new *e*—*f*, *g*—*h*, as well as of *i*—*k*, *l*—*m*, intended to represent 1″ in each division, it was thought prudent to adopt those values; and accordingly from that time each division is supposed to be equal to 1″. The following comparisons have been made for the purpose of testing the accuracy of these adopted values. In all the instances in which a considerable change in the levels was produced by reversing the instrument, the amount of that change in level divisions was taken from the different levels, and all were grouped together for each level.

For *E*—*F* and *G*—*H*.

By the mean of 80 reversions between May 23 and December 27, 30·61 divisions of *E*—*F* corresponded to 36·66 divisions of *G*—*H*. These numbers require values differing a little more than those given above.

For *e*—*f*, *g*—*h*, *i*—*k*, *l*—*m*.

By the mean of 80 reversions between 1847, Nov. 15, and 1848, June 15, the following numbers of divisions were found to correspond.

e—*f*	*g*—*h*	*i*—*k*	*l*—*m*
37·41	38·66	36·93	39·44

These agree nearly enough; and the two lower levels, considered as one group, agree almost exactly with the two upper levels, considered as another group.

V. Determination of the relation of the position of the axis of the Vertical Circle to the axis of revolution in azimuth.

It will be seen hereafter that the observations of stars give the means of determining the Level Reading for the mean of *e*—*f*, *g*—*h*, *i*—*k*, *l*—*m*, corresponding to the horizontal position of the axis of the Vertical Circle. As these observations cannot always be obtained, and as mean level readings for the vertical position of the axis of revolution can always be obtained by reversion, it appeared desirable to compare them, so as to be able to infer the former from the latter. By 14 comparisons between May 21 and June 22, it appeared that the latter exceeds the former by + 2″·54: this number was used where necessary from May 16 to June 22. From May 21 to July 8, 18 comparisons gave + 2″·18: this was used from June 23 to July 8. From July 18 to September 4, 17 comparisons gave + 0″·35: this was used from July 18 to September 6. From July 18 to October 7, 24 comparisons gave + 0″·14: this was used from September 14 to October 7. From October 18 to November 5, 7 comparisons gave — 1″·49, which was used from October 13 to November 5. From October 18 to November 10, 8 comparisons gave — 1″·55, which was used on November 10. During the remainder of the month of November the zero derived from the reversion was not used, as it appeared uncertain. From December 11 to December 16, 3 comparisons gave — 1″·63, which was used from December 11 to December 31.

It would appear from the progression of these numbers that the Y's, or (less probably) the pivots of the Vertical Circle, have worn unequally.

VI. Alteration of the counterpoises of the axis of the Vertical Circle, and alteration of the object-glass.

The irregularity of the Zero in Azimuth having made it probable that the pivots of the Vertical Circle were not pressed into their Y's with sufficient force, on July 15 about one-third part of the counterpoises was cut off. The object-glass was also taken off for examination, and apparently was not replaced accurately in the same position.

VII. Determination of the Intervals of Wires in the Eye-piece of the Telescope.

(α). For the intervals of horizontal wires, or those used in the observation of vertical transits.

Fifty vertical transits of stars, from July 21 to November 18, were treated in the following manner:—The means of the wires having been previously formed, the interval between each wire and the mean of all was taken. As in different observations these transits occur in different orders on the wires, it was necessary to adopt one order of passage as the standard. The order adopted for the wires I, II, III, IV, V, VI, is that in which stars pass which are West of the Meridian, the graduated face of the Vertical Circle being Right: when one only of these conditions is changed, the passage takes place in the opposite direction. Due respect was given to this consideration in taking out the intervals between the transit over each wire and the mean of all. The vertical movement of a star in 1^s of sidereal time is 15″ × cos latitude × sin azimuth from North or South. Hence the angular interval of each wire from the mean, in seconds of arc, is

Observed interval in seconds of time × 15″ × cos latitude × sin azimuth.

This calculation being performed for every interval of each of the stars, and the mean of the results being taken, the distances of the wires from the mean of wires were found to be as follows:

		″
Wire I	+	300·43
II	+	180·70
III	+	59·78
IV	−	59·85
V	−	180·18
VI	−	300·79

(β). For the vertical wires, or those used in horizontal transits. The process of taking the interval of time between each wire and the mean of all was the same as in the former case. But as no stars are ever observed higher than the pole, the horizontal motion of stars is always in the direction N., E., S., W., N.; and therefore it was necessary to discriminate the transits only by the position of the instrument. The position adopted for the order of the wires 1, 2, 3, 4, 5, 6, is that in which stars pass when the graduated face of the Vertical Circle is Right. The square of the horizontal movement of a star in one sidereal second, is found by subtracting the square of the vertical movement just found from the square of the whole movement, or $(15'' \times \sin \text{N.P.D.})^2$. Hence, distance of a wire from the mean of wires = interval of time $\times\ 15'' \times \surd\ \{\sin^2 \text{N.P.D.} - \cos^2 \text{lat.} \sin^2 \text{azimuth}\}$. The latter term is calculated easily by the use of an auxiliary angle θ, such that $\sin \theta = \cos \text{lat.} \sin \text{azimuth.} \operatorname{cosec} \text{N.P.D.}$ Treating 50 transits in this manner, from July 21 to September 22, the intervals in arc of each wire from the mean of wires were found to be as follows:

		″
Wire 1	+	600·04
2	+	363·04
3	+	121·43
4	−	120·89
5	−	361·63
6	−	601·93

VIII. Examination into the effect of the heat of the Lamp, carried by the Instrument, upon the radial bars of the upper triangle which carry the Y for the upper pivot of the azimuthal axis.

On March 10 and March 11 observations were made, the instrument being so turned that the lamp was immediately under one of the bars. In both the effect was the same: that in 15^{m} of time the readings of the levels $e-f$, $g-h$, diminished about 2″, shewing a corresponding expansion of the radial bar. As this expansion does not in itself produce any injurious effect (as the only possible injury would be in the change of position between the observation with the telescope and the reading of the levels, or during a very short time), and as the general unsteadiness depending on it is insignificant, no attempt has been made to shield the bars.

The five-feet Equatoreal, constructed by Ramsden.

This instrument was the property of Sir George Shuckburgh, and is fully described by him in the Philosophical Transactions for 1793. It was presented to the Observatory in the year 1811. The instrument is one of that class in which the two pivots of the polar axis are at the two extremities of the polar axis, and the two pivots of the declination-axis are at the two extremities of the declination-axis: the telescope being between the pivots of the declination-axis, and the declination-axis being within the frame of the polar axis. The whole length of the polar axis, between the extremities of the pivots, is about 9 feet. These pivots turn in Y's (having proper adjustments), which are carried by two piers on opposite sides of the Dome. The North pivot is at the center of a circular frame; the South pivot is at the apex of a cone; and the polar frame consists of six pillars, connecting the base of this cone with the circular frame. Three pillars are united by intervening bars to form the eastern side of the polar frame, and three to form the western side: they carry the Y's for the declination-axis, and the microscopes for reading the declination-circle. The length of the declination-axis between the extremities of its pivots is about 2 feet 2 inches: the diameter of the declination-circle is 4 feet, and the circle is divided to 5′ of arc. The telescope is 5 feet 4 inches in length, and has an object-glass of 4·1 inches aperture. The hour-circle is connected with the cone; its diameter is 4 feet, and it is divided to 10′ of arc: these divisions are read by fixed micrometer-microscopes. The instrument is mounted in the North-Eastern Dome, the situation of which is most unfavourable, as the whole south-western sky, to the altitude of 35°, and a considerable extent to the altitude of 53°, is concealed by the Octagon Room of the original building of the Observatory.

The Equatoreal in the South-Eastern Dome.

This instrument was erected in the year 1838. The aperture of the object-glass is about 6·7 inches, and its focal length about 8 feet 2 inches. The object-glass was made by M. Cauchoix, of Paris, and was presented to the Observatory by the Rev. R. Sheepshanks. Its definition is good: a small quantity of colour from the secondary spectrum, and a diffusion of light from brilliant objects, being the principal defects. It is mounted in the South-Eastern Dome, with a mounting similar in general form to that of the Dorpat telescope. A stone pier is erected, whose extreme breadth from E. to W. is 1 foot 4 inches, and from N. to S. is 5 feet 4 inches: the southern part of the upper surface of this pier is sloped so that its plane produced passes through the celestial pole: upon the surface is fixed a cradle of cast-iron, having the lower bearing of the polar axis in a projection from its lower end, and the upper bearing at its upper end: the distance between the two bearings is 3 feet 7 inches. The axis is of cast-iron; its form is nearly conical: the end which rests in the lower bearing is a more obtuse cone. The diameter of the axis, where it turns in the upper bearing, is 6 inches: it rests here in a Y upon two plates of agate. At a small distance below the upper bearing, a strong circular plate, parallel to the equator, 14 inches in diameter, is fixed to the axis; and close above it, another plate of the same size is mounted, parallel to the former, turning freely round the axis: in that surface of each of these two plates which is nearest to the other plate, a dove-tailed groove is turned, and a moveable clamping-piece has one clamp in the groove of one plate, and the other clamp in the groove of the other plate. By means of this clamping-piece, the two circular plates can be fixed together at pleasure, in any relative position. The moveable circular plate is inseparably connected with a long flat arm, or sector, of 24 inches in length (measured from the circumference of the plate), in the plane of the equator: the edge of this sector is cut into teeth, in which works the endless screw carried by the clock, which is fixed to the North side of the pier. Therefore, if the clamping-piece above mentioned is not fixed to either plate, or is fixed to only one, the action of the clock-work upon the sector, though it turns the moveable circular plate, does not turn the fixed circular plate; but if the clamping-piece is fixed to both plates, the action of the clock-work on the sector carries the moveable plate and the fixed plate (now connected with it), and therefore turns the polar axis, and the telescope, &c., which is supported by the polar axis. Between that part of the clamping-piece which is connected with the fixed plate, and that part which is connected with the moveable plate, there is a slow-motion screw, turned by means of a hook's joint and a long handle. Immediately above the upper bearing, the polar axis carries the hour-circle, 12 inches in diameter; it is divided on its edge to 1^m of time, and is read off to 2^s by two verniers. Above this, a square box is firmly fixed to the axis; perforated in one direction parallel to the equator for the insertion of the declination-axis. The diameter of the declination-axis at each of its two bearings is about 4 inches: it is supported at each in a Y. To one end of the declination-axis is fixed the cradle, carrying the telescope; to the other end is fixed the declination-circle, and the counterpoise. The diameter of the declination-circle is 11 inches; it is divided on its edge to $15'$ of arc, and is read off to $30''$ by two verniers attached to the square box. The telescope-tube is of wood; its form is square in the middle, chamfered off towards the ends so as to become octagonal; several stops, or transversal plates with holes of the proper magnitude, are fixed in it; it is very firm and free from tremours. Upon a large ring which is fixed to the square box there turns with stiff friction another ring, carrying two sector arms, graduated at their extremities: these graduations are read by micrometer-microscopes, carried, one by the eye-end of the telescope-tube, and one by the object-end: the use of this graduated double sector is, to measure small differences of declination (not exceeding 10°) with great accuracy; as, being brought by the hand under the telescope, it is then retained in its position by friction, and is not affected by the motion of the telescope. Upon another ring, which is fixed to the square box, there turns a ring-clamp, or brake, that admits of being fastened to it in any position; with this ring-clamp the telescope-cradle is connected by means of a slow-motion screw, which fixes the telescope in declination, or gives the means of imparting to it a slow-motion in declination. The speed of the clock is regulated by two balls, suspended to the end of a horizontal arm of 4¾ inches in length, which is carried by a vertical spindle; when the velocity is so great as to cause the suspending-rods to make a certain angle with the vertical, small projections, carried by the balls, are thereby made to rub against the lower surface of a fixed horizontal ring, and the friction thus caused prevents the weight which urges the clock from increasing the velocity. This mounting was constructed by Mr. T. Grubb, of Dublin.

The great Zenith Sector.

The focal length of the vertical telescope is about 25 feet, and its aperture 5 inches. It turns horizontally upon a conical pivot at its lowest end, and in a collar with steadying springs at nearly 5 feet from its upper end. This collar is carried by the upper extremity of a very large iron tube, within which the tube of the telescope revolves without touching it: the iron tube is supported by four curved iron legs diverging from its lower extremity, which is 4 feet 8 inches above the lower extremity of the telescope: the iron tube has no other support; and neither the iron tube nor its legs is connected with the walls of the building. At 3½ inches below the object-glass, the wire of the plumb-line is attached to a reel exterior to the telescope-tube (carried by the tube), and, passing over a screw whose axis is horizontal, depends in the interior of the tube. The use of the screw is, to enable the observer to move the point of suspension laterally, either for the convenience of bringing the wire to the center of the field of the microscopes, or for the estimation of the relative values of the micrometers (to be mentioned hereafter). The wire in the greater part of its length passes within a small tube fixed within the telescope-tube: the plumb-bob hangs in a pot of water resting below the plate closing the lower end of the telescope-tube. At 5½ inches below the screw, a micrometer-microscope is fixed on the same side of the tube, for observing the upper part of the wire: at the opposite side of the tube is an aperture with a reflector, for illuminating the microscope. At 1½ inches above the lower end of the telescope, another micrometer-microscope is fixed on the opposite side of the tube, for observing the lower part of the wire. In the eye-piece of the telescope there are, carried by a fixed plate, ten pairs of wires arranged as acute crosses; and, carried by the moveable micrometer-plate, eleven single wires, whose intervals are not very different from those of the fixed crosses. This moveable plate is made to slide by a micrometer-screw acting in opposition to a spring in the usual way: its range is such as will carry any one of the moveable wires to touch the adjacent fixed wires on each side. The eye-piece is a four-glass eye-piece with a diagonal reflector: it is carried by a separate slider.

In order to guard against the chance of error which might arise from a rotation of the plumb-line on reversing the instrument, the following apparatus is added:—

Instead of supporting the weight of the bob upon one long plumb-line, two plumb-lines are used, one of them being the original long plumb-line without alteration of position, the other being a wire about 3 feet long at the distance of 11 inches from the former; the plane which passes through the two wires passing also through the axis of the microscope which views the lower part of the plumb-line. These two plumb-lines support the two ends of a horizontal bar, and to this the weights are suspended from two points. Near the commencement of the year 1843, the pulley over which the auxiliary plumb-line passes was attached to a plate sliding in grooves and moveable by a screw, by which a delicate motion can be given to it either towards or from the principal plumb-line; and this is used for insuring the perfect verticality of the principal plumb-line, by observing carefully whether the image of the principal plumb-line, as seen through the microscopes, is equally good when free and when attached to the bar connecting it with the auxiliary plumb-line. The instrument is made capable of observing the same star in reversed positions at the same transit, chiefly by the insertion of two supplementary strong wires, moved by the micrometer, and placed at a distance from each other nearly corresponding to the double of the Zenith distance of γ Draconis. A handle placed at a convenient height enables the observer to reverse the tube rapidly, and the manner of making the double observation is therefore closely analogous to that of observing a star directly and by reflexion at the same transit with the Mural Circle.

This instrument was dismounted in the spring of 1848, as the results of observations did not appear to justify the trouble of using it, and the room was wanted for other purposes.

Three detached Telescopes, two of which are now usually kept in the Transit Room and one in the Magnetic Observatory.

Their lengths are 46 inches, 62 inches, and 30 inches, and the diameters of their object-glasses 3·6 inches, 3·8 inches, and 2·7 inches respectively.

The Transit Clock, constructed by Hardy, and originally furnished with Hardy's escapement.

A dead-beat escapement was substituted for this by Dent in the year 1829. The jewelled holes were removed by Dent in 1836, and the pivots now turn in brass holes.

A clock in the North-Eastern Dome, marked Arnold 1; one in the South-Eastern Dome, marked Earnshaw; one in the New South Dome (erected for the Altitude and Azimuth instrument that was mounted in 1847), marked Graham 1; one in the Circle Room, marked Graham 2, and another, marked Mudge and Dutton, which was presented in the year 1846 to the Observatory by the Rev. Charles Turnor; one near the bottom of the Zenith Tube, marked Arnold 2; and some journeyman or assistant clocks.

There is also another achromatic telescope which has rarely been mounted, and two reflectors, the largest being one of 10 feet, by Sir W. Herschel.

III. *Subjects of Observation in the Year* 1847.

The Sun and Planets have been observed on the meridian at every practicable opportunity, except on Sundays, and except on one day in each month which is considered a holiday: the Moon and moon-culminating stars have been observed at every opportunity without exception.

The occultations of stars by the Moon, and the eclipses of Jupiter's satellites, have been regularly looked for. The immersions and emersions of the satellites behind Jupiter, and the ingresses and egresses before him, have been looked for, when occurring at convenient hours.

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

The other stars observed are: Stars remaining from the lists of former years, consisting chiefly of Stars compared with Comets observed with the Equatoreals, or found in the moon-culminating lists of the Nautical Almanac from 1840 to 1847 inclusive; Stars observed with Hind's Second Comet; Groombridge 1830 and the companion to it, which were observed with the N.E. Equatoreal in 1847; Stars from the moon-culminating lists of the Nautical Almanac from 1848 to 1850 inclusive; Stars observed to complete the Greenwich Catalogues of preceding years; Stars that have been occulted by the Moon;

and, finally, Stars near the North and South Horizon for correction of the constant of refraction.

The Altitude and Azimuth Instrument has been used for observations of the Moon at every opportunity without exception, and for observations of the stars necessary for the instrumental adjustments.

The Zenith Tube has been used for the observations of γ Draconis at every opportunity, exclusive of Sundays and monthly holidays.

The North-East Equatoreal has been employed in taking transits of the Moon's limbs when both are nearly full, for the comparison of her diameter with that given by Burckhardt's Tables; for comparing the star Groombridge 1830, of which the proper motion is large, with a neighbouring star for the purpose of determining its parallax; and for observations of occultations of Stars by the Moon, and of phenomena of Jupiter's Satellites.

The South-East Equatoreal was employed for observing Hind's Second Comet.

The Double-image Micrometer attached to the South-East Equatoreal has been used for measuring the diameters of the Planets Venus, Mars, and Jupiter, and the distance and position of the components of γ Virginis.

IV. *Explanation of the Printed Observations.*

§ 1. *Transits as observed, and computations of Apparent Right Ascension*, page [2] to [131].

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

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

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

1. The Greek or Italic letter of Bayer, as adopted in Baily's Flamsteed, with the name of the constellation.

2. Flamsteed's number, with the name of the constellation.
3. The number in the Catalogue of the British Association.
4. Piazzi's hour and number.
5. The number in Groombridge's Catalogue.
6. The number in Bessel's Bradley.
7. The number in Baily's edition of Flamsteed's Catalogue.
8. The number in Santini's Catalogue of 1677 Stars, published in the Memoirs of the Royal Astronomical Society, vol. xii.
9. The number in the Catalogue of Lalande or Lacaille, published by the British Association, though this is done more systematically in the following Sections.
10. The North Polar Distance; which may be a few minutes in error.

Generally, also, the letter of reference is attached to anonymous stars which have been compared with Comets, though this is done more systematically in the following sections.

The *next seven* columns contain the seconds and decimals of seconds of time (and, for several stars near the pole, the minutes,) at which the object was observed to pass each of the wires: the hour and minute also being given in the *tenth* column. When the object is not observed at the seventh wire, the hour and minute are those which correspond to the last wire at which an observation was made.

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

The clocks are wound up every Monday.

In observing the Sun, a light shade is placed upon the telescope-tube, which completely screens the axis from the Sun's rays.

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

The *eleventh* column contains the correction which is to be applied to the mean of the wires actually observed, in order to give the result which would have been obtained if observations had been made on all the wires, or the transit across a line corresponding to the mean of all the wires (supposing the observation perfect).

The determination of the values of the intervals between the wires of the transit-instrument, used throughout the year, was made in 1846. For this purpose, nine complete transits of Polaris, ending with 1846, December 30, were discussed in the following manner:—For each transit the difference between each wire and the mean of all the wires was taken; then the mean of all those determinations relating to the same wire in the different transits was taken, and was supposed to apply to the mean of all the polar distances of the star. Then,

$$\text{Equatoreal distance in seconds of time} = \frac{\text{sin star's N. P. D.} \times \text{sin dist. in time for star}}{15 \sin 1''}:$$

and, by a reverse operation, the distances in time for a star at N. P. D. 1°.30′ and 1°.31′, and for a star at N. P. D. 3°.24′ and 3°.25′, were found. The results of these operations are contained in the following table:—

INTERVALS OF EACH WIRE FROM THE MEAN.

For an equatoreal star.

		s
A	+	38·572
B	+	25·732
C	+	12·826
D	—	0·007
E	—	12·847
F	—	25·684
G	—	38·593

For Polaris, declination = 88°.29′ + *n*″.

		m s				s
A	+	24. 20·06	+	*n*	×	0·271
B	+	16. 13·01	+	*n*	×	0·181
C	+	8. 4·69	+	*n*	×	0·090
D	—	0·26				
E	—	8. 5·49	—	*n*	×	0·090
F	—	16. 11·19	—	*n*	×	0·180
G	—	24. 20·87	—	*n*	×	0·272

For δ Ursæ Minoris, declination = 86°.36′ + *n*″.

		m s				s
A	+	10. 50·63	+	*n*	×	0·053
B	+	7. 13·95	+	*n*	×	0·035
C	+	3. 36·27	+	*n*	×	0·018
D	—	0. 0·11				
E	—	3. 36·62	—	*n*	×	0·018
F	—	7. 13·15	—	*n*	×	0·035
G	—	10. 50·99	—	*n*	×	0·053

On December 27, at noon, the first wire broke and was replaced by a new one, but the same intervals as before were used to the end of the year.

The signs in the preceding table must be changed when the illuminated end is East and the star below the pole, or when the illuminated end is West and the star above the pole.

The correction to the imperfect transit of a star is found, by adding together the equatoreal numbers from the table above for wires observed, dividing by the number of the wires, and multiplying by the secant of the star's declination.

For a planet, the number thus obtained is multiplied by

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

the computation being facilitated by the following small table, of which the argument is the hourly increase of Right Ascension of the planet, taken from the Nautical Almanac.

I = Var. in R.A. in 1^h.	$\frac{3600+I}{3600}$		I = Var. in R.A. in 1^h.	$\frac{3600+I}{3600}$	
	Nat. Number.	Log.		Nat. Number.	Log.
s			s		
+ 1	1 ·00028	0 ·00012	— 1	0 ·99972	9 ·99988
2	·00056	·00024	2	·99944	·99976
3	·00083	·00036	3	·99917	·99964
4	·00111	·00048	4	·99889	·99952
5	·00139	·00060	5	·99861	·99940
6	·00167	·00072	6	·99833	·99927
7	·00194	·00084	7	·99806	·99916
8	·00222	·00096	8	·99778	·99903
9	·00250	·00108	9	·99750	·99891
10	·00278	·00120	10	·99722	·99879
11	·00306	·00132	11	·99694	·99867
12	·00333	·00144	12	·99667	·99855
13	·00361	·00156	13	·99638	·99842
14	·00389	·00169	14	·99611	·99831
15	·00417	·00181	15	·99583	·99819
16	·00444	·00192	16	·99556	·99807
17	·00472	·00204	17	·99528	·99795
18	·00500	·00216	18	·99500	·99782
19	·00528	·00229	19	·99472	·99770
20	·00555	·00240	20	·99445	·99758
21	·00583	·00252	21	·99417	·99746
22	·00611	·00265	22	·99389	·99734
23	·00639	·00277	23	·99361	·99722
24	·00667	·00289	24	·99333	·99709
25	·00694	·00300	25	·99306	·99698
26	·00722	·00312	26	·99278	·99685
27	·00750	·00324	27	·99250	·99673
28	·00778	·00337	28	·99222	·99661
29	·00806	·00349	29	·99194	·99649
+ 30	1 ·00833	0 ·00361	— 30	0 ·99167	9 ·99637

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

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

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

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

I = Var. in R.A. for 1^h of Longitude.	$\frac{3600 + \mathrm{I}}{3600}$		I = Var. in R. A. for 1^h of Longitude.	$\frac{3600 + \mathrm{I}}{3600}$	
	Nat. Number.	Log.		Nat. Number.	Log.
s			s		
100	1·02778	0·01190	134	1·03722	0·01587
101	·02806	·01202	135	·03750	·01599
102	·02834	·01213	136	·03778	·01611
103	·02861	·01225	137	·03806	·01622
104	·02889	·01237	138	·03833	·01634
105	·02917	·01249	139	·03861	·01645
106	·02945	·01260	140	·03889	·01657
107	·02972	·01272	141	·03917	·01669
108	·03000	·01284	142	·03945	·01680
109	·03028	·01296	143	·03972	·01692
110	·03055	·01307	144	·04000	·01703
111	·03084	·01319	145	·04028	·01715
112	·03111	·01330	146	·04056	·01727
113	·03139	·01342	147	·04083	·01738
114	·03167	·01354	148	·04111	·01750
115	·03195	·01366	149	·04139	·01761
116	·03222	·01377	150	·04166	·01773
117	·03250	·01389	151	·04195	·01784
118	·03278	·01401	152	·04222	·01796
119	·03306	·01413	153	·04250	·01808
120	·03333	·01424	154	·04278	·01819
121	·03361	·01436	155	·04306	·01831
122	·03389	·01447	156	·04333	·01842
123	·03417	·01459	157	·04361	·01854
124	·03444	.01471	158	·04389	·01866
125	·03472	·01482	159	·04417	·01877
126	·03500	·01494	160	·04444	·01888
127	·03528	·01506	161	·04472	·01900
128	·03556	·01518	162	·04500	·01912
129	·03583	·01529	163	·04528	·01923
130	·03611	·01541	164	·04556	·01935
131	·03639	·01552	165	·04583	·01946
132	·03667	·01564	166	·04611	·01958
133	·03694	·01575	167	·04639	·01969
134	1·03722	0·01587	168	1·04667	0·01981

I = Var. in R.A. for 1h of Longitude.	$\frac{3600 + I}{3600}$		I = Var. in R.A. for 1h of Longitude	$\frac{3600 + I}{3600}$	
	Nat. Number.	Log.		Nat. Number.	Log.
168^{s}	1·04667	0·01981	179^{s}	1·04972	0·02107
169	·04694	·01992	180	·05000	·02119
170	·04722	·02004	181	·05028	·02130
171	·04750	·02015	182	·05056	·02142
172	·04778	·02027	183	·05083	·02153
173	·04806	·02039	184	·05111	·02165
174	·04833	·02050	185	·05139	·02176
175	·04861	·02061	186	·05167	·02188
176	·04889	·02073	187	·05194	·02199
177	·04916	·02084	188	·05222	·02211
178	·04944	·02096	189	·05250	·02222
179	1·04972	0·02107	190	1·05278	0·02234

The *twelfth* column contains the mean of the seven wires; or the mean of the wires observed, corrected by the quantity in the eleventh column. It is therefore the time of transit over an imaginary line near to the wire D.

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

The *second* column on the *right-hand* page contains the value, in seconds of arc, of the error of collimation, supposed positive when it implies an additive correction to the transits of stars above the pole. For the measurement of the error of collimation, the following method has been used:—

A collimator of 63 inches focal length and 3·9 inches aperture, mounted like a transit-instrument in the north opening of the transit-room, is used as a fixed mark for observing with the transit in reversed positions. The wires in the field of the collimator are arranged in the form of an acute cross, or X, which admits of being observed with great accuracy, by means of the micrometer-wire of the transit eye-piece. A metallic reflector is attached to the eye-piece of the collimator, for the purpose of throwing the light of the sky upon its wires.

In November, 1846, a new determination of the value of the micrometer-screw was made by means of six transits of Polaris over the two wires moved by the micrometer. The mean of the intervals of the times of transit was found to be 3^{m}. $1^{\mathrm{s}}\cdot 17$; and, the polar distance of Polaris being $1^{\circ}.30'.9''\cdot 3$, this corresponds to an interval of space $= 71''\cdot 188$. But, by bringing each micrometer-wire several times into contact with the fixed central wire, this interval was found to correspond also to $4^{\mathrm{r}}\cdot 368$ of the micrometer. Hence, one revolution $= 16''\cdot 297$.

The following are the details of the observations for the error of collimation in 1847:—

1847, Feb. 4, 23^{h}. Observer, Mr. Henry. The morning was favourable, calm and cloudy, with a steady temperature of 35° both within and without the room.

	r
Illuminated end West	
Micrometer reading on coincidence with collimator (6 measures)	8·548
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	10·546
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	8·486
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	10·574
Hence reading for true line of collimation by 1st and 2nd Sets.	9·547
,, ,, ,, by 3rd and 4th Sets.	9·530
Reading for true line of collimation	9·539
Micrometer reading on coincidence with *D*.	9·602
Hence apparent error of collimation for *D*	0·063

The illuminated end of the axis was left West, which was also the position of the micrometer-head; and, as the readings of the micrometer increase as the wire moves apparently from the head, *D* was therefore East of the line of collimation, and stars pass it too late, or the error of collimation of *D* is $-0^{r}\cdot063$, which is equivalent to $-1''\cdot024$. Also, with the illuminated end West, Polaris passes the mean of wires later than it passes *D* by $0^{s}\cdot26$, which, in arc, is equivalent to $-0''\cdot10$; and the correction for diurnal aberration is $-0''\cdot19$. Hence, the corrected error of collimation is $-1''\cdot31$.

1847, April 11, 22^{h}. Observer, Mr. Henry. The morning was favourable, after a calm, rainy night, with a uniform temperature within and without the room, of about 48°.

	r
Illuminated end West.	
Micrometer reading on coincidence with collimator (5 measures)	8·716
Illuminated end East.	
Micrometer reading on coincidence with collimator (5 measures)	10·310
Illuminated end West.	
Micrometer reading on coincidence with collimator (5 measures)	8·741
Illuminated end East.	
Micrometer reading on coincidence with collimator (5 measures)	10·348
Hence reading for true line of collimation by 1st and 2nd Sets	9·513
,, ,, ,, by 3rd and 4th Sets	9·545
Reading for true line of collimation	9·529
Micrometer reading on coincidence with *D*	9·596
Hence apparent error of collimation for *D*	0·067

Hence the error of collimation is $-0^{r}\cdot067$ or $-1''\cdot089$. Correcting this as before by $-0''\cdot29$ for diurnal aberration and reduction to mean of wires, the error of collimation is finally $-1''\cdot38$.

1847, July 9, 22^{h}. Observer Mr. Henry. The morning was cloudy, wind South-West, the temperature within and without the room being about 68°.

	r
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	**10 ·615**
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	**8 ·347**
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	**10 ·642**
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	**8 ·318**
Hence reading of true line of collimation by 1st and 2nd Sets	**9 ·481**
,, ,, ,, by 3rd and 4th Sets	**9 ·480**
Reading for true line of collimation	**9 ·481**
Micrometer reading on coincidence with *D*	**9 ·613**
Hence apparent error of collimation for *D*	**0 ·132**

Hence, the error of collimation is $-0^{r}\cdot132$ or $-2''\cdot146$; correcting this by $-0''\cdot29$ for diurnal aberration and reduction to mean of wires, the error of collimation is finally $-2''\cdot44$.

1847, October 4, 22^{h}. Observer, Mr. Henry. The morning cloudy, with little wind and favourable. The temperature within and without the room about 50°.

	r
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	**10 ·825**
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	**8 ·118**
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	**10 ·949**
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	**8 ·053**
Hence reading for true line of collimation by 1st and 2nd Sets	**9 ·472**
,, ,, ,, by 3rd and 4th Sets	**9 ·501**
Reading for true line of collimation	**9 ·486**
Micrometer reading on coincidence with *D*	**9 ·611**
Hence apparent error of collimation for *D*	**0 ·125**

Hence, the error of collimation is $-0^{r}\cdot125$ or $-2''\cdot037$. Correcting this, as before, by $-0''\cdot29$ for diurnal aberration and reduction to mean of wires, the error of collimation is finally $-2''\cdot33$.

1847, December 29, 0^{h}. Observer, Mr. Main. The eye-piece having been taken out for insertion of the first wire, the transit-instrument was collimated. The day favourable, the sky being gloomy, and the temperature low and equable.

	r
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	10·550
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	8·509
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	10·562
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	8·495
Hence reading of true line of collimation by 1st and 2nd Sets	9·530
,, ,, ,, by 3rd and 4th Sets	9·529
Reading for true line of collimation	9·530
Micrometer reading on coincidence with *D*	9·705
Hence apparent error of collimation for *D*	0·175

Hence the error of collimation is $-0^{r}\cdot175$ or $-2''\cdot85$. Correcting this as before by $-0''\cdot29$, for diurnal aberration and reduction to mean of wires, the error of collimation is finally $-3''\cdot14$. After the above observations, the position of the wire-frame was altered, so that the result is used only for the observations of December 28.

1847, December 29, 1^{h}. Observer, Mr. Main. Immediately after the above observations, Mr. Main altered the position of the wire-frame, so as to reduce the amount of the error of collimation, and the following observation was afterwards made :

	r
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	8·640
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	10·204
Hence reading for the true line of collimation by the two Sets	9·422
Micrometer reading on coincidence with *D*	9·489

1847, December 31, 22^{h}. Observer, Mr. Henry. The morning cloudy and calm, and the temperature within and without the room about 34°.

	r
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	8·778
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	9·986
Illuminated end West.	
Micrometer reading on coincidence with collimator (6 measures)	8·734
Illuminated end East.	
Micrometer reading on coincidence with collimator (6 measures)	9·961
Hence reading for true line of collimation by 1st and 2nd Sets.	9·382
,, ,, ,, by 3rd and 4th Sets.	9·349
,, ,, ,, by the two Sets of Dec. 29.	9·422

	r
Reading for true line of collimation	9·384
Micrometer reading on coincidence with *D*	9·488
Hence apparent error of collimation for *D*	0·104

Hence, error of collimation $= -0^{r}\cdot104$ or $-1''\cdot696$. Correcting this as before by $-0''\cdot29$ for diurnal aberration and reduction to mean of wires, the error of collimation is finally $-1''\cdot99$.

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

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

The *third* column on the right hand page contains the level error, considered positive when the western pivot is too high. This is ascertained by the application of a large spirit-level, which is placed upon the pivots. In the year 1842, the level was twice fastened by strong copper wire to the Mural Circle, for the purpose of ascertaining the value of a division of its scale. The mean of two results obtained on January 7, by measuring upwards of 60 divisions of the scale, gave, for the value of one division, $1''\cdot329$. The mean of three results, obtained on November 23, from upwards of 80 divisions of the scale, gave, for the value of 1 division, $1''\cdot170$. The value used is $1''\cdot2$.

On January 12 of the same year, the level was applied 6 times in reversed positions of the pivots of the transit-instrument, to determine the value of the inequality of the pivots. The mean of the three results when the illuminated end of the axis was East, shewed that the western pivot was too high by $+\,1^{d}\cdot44$; and the mean of the other three results, when the illuminated end of the axis was West, shewed that the western pivot was too high by $+\,1^{d}\cdot38$. The correction for this inequality has been considered too insignificant and uncertain to be applied.

The error of level is determined by applying the spirit-level 12 times (6 times in one position, and 6 times in the reversed position). The level is usually applied every Saturday; the time is, however, always mentioned in the Notes.

The numerical correction of the transit is,

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

On the morning of January 6 the level was applied to the pivots, and the readings of the ends of the bubble were taken, while the instrument was turned slowly as far as the construction of the level would permit. The following are the readings:—

Position of Object-glass.	Elevation of Object-glass.	Reading of East Scale.	Reading of West Scale.	Position of Object-glass.	Elevation of Object-glass.	Reading of East Scale.	Reading of West Scale.
	°	div.	div.		°	div.	div.
S	0	131·0	114·0	N	0	130·7	113·5
	10	131·1	114·0		10	130·5	113·7
	20	131·0	113·9		20	130·5	113·7
	30	131·0	113·8		30	130·5	113·7
	40	130·9	113·8		40	130·5	113·6
	50	130·9	113·8		50	130·5	113·5
	60	130·9	113·7		60	130·4	113·5
	0	130·8	113·8		0	130·3	113·7
	− 10	130·8	113·7		− 10	130·0	113·5
	− 20	130·7	113·7		− 20	130·1	113·5
	− 30	130·7	113·6		− 30	130·0	113·4
	− 40	130·7	113·5		− 40	130·0	113·4
	− 50	130·6	113·6		− 50	130·1	113·4
	− 60	130·6	113·6		− 60	130·1	113·4

The above observations shew that there is no appreciable irregularity of an anomalous character in the form of the pivots, and no irregularity which affects, by an appreciable quantity, the relative elevation of the pivots. This remark does not exclude the possibility of an oval form, which would cause horizontal disturbance of the pivots; but it renders it extremely improbable.

Shortly after the above observations, the pivots were examined minutely by touch and with a magnifying glass, and, as in former years, they were found to be in excellent condition.

The *fourth* column contains the transits corrected for the error of collimation and the level-error. These are set down only for those stars which are used for deducing the azimuthal error.

The *fifth* column contains the azimuthal error, considered positive when the eastern pivot is too far north. This is generally determined from observations of Polaris, at consecutive passages above and below the pole; or from one observation of Polaris, combined with one observation of another star; or, occasionally, from observations of δ Ursæ Minoris combined with those of other stars. The stars used for this purpose are mentioned in the notes; the method of using them is as follows:—

If two consecutive passages of Polaris have been observed, the first transit (as corrected for the error of collimation and level-error) is altered by the change of the star's R. A. and by the estimated clock-rate for 12^h; and the difference, in seconds of time, between the altered first transit and the second transit (rejecting 12^h) is divided by 3·148 to obtain the azimuthal error in seconds of space.

If three transits have been observed, the difference between the first and second is taken (rejecting 12^h), and the difference between the second and third in like manner: and the mean between these is supposed to be independent of the change of R. A. and the clock's rate, and is then divided by 3·148.

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

In a few instances, δ Ursæ Minoris has been used instead of Polaris. The divisor used with it is 1·396.

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

The error is positive when the transit of Polaris or δ Ursæ Minoris above the pole is too late.

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

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

The numerical values of the above-mentioned three factors, for error of collimation, for error of level, and for azimuthal error, are obtained at sight from the following tables: of which the first is constructed for the stars of the Nautical Almanac, and the second is general, having for its argument the polar distance of the object observed.

Star.	Collimation $\frac{1}{15 \text{ Sin N.P.D.}}$	Level. $\frac{\text{Cos Z.D.}}{15 \text{ Sin N.P.D.}}$	Azimuth. $\frac{\text{Sin Z.D.}}{15 \text{ Sin N.P.D.}}$	Star.	Collimation $\frac{1}{15 \text{ Sin N.P.D.}}$	Level. $\frac{\text{Cos Z.D.}}{15 \text{ Sin N.P.D.}}$	Azimuth. $\frac{\text{Sin Z.D.}}{15 \text{ Sin N.P.D.}}$
α Andromedæ	+0·076	+0·069	+0·030	α Cassiopeiæ S.P.	−0·118	−0·035	+0·113
γ Pegasi	+0·069	+0·055	+0·042	12 Canum Venaticûm	+0·086	+0·084	+0·018
α Cassiopeiæ	+0·118	+0·118	−0·009	Polaris S.P.	−2·528	−1·936	+1·626
β Ceti	+0·070	+0·024	+0·066	Spica	+0·068	+0·032	+0·060
Polaris	+2·528	+2·019	−1·522	η Ursæ Majoris	+0·104	+0·104	+0·002
θ Ceti	+0·067	+0·033	+0·059	η Bootis	+0·070	+0·060	+0·038
η Ursæ Majoris S.P.	−0·104	−0·021	+0·102	Arcturus	+0·071	+0·061	+0·037
α Arietis	+0·072	+0·063	+0·035	ε Bootis	+0·075	+0·069	+0·030
γ Ceti	+0·067	+0·044	+0·050	α Libræ	+0·069	+0·027	+0·064
β Ursæ Minoris S.P.	−0·254	−0·151	+0·205	β Ursæ Minoris	+0·254	+0·234	−0·101
α Ceti	+0·067	+0·045	+0·050	β Libræ	+0·067	+0·033	+0·058
α Persei	+0·102	+0·102	+0·004	α Persei S.P.	−0·102	−0·019	+0·100
η Tauri	+0·073	+0·064	+0·034	α Coronæ	+0·075	+0·069	+0·031
γ Eridani	+0·069	+0·028	+0·062	α Serpentis	+0·067	+0·048	+0·047
ζ Ursæ Minoris S.P.	−0·329	−0·210	+0·253	ζ Ursæ Minoris	+0·329	+0·293	−0·148
η Draconis S.P.	−0·141	−0·056	+0·130	β^1 Scorpii	+0·071	+0·023	+0·067
Aldebaran	+0·070	+0·057	+0·040	δ Ophiuchi	+0·067	+0·038	+0·054
ε Ursæ Minoris S.P.	−0·497	−0·344	+0·359	Antares	+0·074	+0·016	+0·072
Capella	+0·095	+0·095	+0·009	η Draconis	+0·141	+0·139	−0·026
Rigel	+0·067	+0·034	+0·058	ε Ursæ Minoris	+0·497	+0·427	−0·255
β Tauri	+0·076	+0·070	+0·030	Capella S.P.	−0·095	−0·012	+0·095
δ Orionis	+0·067	+0·041	+0·052	α Herculis	+0·069	+0·055	+0·041
α Leporis	+0·070	+0·025	+0·066	β Draconis	+0·109	+0·109	−0·002
β Draconis S.P.	−0·109	−0·026	+0·106	α Ophiuchi	+0·068	+0·053	+0·043
ε Orionis	+0·067	+0·040	+0·053	γ Draconis	+0·107	+0·107	0·000
α Columbæ	+0·080	+0·006	+0·080	μ Sagittarii	+0·071	+0·021	+0·068
α Orionis	+0·067	+0·048	+0·047	Cephei 51 (Hev.) S.P.	−1·394	−1·048	+0·920
γ Draconis S.P.	−0·107	−0·024	+0·104	δ Ursæ Minoris	+1·122	+0·918	−0·646
μ Geminorum	+0·072	+0·063	+0·035	α Lyræ	+0·086	+0·083	+0·019
Cephei 51 (Hev.)	+1·394	+1·131	−0·815	β Lyræ	+0·080	+0·076	+0·025
δ Ursæ Minoris S.P.	−1·122	−0·834	+0·750	ζ Aquilæ	+0·068	+0·054	+0·042
Sirius	+0·070	+0·026	+0·065	δ Aquilæ	+0·067	+0·044	+0·050
ε Canis Majoris	+0·076	+0·013	+0·075	γ Aquilæ	+0·068	+0·051	+0·045
δ Geminorum	+0·072	+0·063	+0·035	α Aquilæ	+0·067	+0·049	+0·046
Castor	+0·079	+0·074	+0·026	β Aquilæ	+0·067	+0·047	+0·048
Procyon	+0·067	+0·047	+0·048	α^2 Capricorni	+0·068	+0·029	+0·062
Pollux	+0·075	+0·070	+0·030	λ Ursæ Minoris	+3·300	+2·622	−2·002
15 Argûs	+0·073	+0·018	+0·070	α Cygni	+0·094	+0·093	+0·011
λ Ursæ Minoris S.P.	−3·300	−2·539	+2·106	ι Ursæ Majoris S.P.	−0·101	−0·018	+0·099
α Cygni S.P.	−0·094	−0·010	+0·093	61 Cygni	+0·085	+0·082	+0·020
ε Hydræ	+0·067	+0·048	+0·047	ζ Cygni	+0·077	+0·071	+0·029
ι Ursæ Majoris	+0·101	+0·101	+0·005	α Cephei	+0·141	+0·139	−0·026
α Cephei S.P.	−0·141	−0·056	+0·130	θ Ursæ Majoris S.P.	−0·109	−0·026	+0·106
α Hydræ	+0·067	+0·034	+0·058	β Aquarii	+0·067	+0·036	+0·057
θ Ursæ Majoris	+0·109	+0·109	−0·002	β Cephei	+0·193	+0·184	−0·061
β Cephei S.P.	−0·193	−0·101	+0·165	ε Pegasi	+0·067	+0·050	+0·045
ε Leonis	+0·073	+0·065	+0·033	α Aquarii	+0·067	+0·040	+0·053
Regulus	+0·068	+0·053	+0·043	ζ Pegasi	+0·068	+0·051	+0·045
α Ursæ Majoris	+0·145	+0 142	−0·028	Fomalhaut	+0·077	+0·011	+0·077
δ Leonis	+0·072	+0·062	+0·036	α Ursæ Majoris S.P.	−0·145	−0·059	+0·132
δ Crateris	+0·069	+0·029	+0·062	α Pegasi	+0·069	+0·055	+0·041
γ Cephei S.P.	−0·290	−0·179	+0·228	ι Piscium	+0·067	+0·046	+0·049
β Leonis	+0·069	+0·056	+0·041	γ Cephei	+0·290	+0·262	−0·124
γ Ursæ Majoris	+0·115	+0·115	−0·006	γ Ursæ Majoris S.P.	−0·115	−0·032	+0·111
β Corvi	+0·072	+0·020	+0·069				

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

N. P. D.	Collimation.	Level.	Azimuth.	N. P. D.	Collimation.	Level.	Azimuth.
	$\frac{1}{15 \text{ Sin N.P.D.}}$	$\frac{\text{Cos Z.D.}}{15 \text{ Sin N.P.D.}}$	$\frac{\text{Sin Z.D.}}{15 \text{ Sin N P.D.}}$		$\frac{1}{15 \text{ Sin N.P.D.}}$	$\frac{\text{Cos Z.D.}}{15 \text{ Sin N.P.D.}}$	$\frac{\text{Sin Z.D.}}{15 \text{ Sin N.P.D.}}$
° ′				° ′			
40. 0	+0·104	+0·104	+0·003	83. 0	+0·067	+0·048	+0·047
41. 0	+0·102	+0·101	+0·004	84. 0	+0·067	+0·047	+0·048
42. 0	+0·100	+0·099	+0·006	85. 0	+0·067	+0·046	+0·048
43. 0	+0·098	+0·097	+0·007	86. 0	+0·067	+0·045	+0·049
44. 0	+0·096	+0·096	+0·009	87. 0	+0·067	+0·044	+0·050
45. 0	+0·094	+0·094	+0·011	88. 0	+0·067	+0·043	+0·051
46. 0	+0·093	+0·092	+0·012	89. 0	+0·067	+0·042	+0·052
47. 0	+0·091	+0·090	+0·013	90. 0	+0·067	+0·041	+0·052
48. 0	+0·090	+0·088	+0·015	91. 0	+0·067	+0·040	+0·053
49. 0	+0·088	+0·087	+0·016	92. 0	+0·067	+0·040	+0·054
50. 0	+0·087	+0·085	+0·017	93. 0	+0·067	+0·039	+0·054
51. 0	+0·086	+0·084	+0·018	94. 0	+0·067	+0·038	+0·055
52. 0	+0·085	+0·082	+0·020	95. 0	+0·067	+0·037	+0·056
53. 0	+0·083	+0·081	+0·021	96. 0	+0·067	+0·036	+0·057
54. 0	+0·082	+0·080	+0·022	97. 0	+0·067	+0·035	+0·057
55. 0	+0·081	+0·078	+0·023	98. 0	+0·067	+0·034	+0·058
56. 0	+0·080	+0·077	+0·024	99. 0	+0·067	+0·033	+0·059
57. 0	+0·080	+0·075	+0·025	100. 0	+0·068	+0·032	+0·060
58. 0	+0·079	+0·074	+0·026	101. 0	+0·068	+0·031	+0·060
59. 0	+0·078	+0·073	+0·027	102. 0	+0·068	+0·030	+0·061
60. 0	+0·077	+0·072	+0·028	103. 0	+0·068	+0·029	+0·062
61. 0	+0·076	+0·070	+0·029	104. 0	+0·069	+0·028	+0·063
62. 0	+0·976	+0·069	+0·030	105. 0	+0·069	+0·027	+0·063
63. 0	+0·075	+0·068	+0·031	106. 0	+0·069	+0·027	+0·064
64. 0	+0·074	+0·067	+0·032	107. 0	+0·070	+0·026	+0·065
65. 0	+0·073	+0·066	+0·033	108. 0	+0·070	+0·025	+0·066
66. 0	+0·073	+0·065	+0·034	109. 0	+0·071	+0·024	+0·066
67. 0	+0·072	+0·064	+0·035	110. 0	+0·071	+0·023	+0·067
68. 0	+0·072	+0·063	+0·035	111. 0	+0·072	+0·022	+0·068
69. 0	+0·071	+0·061	+0·036	112. 0	+0·072	+0·021	+0·069
70. 0	+0·071	+0·060	+0·037	113. 0	+0·073	+0·020	+0·070
71. 0	+0·071	+0·059	+0·038	114. 0	+0·073	+0·019	+0·071
72. 0	+0·070	+0·058	+0·039	115. 0	+0·074	+0·017	+0·072
73. 0	+0·070	+0·057	+0·039	116. 0	+0·075	+0·016	+0·072
74. 0	+0·069	+0·056	+0·040	117. 0	+0·075	+0·015	+0·073
75. 0	+0·069	+0·055	+0·041	118. 0	+0·076	+0·014	+0·074
76. 0	+0·069	+0·054	+0·042	119. 0	+0·076	+0·013	+0·075
77. 0	+0·068	+0·053	+0·043	120. 0	+0·077	+0·012	+0·076
78. 0	+0·068	+0·053	+0·043	121. 0	+0·078	+0·011	+0·077
79. 0	+0·068	+0·052	+0·044	122. 0	+0·079	+0·009	+0·078
80. 0	+0·068	+0·051	+0·045	123. 0	+0·080	+0·008	+0·079
81. 0	+0·067	+0·050	+0·045	124. 0	+0·080	+0·007	+0·080
82. 0	+0·067	+0·049	+0·046	125. 0	+0·081	+0·005	+0·081
83. 0	+0·067	+0·048	+0·047	126. 0	+0·082	+0·004	+0·082

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

The *seventh* column contains the seconds of the tabular R.A. of the stars which are used for determining the clock-error. The stars are taken from the list of the Nautical Almanac, those only being used whose N.P.D. exceeds 50°. The tabular R.A. of Polaris is set down, to enable the reader to judge of the general state of adjustment of the instrument: that of δ Ursæ Minoris is also set down.

The tabular Right Ascensions are computed by applying to the Right Ascensions of the stars given in the Nautical Almanac, corrections deduced from the Greenwich Catalogues of stars for four preceding years, from 1842 to 1845, inclusive. The Right Ascensions of these stars are all brought up to the year 1847 by applying the annual variations of the Nautical Almanac for stars which are marked with asterisks, without further alteration; and, for other stars, by adding to the precessions of the Nautical Almanac the proper motions given in the Catalogue of the British Association. A mean is then taken for each star according to the number of observations in each year, and the resulting Right Ascensions are compared with those given in the Nautical Almanac. Thus, the periodical corrections of the Nautical Almanac are employed, while the mean places adopted are those derived from the Greenwich Observations, in combination with the proper motions of the British Association Catalogue. For Polaris and δ Ursæ Minoris, the additional correction depending on the place of the Moon is also taken into account. The following table gives the mean R.A. for 1847, Jan. 1, which, in fact, are used in these computations, and the constant alterations to the Right Ascensions of the Nautical Almanac:—

Star's Name.	Assumed Mean R.A. Jan. 1, 1847.	Correction to N.A.	Star's Name.	Assumed Mean R.A. Jan. 1, 1847.	Correction to N.A.
	h m s	s		h m s	s
α Andromedæ .	0. 0. 29 ·26	— 0 ·07	Castor	7. 24. 49 ·71	— 0 ·21
γ Pegasi . . .	0. 5. 21 ·69	— 0 ·08	Procyon . . .	7. 31. 17 ·35	— 0 ·03
β Ceti	0. 35. 54 ·31	— 0 ·03	Pollux	7. 35. 56 ·71	— 0 ·13
Polaris . . .	1. 4. 8 ·58	— 0 ·78	15 Argûs . . .	8. 1. 1 ·70	— 0 ·09
θ Ceti	1. 16. 22 ·53	— 0 ·16	ε Hydræ . . .	8. 38. 40 ·16	— 0 ·19
α Arietis . . .	1. 58. 33 ·53	— 0 ·01	α Hydræ . . .	9. 20. 4 ·06	— 0 ·06
γ Ceti	2. 35. 22 ·55	— 0 ·19	ε Leonis . . .	9. 37. 9 ·38	— 0 ·14
α Ceti	2. 54. 17 ·13	— 0 ·07	Regulus . . .	10. 0. 13 ·04	— 0 ·24
η Tauri	3. 38. 23 ·84	— 0 ·09	δ Leonis . . .	11. 5. 57 ·79	+ 0 ·01
γ Eridani . . .	3. 50. 53 ·53	— 0 ·02	δ Crateris . . .	11. 11. 41 ·63	— 0 ·09
Aldebaran . .	4. 27. 8 ·76	— 0 ·07	β Leonis . . .	11. 41. 15 ·02	— 0 ·11
Rigel	5. 7. 11 ·16	— 0 ·10	β Corvi	12. 26. 21 ·54	— 0 ·06
β Tauri	5. 16. 37 ·38	— 0 ·07	Spica	13. 17. 8 ·28	— 0 ·11
δ Orionis . . .	5. 24. 11 ·46	— 0 ·03	η Bootis . . .	13. 47. 23 ·93	— 0 ·07
α Leporis . . .	5. 25. 58 ·97	— 0 ·08	Arcturus . . .	14. 8. 40 ·99	— 0 ·11
ε Orionis . . .	5. 28. 27 ·05	— 0 ·05	ε Bootis . . .	14. 38. 18 ·23	— 0 ·10
α Columbæ . .	5. 34. 6 ·52	— 0 ·18	α Libræ . . .	14. 42. 25 ·34	— 0 ·10
α Orionis . . .	5. 46. 53 ·35	— 0 ·08	β Libræ . . .	15. 8. 46 ·79	— 0 ·03
μ Geminorum .	6. 13. 42 ·16	— 0 ·09	α Coronæ . . .	15. 28. 12 ·61	0 ·00
Sirius	6. 38. 24 ·46	— 0 ·07	α Serpentis . .	15. 36. 44 ·03	+ 0 ·01
ε Canis Majoris .	6. 52. 36 ·77	— 0 ·03	β^1 Scorpii . . .	15. 56. 32 ·83	— 0 ·04
δ Geminorum . .	7. 10. 58 ·83	— 0 ·06	δ Ophiuchi . .	16. 6. 19 ·88	— 0 ·09

*

Star's Name.	Assumed Mean R.A. Jan. 1, 1847.	Correction to N.A.	Star's Name.	Assumed Mean R.A. Jan. 1, 1847.	Correction to N.A.
	h. m. s.	s.		h. m. s.	s.
Antares . . .	16. 20. 2·05	− 0·07	β Aquilæ . . .	19. 47. 47·76	− 0·05
α Herculis. . .	17. 7. 40·27	− 0·08	α^2 Capricorni . .	20. 9. 33·62	− 0·03
α Ophiuchi . .	17. 27. 49·97	− 0·02	ζ Cygni . . .	21. 6. 25·53	− 0·09
μ Sagittarii . .	18. 4. 36·79	− 0·07	β Aquarii . . .	21. 23. 29·97	− 0·07
δ Ursæ Minoris .	18. 21. 41·52	+ 0·08	ε Pegasi . . .	21. 36. 40·19	− 0·10
α Lyræ	18. 31. 45·41	+ 0·01	α Aquarii . . .	21. 57. 55·34	− 0·07
β Lyræ	18. 44. 25·80	− 0·11	ζ Pegasi . . .	22. 33. 49·86	− 0·10
ζ Aquilæ . . .	18. 58. 22·58	− 0·14	Fomalhaut . .	22. 49. 11·03	+ 0·19
δ Aquilæ . . .	19. 17. 46·93	+ 0·03	α Pegasi . . .	22. 57. 8·51	− 0·05
γ Aquilæ . . .	19. 38. 59·07	− 0·06	ι Piscium . . .	23. 32. 4·89	+ 0·10
α Aquilæ . . .	19. 43. 18·96	− 0·09			

The *eighth* column contains the error of the clock, found by subtracting the numbers in the sixth column from those in the seventh. The correction is therefore positive when the clock is slow.

The *ninth* and *tenth* columns contain the adopted losing rate, and the adopted error of the clock at 0^h sidereal, as found by the following process. The observations are divided into groups, marked by bars across these columns (in all instances the same as the limits of each individual's observations). The mean of the clock-errors given by all the clock-stars in the same group is then taken, and this is held to be the clock-error corresponding to the mean of all the times of transit of the same stars. The next step is to allow for personal equation. It will be seen by one of the following tables in this Introduction, that the clock-error given by Mr. Rogerson's observations is greater than that given by Mr. Henry's observations, by $0^s\cdot38$, as deduced from the observations suitable for the determination of the personal equation in the year 1847: in the year 1846 the difference had been found to be $0^s\cdot31$. In the first part of the year 1847, therefore, the quantity $-0^s\cdot30$ is used as a correction to Mr. Rogerson's clock-errors, and in the latter part of the year $-0^s\cdot35$; and it is then considered that we have a set of clock-errors justly comparable amongst themselves. Each mean clock-error is now compared with that which precedes and with that which follows; a preceding rate and a following rate are thus found, and by this the computer is guided in adopting the clock-rate to be used through the group of observations: this adopted clock-rate is set down in the ninth column. For facility of calculation, the proportional part of this rate, corresponding to the mean sidereal time or mean of all the times of transit for the group, is applied with changed sign to the mean clock-error; and thus the clock-error at 0^h sidereal is found. If it happen that any observations included in the same group are made in the sidereal day preceding or following that for which the mean error has been found, the whole adopted daily rate is subtracted from or added to the error found for 0^h; and thus the error for 0^h of the preceding or the following sidereal day is obtained. These errors at 0^h are set down in the tenth 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. Henry or Mr. Rogerson), no further computation is necessary for obtaining the right ascensions of these objects than the application to the time of transit of the clock-error at 0^h, and a proportional part of the clock-rate corresponding to the right ascension of the object: but if the clock-stars are observed by Mr. Rogerson, and the other object by Mr. Henry, a farther correction of – 0^s·37 must be applied, this quantity having been finally determined on for the correction to the Right Ascensions; if the clock-stars are observed by Mr. Henry, and the object by Mr. Rogerson, + 0^s·37 must be applied. These quantities are *not* applied in the column of *Apparent Right Ascensions from the Observations* in this Section.

In the preceding years, observations were exhibited which give the relative personal equations of the different observers with the transit, as far as means existed for determining them. In the year 1847, the following sets of observations have been found available for determining personal equations. They have been treated in the same manner as in former years, by comparing the clock-error at the same sidereal noon given by two different groups of stars observed by different persons.

OBSERVATIONS for the PERSONAL EQUATION between the ASTRONOMER ROYAL (G.B.A.) and MR. HENRY.

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by GBA.	Clock Slow at 0^h by H.	H – G B A.
	h		s	s	s
October 24 and 25	1	GBA H	3. 91	3 ·96	+ 0 ·05

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0^h by M.	Clock Slow at 0^h by H.	H – M
	h		s	s	s
July 8	10	H M	2 ·61	2 ·52	– 0 ·09
July 26 and 27	12	M H	10 ·70	10 ·77	+ 0 ·07
July 31	6	M H	13 ·74	13 ·67	– 0 ·07
August 6 and 7	11	M H	17 ·33	17 ·33	0 ·00

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by M.	Clock Slow at 0h by E.	E–M.
	h		s	s	s
July 29	3	M E	12·64	12·89	+ 0·25

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by M.	Clock Slow at 0h by R.	R–M.
	h		s	s	s
September 3 and 4	9	R M	35·90	36·23	+ 0·33
4	9	M R	36·45	36·75	+ 0·30

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by M.	Clock Slow at 0h by D.	D–M.
	h		s	s	s
August 1	4	D M	14·51	14·24	– 0·27

OBSERVATIONS for the PERSONAL EQUATION between Mr. MAIN and Mr. HUGH BREEN, Jun.

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by M.	Clock Slow at 0h by H B.	H B–M.
	h		s	s	s
August 21	2	M HB	28·06	27·85	– 0·21
27	4	HB M	31·84	31·74	– 0·10
September 3 and 4	2	M HB	36·45	36·38	– 0·07

OBSERVATIONS for the PERSONAL EQUATION between Mr. MAIN and Mr. G. HUMPHREYS.

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by M.	Clock Slow at 0h by G H.	G H–M.
	h		s	s	s
August 6	3	M GH	17·33	17·14	– 0·19
September 1	2	M GH	34·95	34·92	– 0·03

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by E.	E–H.
	h		s	s	s
February 23 and 24	6	E H	21 ·29	21 ·35	+ 0 ·06
October 20	3	H E	1 ·92	2 ·28	+ 0 ·36
20 and 21	3	E H	1 ·93	2 ·28	+ 0 ·35
24 and 25	4	H E	4 ·17	4 ·37	+ 0 ·20
November 16	6	E H	15 ·65	15 ·75	+ 0 ·10
18 and 19	7	E H	16 ·40	16 ·54	+ 0 ·14

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by R.	R–H.
	h		s	s	s
January 13 and 14	12	R H	38 ·80	39 ·21	+ 0 ·41
25 and 26	13	R H	51 ·87	52 ·10	+ 0 ·23
26 and 27	12	H R	52 ·67	52 ·95	+ 0 ·28
29	6	R H	54 ·90	55 ·29	+ 0 ·39
February 6	7	H R	3 ·28	3 ·68	+ 0 ·40
9 and 10	12	R H	6 ·18	6 ·52	+ 0 ·34
10 and 11	12	H R	8 ·00	8 ·34	+ 0 ·34
11	11	R H	7 ·98	8 ·34	+ 0 ·36
23 and 24	11	R H	21 ·29	21 ·62	+ 0 ·33
25 and 26	12	R H	23 ·86	24 ·10	+ 0 ·24
March 9 and 10	10	H R	38 ·90	39 ·22	+ 0 ·32
10 and 11	5	R H	39 ·92	40 ·32	+ 0 ·40
April 8 and 9	7	H R	6 ·51	6 ·67	+ 0 ·16
May 19 and 20	12	R H	38 ·15	38 ·49	+ 0 ·34
21 and 22	12	R H	39 ·34	39 ·74	+ 0 ·40
25 and 26	11	R H	41 ·11	41 ·43	+ 0 ·32
27 and 28	10	R H	42 ·43	42 ·67	+ 0 ·24
June 8 and 9	10	H R	48 ·02	48 ·40	+ 0 ·38
22 and 23	9	H R	55 ·32	55 ·72	+ 0 ·40
28 and 29	12	H R	58 ·41	58 ·82	+ 0 ·41
October 7 and 8	11	H R	55 ·55	55 ·88	+ 0 ·33
18	10	H R	1 ·08	1 ·57	+ 0 ·49
19 and 20	12	R H	1 ·60	2 ·02	+ 0 ·42
20 and 21	2	H R	2 ·35	2 ·90	+ 0 ·55
21	2	H R	2 ·57	2 ·84	+ 0 ·27
21 and 22	6	R H	2 ·44	2 ·84	+ 0 ·40
Oct. 31 and Nov. 1	6	H R	8 ·61	9 ·05	+ 0 ·44

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. ROGERSON—*continued.*

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by R.	R–H.
	h		s	s	s
November 15 and 16	6	H R	15·10	15·66	+ 0·56
16	12	R H	15·65	16·11	+ 0·46
23 and 24	2	H R	17·42	17·80	+ 0·38
Nov. 30 and Dec. 1	7	R H	20·05	20·42	+ 0·37
December 13 and 14	11	R H	24·29	24·66	+ 0·37
14	9	H R	24·90	25·25	+ 0·35
16	1	R H	26·05	26·54	+ 0·49

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by H B.	H B–H.
	h		s	s	s
March 18 and 19	11	HB H	48·04	48·09	+ 0·05
July 23	4	H HB	8·80	8·59	— 0·21
December 10	3	H HB	22·36	22·39	+ 0·03

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by G.	G–H.
	h		s	s	s
August 3 and 4	5	H G	15·48	15·54	+ 0·06
October 22	2	H G	2·78	2·86	+ 0·08

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by L.	L–H.
	h		s	s	s
November 18 and 19	9	L H	16·40	16·47	+ 0·07

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

Day, 1847.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by T D.	T D–H.
		h		s	s	s
October	7	2	H TD	55·55	55·49	– 0·06
November	1	4	H TD	8·61	7·91	– 0·70

OBSERVATIONS for the PERSONAL EQUATION between MR. HENRY and MR. G. HUMPHREYS.

Day, 1847.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by G H.	G H–H.
		h		s	s	s
August	6 and 7	8	GH H	17·33	17·14	– 0·19
October	5	2	H GH	54·65	54·54	– 0·11
	21	1	GH H	2·57	2·30	– 0·27
November	5	6	H GH	10·35	10·35	0·00

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

Day, 1847.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H.	Clock Slow at 0h by W E.	W E–H.
		h		s	s	s
September	27	3	WE H	50·06	50·66	+ 0·60

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

Day, 1847.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by E.	Clock Slow at 0h by R.	R–E.
		h		s	s	s
February	23	5	R E	20·31	20·55	+ 0·24
November	15 and 16	5	R E	15·75	16·11	+ 0·36
	17 and 18	7	R E	16·29	16·57	+ 0·28

OBSERVATIONS for the PERSONAL EQUATION between Mr. ELLIS and Mr. HUGH BREEN, Jun.

Day, 1847.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by E.	Clock Slow at 0h by H B.	H B – E.
		h		s	s	s
September	14	3	HB E	42·98	42·80	— 0·18

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

Day, 1847.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by E.	Clock Slow at 0h by T D.	T D – E.
		h		s	s	s
May	12	1	TD E	34·20	33·84	— 0·36

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

Day, 1847.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by E.	Clock Slow at 0h by L.	L – E
		h		s	s	s
November	18	2	L E	16·29	16·22	— 0·07

OBSERVATIONS for the PERSONAL EQUATION between Mr. ROGERSON and Mr. HUGH BREEN, Jun.

Day, 1847.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by R.	Clock Slow at 0h by H B.	H B – R.
		h		s	s	s
March	17 and 18	8	R HB	47·92	47·54	— 0·38
	22	9	R HB	50·15	49·93	— 0·22
August	29	4	HB R	33·56	33·23	— 0·33
September	4	6	HB R	36·75	36·38	— 0·37
November	9 and 10	6	HB R	12·67	12·25	— 0·42

OBSERVATIONS for the PERSONAL EQUATION between Mr. ROGERSON and Mr. GLAISHER.

Day, 1847.		Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by R.	Clock Slow at 0h by G.	G – R.
		h		s	s	s
August	31	2	R G	34·87	34·54	— 0·33

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by R.	Clock Slow at 0h by L.	L—R.
	h		s	s	s
May 4	6	R L	28·47	28·13	— 0·34
June 2	6	L R	45·51	(44·92)	(— 0·59)
September 28 and 29	9	L R	51·16	50·76	— 0·40
November 17 and 18	4	R L	16·57	16·22	— 0·35

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by R.	Clock Slow at 0h by T D.	T D—R.
	h		s	s	s
February 4 and 5	7	TD R	62·39	62·05	— 0·34
March 16 and 17	8	TD R	47·21	46·87	— 0·34
September 2	4	R TD	35·78	35·17	— 0·61
6	2	R TD	38·01	37·11	— 0·90
October 7 and 8	9	TD R	55·88	55·49	— 0·39
November 1 and 2	2	TD R	9·05	7·91	— 1·14

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

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by R.	Clock Slow at 0h by G H.	G H—H.
	h		s	s	s
April 9	4	R GH	6·67	6·04	— 0·63
August 20	3	R GH	27·74	27·35	— 0·39
October 21	1	R GH	2·84	2·30	— 0·54

OBSERVATIONS for the PERSONAL EQUATION between MR. HUGH BREEN, JUN. and Mr. DOWNS.

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0h by H B.	Clock Slow at 0h by T D.	T D—H B.
	h		s	s	s
November 9	7	TD HB	12·25	12·22	— 0·03

OBSERVATIONS for the PERSONAL EQUATION between MR. HUGH BREEN JUN. and MR. HUMPHREYS.

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0ʰ by HB.	Clock Slow at 0ʰ by G H.	G H–H B.
	h		s	s	s
August 10 and 11	7	GH HB	19·66	19·42	– 0·24
November 9	1	GH HB	12·25	12·44	+ 0·19

OBSERVATIONS for the PERSONAL EQUATION between MR. GLAISHER and MR. HUMPHREYS.

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0ʰ by G.	Clock Slow at 0ʰ by G H.	G H–G.
	h		s	s	s
August 14	1	GH G	22·92	22·81	– 0·11

OBSERVATIONS for the PERSONAL EQUATION between MR. DOWNS and MR. HUMPHREYS.

Day, 1847.	Interval of nearest Stars.	Order of Observations.	Clock Slow at 0ʰ by TD.	Clock Slow at 0ʰ by GH.	G H–T D.
	h		s	s	s
September 9	7	GH TD	39·59	39·41	– 0·18
November 9	5	TD GH	12·22	12·44	+ 0·22

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

For G. B. A.

s
G B A – H = – 0·05

For M.

4 (M – H) = + 0·09
M – E = – 0·25
2 (M – R) = – 0·63
M – D = + 0·27
3 (M – H B) = + 0·38
2 (M – G H) = + 0·22

For H.

s
(H – G B A) = + 0·05
4 (H – M) = – 0·09
6 (H – E) = – 1·21
34 (H – R) = –12·57
3 (H – H B) = + 0·13
2 (H – G) = – 0·14
H – L = – 0·07
2 (H – T D) = + 0·76
4 (H – G H) = + 0·57
H – W E = – 0·60

For E.

s
E − M = + 0·25
6 (E − H) = + 1·21
3 (E − R) = − 0·88
E − HB = + 0·18
E − L = + 0·07
E − TD = + 0·36

For R.

2 (R − M) = + 0·63
34 (R − H) = +12·92
3 (R − E) = + 0·88
5 (R − HB) = + 1·72
R − G = + 0·33
3 (R − L) = + 1·09
6 (R − TD) = + 3·72
3 (R − GH) = + 1·62

For D.

D − M = − 0·27

For HB.

3 (HB − M) = − 0·38
3 (HB − H) = − 0·13
HB − E) = − 0·18
5 (HB − R) = − 1·72
HB − TD = + 0·03
HB − GH = + 0·05

For G.

s
2 (G − H) = + 0·14
G − R = − 0·33
G − GH = + 0·11

For L.

L − H = + 0·07
L − E = − 0·07
3 (L − R) = − 1·09

For TD.

2 (TD − H) = − 0·76
TD − E = − 0·36
6 (TD − R) = − 3·72
TD − HB = − 0·03
2 (TD − GH) = − 0·04

For GH.

2 (GH − M) = − 0·22
4 (GH − H) = − 0·57
3 (GH − R) = − 1·62
2 (GH − HB) = − 0·05
GH − G = − 0·11
2 (GH − TD) = + 0·04

For WE.

WE − H = + 0·60

Now, since one of the above quantities, GBA, M, H, &c., must evidently be indeterminate, we will refer all the rest to H as the standard; and, putting H = 0, the letters GBA, M, E, &c., will represent the values of "clock-slow," which would be given by the observations of the Astronomer Royal, Mr. Main, Mr. Ellis, &c., when that given by the observations of Mr. Henry is = 0.

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

s
GBA = − 0·05
13 M − E − 2 R − D − 3 HB − 2 GH = + 0·08
13 E − M − 3 R − HB − L − TD = + 1·19
57 R − 2 M − 3 E − 5 HB − G − 3 L − 6 TD − 3 GH = +22·91

$$\begin{array}{lr}
 & {}^{s} \\
D - M & = -0{\cdot}27 \\
14\,HB - 3\,M - E - 5\,R - TD - GH & = -2{\cdot}33 \\
4\,G - R - GH & = -0{\cdot}08 \\
5\,L - E - 3\,R & = -1{\cdot}09 \\
12\,TD - E - 6\,R - HB - 2\,GH & = -4{\cdot}91 \\
14\,GH - 2\,M - 3\,R - 2\,HB - G - 2\,TD & = -2{\cdot}53 \\
WE & = +0{\cdot}60
\end{array}$$

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

GBA = $-0^{s}{\cdot}05$; M = $+0^{s}{\cdot}03$; E = $+0^{s}{\cdot}16$; R = $+0^{s}{\cdot}38$; D = $-0^{s}{\cdot}24$; HB = $-0^{s}{\cdot}04$; G = $+0^{s}{\cdot}04$; L = $+0^{s}{\cdot}04$; TD = $-0^{s}{\cdot}23$; GH = $-0^{s}{\cdot}13$; WE = $+0^{s}{\cdot}60$.

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

$$\begin{array}{lr|lr}
 & {}^{s} & & {}^{s} \\
H - GBA & = +0{\cdot}05 & H - G & = -0{\cdot}04 \\
H - M & = -0{\cdot}03 & H - L & = -0{\cdot}04 \\
H - E & = -0{\cdot}16 & H - TD & = +0{\cdot}23 \\
H - R & = -0{\cdot}38 & H - GH & = +0{\cdot}13 \\
H - D & = +0{\cdot}24 & H - WE & = -0{\cdot}60 \\
H - HB & = +0{\cdot}04 & &
\end{array}$$

The above values, or quantities very slightly differing from them, have been used whenever they were needed throughout the year 1847.

The *eleventh* column contains the duration of passage of the semidiameter of a planet, &c. when both limbs have not been observed. For the Sun, this quantity is taken from the Nautical Almanac: for the Moon, from the section of Moon-culminating stars in that work: and for the Planets, from the Meridian Ephemeris in the same work. No corrections are made in this section to the semidiameters: these are noticed in a subsequent section.

The *twelfth* column contains the right ascension of the center of the body observed: it is formed by adding the time from the sixth column, the clock error at 0^{h} next preceding from the tenth column, the proportional part of the rate in the ninth column corresponding to the right ascension, and the duration of semidiameter's passage from the eleventh column. No result is set down for a clock-star, unless four clock-stars, excluding Polaris, have been observed; and no result is set down for Polaris, unless Polaris or δ Ursæ Minoris has been observed at opposite passages.

The *fourteenth* column contains the correction with its proper sign, as it is to be applied for reducing the apparent right ascension at the time of observation to the mean right ascension on the 1st of January, 1847. It is computed in the following way.

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

For other stars, the corrections are computed by the formula

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

which is derived from the well known formula

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

or its equivalent

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

by a process which is explained with sufficient detail in No. 11 of the 7th volume of the Notices of the Astronomical Society. It will be sufficient here to state that $E = A + 25$ $F = B + 25$, $G = C + 1{\cdot}2$, $H = D + 25$, $e = a + 1{\cdot}2$, $f = b + 1{\cdot}2$, $g = c + 25$, $h = d + 1{\cdot}2$, $L = 210 - 1{\cdot}2 \times E - 1{\cdot}2 \times F - 25 \times G - 1{\cdot}2 \times H$, $l = 210 - 25 \times e - 25 \times f - 1{\cdot}2 \times g - 25 \times h$. The values of the day-constants log. E, log. F, log. G, log. H, and L, for the years from 1849 to 1860, both inclusive, and the values of the star-constants log. e, log. f, log. g, log. h, and l, are contained in the "Greenwich Twelve-Year Catalogue," also appended to the present volume. The values of log. A, log. B, log. C, log. D, for the formation of the above numbers, have been taken from the Nautical Almanac for all the published volumes, and for the other years they have been, obligingly supplied at my request by Lieut. Stratford, the Superintendant of that work. The values of log. a, log. b, log. c, log. d, have been taken from the Catalogue of the British Association, whenever the star was found in that Catalogue.

The sign of the computed quantity is changed before application.

§ 2. *Apparent Right Ascensions of Polaris and δ Ursæ Minoris, and Mean Right Ascensions of Stars observed in the Year* 1847, page [134] to [148].

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

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

i 2

The resulting mean right ascensions have been increased by 0^{s}·37 when the object whose right ascension is determined was observed by Mr. Rogerson, and the clock-stars by Mr. Henry. The corrections applied for personal equation in the cases of other observers have been already mentioned.

The rules for the nomenclature of the stars are the same as those in the section of the *Transits as observed*, detailed in page xxxiii, with the following additions :

In this section there is added to the nomenclature of anonymous stars in order of preference the hour and number of the star when found in Weisse's Catalogue of the stars in Bessel's Zones, or the number of the star when found in Lalande's or Lacaille's Catalogue recently published by the British Association. For other anonymous stars which have been compared with Comets at the Royal Observatory, the letter and ordinal number are given by which the star is denoted in the Cometary Observations.

§ 3. *Observations with Troughton's Mural Circle*, page (2) to (133).

The observations throughout the year 1847 were made with Troughton's Circle only.

Before describing the method of observing with it, and explaining the printed observations in detail, I shall give those observations from which the approximate position of the instrument with regard to the meridian is inferred.

For this purpose the transits of different stars have been observed with the clock which is near the Circle. This clock is immediately compared with the transit clock, and the sidereal time of transit is, therefore, readily found, and admits of comparison with the right ascension, or the correct time of transit over the astronomical meridian. The following table contains the principal steps, the parts omitted having been carefully verified :—

TRANSITS FOR THE POSITION OF TROUGHTON'S CIRCLE

throughout the Year 1847.

Day, 1847.		Object.	Transit by Mudge.	Transit by Hardy.	Sidereal Time.	Sec. of Tabular R.A.	Error.
			h m s	h m s	h m s	s	s
January	10	δ Libræ	14. 52. 51·80	14. 52. 13·60	14. 52. 48·83	48·44	+ 0·39
	,,	β Libræ	15. 8. 50·30	15. 8. 12·10	15. 8. 47·34	46·83	+ 0·51
	,,	β Draconis . . .	17. 26. 59·20	17. 26. 21·40	17. 26. 56·74	57·01	− 0·27
	,,	γ Draconis. . . .	17. 53. 3·30	17. 52. 25·50	17. 53. 0·86	1·56	− 0·70
	11	α Aquilæ	19. 43. 20·40	19. 42. 42·60	19. 43. 18·04	18·28	− 0·24
	,,	β Ursæ Minoris S.P.	2. 51. 12·50	2. 50. 36·00	2. 51. 11·76	9·23	+ 2·53

TRANSITS FOR THE POSITION OF TROUGHTON'S CIRCLE—*continued.*

Day, 1847.		Object.	Transit by Mudge.	Transit by Hardy,	Sidereal Time.	Sec. of Tabular R.A.	Error.
			h m s	h m s	h m s	s	s
January	13	$*(k_1)$	4. 54. 57·50	4. 54. 30·50	4. 55. 8·73	8·43	+ 0·30
	,,	$*(k_2)$	5. 1. 44·70	5. 1. 17·70	5. 1. 55·94	56·08	— 0·14
	15	$*$	4. 5. 5·60	4. 4. 40·60	4. 5. 21·19	20·74	+ 0·45
	29	γ Eridani	3. 50. 16·40	3. 49. 59·90	3. 50. 55·30	54·61	+ 0·69
	,,	37 Camelopardali	5. 55. 53·80	5. 55. 37·30	5. 56. 32·76	32·32	+ 0·44
	,,	Groombridge 1261.	6. 52. 42·00	6. 52. 25·50	6. 53. 20·99	20·73	+ 0·26
February	13	δ Geminorum	7. 11. 18·00	7. 10. 50·40	7. 11. 0·99	0·94	+ 0·05
	19	μ Geminorum	6. 14. 0·20	6. 13. 27·40	6. 13. 43·93	44·05	— 0·12
	,,	$*(i_{11})$	6. 20. 2·70	6. 19. 29·90	6. 19. 46·44	46·91	— 0·47
	,,	ϵ Canis Majoris	6. 52. 55·10	6. 52. 22·30	6. 52. 38·86	38·55	+ 0·31
	,,	$*(n_5)$	6. 59. 4·20	6. 58. 31·40	6. 58. 47·96	47·77	+ 0·19
	,,	$*(i_{13})$	7. 3. 41·50	7. 3. 8·70	7. 3. 25·26	24·57	+ 0·69
	,,	$*(h_1)$	7. 44. 23·30	7. 43. 50·50	7. 44. 7·09	6·83	+ 0·26
	24	δ Orionis	5. 24. 30·00	5. 23. 51·10	5. 24. 12·64	12·76	— 0·12
	,,	α Columbæ	5. 34. 24·50	5. 33. 45·60	5. 34. 7·15	7·81	— 0·66
	,,	μ Geminorum	6. 14. 1·00	6. 13. 22·10	6. 13. 43·67	43·98	— 0·31
April	8	ι Ursæ Majoris	8. 48. 8·00	8. 48. 38·60	8. 48. 44·79	44·03	+ 0·76
	,,	α Hydræ	9. 19. 29·50	9. 20. 0·10	9. 20. 6·32	5·89	+ 0·43
	,,	δ Leonis	11. 5. 23·80	11. 5. 54·40	11. 5. 60·67	59·85	+ 0·82
	9	δ Leonis	11. 5. 24·40	11. 5. 52·90	11. 5. 59·91	59·85	+ 0·06
	22	α^2 Cancri	8. 50. 21·70	8. 49. 50·10	8. 50. 9·19	8·18	+ 1·01
	,,	Regulus	10. 0. 28·60	9. 59. 56·70	10. 0. 15·84	15·00	+ 0·84
	,,	α Ursæ Majoris	10. 54. 29·50	10. 53. 57·50	10. 54. 16·67	16·72	— 0·05
	,,	δ Crateris	11. 11. 56·90	11. 11. 24·80	11. 11. 43·98	43·94	+ 0·04
May	20	α Arietis	1. 59. 6·10	1. 57. 56·20	1. 58. 35·00	34·09	+ 0·91
	21	α Arietis	1. 59. 6·30	1. 57. 54·60	1. 58. 33·97	34·11	— 0·14
	,,	β Tauri	5. 17. 9·80	5. 15. 58·10	5. 16. 37·53	37·81	— 0·28
	,,	α Orionis	5. 47. 25·30	5. 46. 13·60	5. 46. 52·92	53·72	— 0·80
	25	Spica	13. 17. 42·10	13. 16. 29·80	13. 17. 11·02	10·92	+ 0·10
	,,	Arcturus	14. 9. 14·60	14. 8. 2·30	14. 8. 43·54	43·39	+ 0·15
June	11	η Ursæ Majoris	13. 41. 44·50	13. 40. 42·50	13. 41. 32·58	32·00	+ 0·58
	,,	β Libræ	15. 9. 2·00	15. 8. 0·00	15. 8. 50·12	49·72	+ 0·40
	12	Spica	13. 18. 22·50	13. 17. 20·30	13. 17. 10·64	10·80	— 0·16
	,,	η Ursæ Majoris	13. 41. 44·20	13. 40. 42·00	13. 41. 32·35	31·98	+ 0·37
	,,	η Bootis	13. 47. 37·80	13. 46. 35·60	13. 47. 25·95	26·14	— 0·19
July	21	β Libræ	15. 8. 48·50	15. 8. 42·50	15. 8. 50·24	49·47	+ 0·77
	,,	α Coronæ	15. 28. 13·90	15. 28. 7·90	15. 28. 15·65	14·71	+ 0·94
	,,	α Serpentis	15. 36. 45·90	15. 36. 39·90	15. 36. 47·65	46·52	+ 1·13
	26	Procyon	7. 31. 21·00	7. 31. 7·70	7. 31. 18·69	18·16	+ 0·53
August	10	Sirius	6. 38. 51·10	6. 38. 5·20	6. 38. 25·08	25·34	— 0·26
	,,	Castor	7. 25. 18·20	7. 24. 32·30	7. 24. 52·21	51·12	+ 1·09
	,,	Procyon	7. 31. 44·50	7. 30. 58·60	7. 31. 18·51	18·39	+ 0·12
September	3	Sirius	6. 38. 49·00	6. 37. 49·50	6. 38. 25·55	25·91	— 0·36

TRANSITS FOR THE POSITION OF TROUGHTON'S CIRCLE—*concluded.*

Day, 1847.	Object.	Transit by Mudge.	Transit by Hardy.	Sidereal Time.	Sec. of Tabular R.A.	Error.
		h m s	h m s	h m s	s	s
September 24	β Aquarii	21. 24. 44·50	21. 22. 44·60	21. 23. 33·02	33·44	− 0·42
,,	ε Pegasi	21. 37. 55·00	21. 35. 55·10	21. 36. 43·52	43·69	− 0·17
October 19	ζ Cygni	21. 6. 54·00	21. 6. 27·00	21. 6. 28·97	28·45	+ 0·52
,,	ε Pegasi	21. 37. 9·00	21. 36. 42·00	21. 36. 43·98	43·38	+ 0·60
,,	γ Aquarii	22. 14. 14·00	22. 13. 47·00	22. 13. 48·99	48·27	+ 0·72
20	Arcturus	14. 9. 11·80	14. 8. 40·00	14. 8. 41·79	41·86	− 0·07
21	Arcturus	14. 9. 18·50	14. 8. 39·70	14. 8. 41·88	41·86	+ 0·02
25	Arcturus	14. 9. 23·30	14. 8. 37·50	14. 8. 41·58	41·87	− 0·29
November 12	Arcturus	14. 9. 23·00	14. 8. 27·90	14. 8. 41·92	42·03	− 0·11
13	α Coronæ	15. 28. 54·80	15. 27. 59·70	15. 28. 13·74	13·18	+ 0·56
23	Arcturus	14. 8. 39·20	14. 8. 24·40	14. 8. 42·47	42·21	+ 0·26

I now proceed with the explanation of the columns of the printed Observations.

The *first* column on the left-hand page contains the day, always beginning with the Sun's transit: the *second* contains the numbers of reference: the *third* contains the name of the object observed (the nomenclature of the stars following the same general rule as in the section of *Transits observed,* &c., except that, as a last resource, the place of the star is defined by its right ascension, which may sometimes be in error 10^{s} or more). The letters N. L. and S. L. denote the north and south limbs of planets. The letter M denotes that the reading of the telescope-micrometer is different from that which is assumed as the zero to which all readings are referred in the computation of their equivalents, viz. $5^{r}{\cdot}000$, according to the explanation given in the standing foot-note at each opening. The letter R denotes that the object is observed by reflexion from a trough of mercury. The troughs used for this purpose are about 18 inches long and 4 inches broad: they are placed either on a ledge of the circle-pier, about 30 inches below the lower limb of the Circle, or upon a bracket, which admits of being placed at different elevations on a carriage travelling with wheels on the ledge of the pier.

The *fourth* column contains the pointer-reading. The pointer is merely an index fixed to the pier, and pointing to the division whose reading is greater than that of microscope A by 5°. The pointer is nearer to the floor than the microscope by this quantity.

The columns from the *fifth* to the *tenth* contain the readings of the six microscopes. The application of the letters is the same as in the Observations of preceding years from 1836: the observer beginning with the northern horizontal microscope, and passing the upper microscopes, the southern horizontal, and the lower ones, in the direction of the Circle's circumference, reads them in the order A, C, E, B, D, F. These readings in the observing books are placed in the order $\begin{matrix}A, & C, & E\\ B, & D, & F\end{matrix}$: 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 minutes are given in the fifth column only.

The use of a fixed wire was discontinued in the year 1843, and all the observations have been since made with the wire carried by the micrometer attached to the telescope.

In order to determine the mean reading of the microscopes, the mean of the seconds in the readings of the six microscopes must be taken. This is correct on the supposition that the micrometer in each microscope makes exactly five revolutions in carrying its wire from the image of one division on the limb to the image of the next division. This, however, seldom holds. It is necessary to take into account the error, not only because it is sensible, but also because it is periodic, varying considerably with the general temperature of the season.

It is the practice, at least once in every week, to examine three intervals on the limb with each microscope, and thus to ascertain the excess of reading of the microscope-micrometer in the position commonly used (namely, when the micrometer is turned in the direction increasing its readings, from its zero till the wire coincides with the next image of a division) above its reading for the image of a division on the other side of the zero. The quantity by which this exceeds 5′ being taken for each microscope, the sum of these excesses with sign changed is given as a correction, in the *eleventh* column, called "Correction for Runs." This number is the correction when the microscope-reading amounts to 5′: a proportional part is to be taken for any other reading: and it is to be applied to the sum of the microscope-readings before that sum is divided by 6. Occasionally, when the image of a division is very near the zero of the micrometer, the micrometer is turned in the opposite direction to coincide with that image: this is indicated by the mark †, denoting "the micrometers of the microscopes placed on the next divisions." The amount of correction then necessary is, the correction which would have been applied if the observations had been made in the usual way, diminished by the whole correction for 5′.

The following table contains the amount of error in each microscope for a reading of 5′, as ascertained in the various positions of the Circle in each week.

ERRORS OF EACH MICROSCOPE OF TROUGHTON'S CIRCLE FOR A READING OF 5′
throughout the Year 1847.

Day, 1847.		Pointer Reading.	MICROSCOPES						Sum.
			A	B	C	D	E	F	
		°	″	″	″	″	″	″	″
January	10	1	+ 2·0	+ 1·8	− 1·3	+ 1·8	+ 3·0	+ 0·5	+ 7·8
	,,	23	+ 1·3	+ 2·6	− 0·9	+ 2·5	+ 1·1	+ 2·2	+ 8·8
	,,	44	+ 2·0	+ 2·3	0·0	+ 2·2	+ 1·6	+ 1·8	+ 9·9
	18	61	+ 2·4	+ 2·5	− 1·2	+ 2·0	+ 0·7	+ 1·0	+ 7·4
	,,	83	+ 1·4	+ 3·9	+ 0·9	+ 2·1	+ 0·9	+ 1·9	+11·1
	,,	104	+ 2·2	+ 3·8	+ 0·9	+ 2·3	+ 1·5	+ 1·4	+12·1
	24	126	+ 2·6	+ 5·3	− 0·3	+ 2·6	+ 1·7	− 1·6	+10·3
	,,	148	+ 2·3	+ 2·3	+ 0·8	+ 3·5	+ 1·3	+ 3·4	+13·6
	,,	169	+ 1·7	+ 3·2	+ 1·4	+ 3·1	+ 1·6	+ 1·5	+12·5
February	1	190	+ 3·0	+ 3·1	+ 0·1	+ 2·3	+ 2.8	+ 3·1	+14·4
	,,	212	+ 2·2	+ 2·0	+ 1·5	+ 2·5	− 1·2	+ 2·0	+ 9·0
	,,	233	+ 1·5	+ 3·0	+ 0·6	+ 1·8	+ 2·0	+ 2·6	+11·5
	7	250	+ 1·3	+ 2·6	+ 0·5	+ 0·8	+ 0·2	+ 1·1	+ 6·5
	,,	272	+ 0·4	+ 1·3	− 0·7	+ 1·2	+ 0·7	+ 1·2	+ 4·1
	,,	293	+ 2·4	+ 2·5	+ 0·4	+ 2·6	+ 2·5	+ 2·9	+13·3
	17	320	+ 2·6	+ 2·5	+ 1·6	+ 0·5	+ 2·4	+ 3·1	+12·7
	,,	342	+ 2·3	+ 2·8	+ 0·2	+ 1·4	+ 1·0	+ 2·2	+ 9·9
	,,	3	+ 2·2	+ 2·0	+ 0·4	+ 2·8	+ 1·0	+ 0·8	+ 9·2
	22	25	+ 2·7	+ 3·7	+ 1·6	+ 3·4	+ 2·9	+ 1·7	+16·0
	,,	46	+ 2·7	+ 2·9	+ 0·2	+ 2·9	+ 2·4	+ 2·7	+13·8
	,,	69	+ 3·8	+ 3·4	+ 0·4	+ 2·9	+ 1·5	+ 1·9	+13·9
March	1	90	+ 0·4	+ 3·6	+ 2·1	+ 3·2	+ 0·3	+ 2·6	+12·2
	,,	111	+ 2·1	+ 3·1	+ 1·2	+ 2·4	+ 1·6	+ 0·7	+11·1
	,,	134	+ 1·5	+ 3·9	+ 1·2	+ 2·3	+ 1·6	+ 2·2	+12·7
	7	160	+ 2·7	+ 3·0	+ 1·3	+ 1·7	+ 0·9	+ 2·9	+12·5
	,,	181	+ 1·9	+ 2·8	+ 1·7	+ 1·1	+ 1·0	+ 2·2	+10·7
	,,	204	+ 2·3	+ 3·5	+ 1·7	+ 1·0	+ 0·5	+ 2·0	+11·0
	14	230	+ 2·1	+ 3·2	+ 1·0	+ 0·5	+ 1·3	+ 1·1	+ 9·2
	,,	252	+ 2·2	+ 2·7	+ 1·1	+ 0·2	+ 2·0	+ 0·2	+ 8·4
	,,	273	+ 2·1	+ 2·3	+ 0·8	+ 0·8	+ 1·1	+ 0·7	+ 7·8
	21	300	+ 1·4	+ 2·2	+ 1·0	+ 0·3	+ 0·5	+ 3·3	+ 8·7
	,,	321	+ 2·4	+ 2·0	+ 1·0	+ 0·5	+ 1·1	+ 2·1	+ 9·1
	,,	343	+ 0·9	+ 2·3	+ 1·4	+ 2·1	+ 0·4	+ 2·3	+ 9·4
	28	3	+ 3·5	+ 1·5	+ 1·7	+ 0·8	+ 2·7	+ 1·2	+11·4
	,,	25	+ 1·5	+ 1·4	+ 0·4	+ 1·5	+ 0·3	+ 0·3	+ 5·4
	,,	48	+ 2·4	+ 1·2	+ 0·3	+ 0·8	+ 1·1	+ 0·7	+ 6·5

ERRORS OF EACH MICROSCOPE OF TROUGHTON'S CIRCLE—*continued.*

Day, 1847.	Pointer Reading.	MICROSCOPES						Sum.
		A	B	C	D	E	F	
April........4	70°	+ 3″·5	+ 2″·9	+ 0″·8	+ 2″·0	+ 0″·8	+ 1″·8	+11′·8
,,	91	+ 1·5	+ 2·3	+ 1·5	+ 2·2	+ 1·5	+ 1·2	+10·2
,,	114	+ 1·8	+ 2·5	+ 0·3	+ 0·7	+ 1·0	+ 2·0	+ 8·3
11	137	+ 2·6	+ 1·5	+ 0·6	+ 0·8	+ 2·1	+ 2·8	+10·4
,,	158	+ 2·9	+ 2·2	+ 1·8	+ 2·3	+ 2·8	+ 2·3	+14·3
,,	181	+ 2·1	+ 2·2	+ 0·3	+ 0·3	+ 0·6	+ 0·9	+ 6·4
18	203	+ 2·5	+ 3·0	+ 0·8	+ 2·2	+ 1·5	+ 1·5	+11·5
,,	224	+ 1·9	+ 1·9	+ 0·1	+ 0·2	+ 2·1	+ 1·7	+ 7·9
,,	246	+ 1·9	+ 2·7	− 1·0	+ 2·0	+ 1·9	+ 2·0	+ 9·5
25	269	+ 3·8	+ 3·2	+ 1·9	+ 2·4	+ 0·9	+ 2·5	+14·7
,,	290	+ 3·0	+ 2·7	+ 3·3	+ 0·8	+ 2·2	− 1·3	+10·7
,,	315	+ 3·8	+ 3·5	+ 0·7	− 0·5	+ 1·9	− 2·3	+ 7·1
May.........3	330	+ 1·8	+ 3·9	+ 1·1	+ 1·4	+ 2·1	+ 1·9	+12·2
,,	355	+ 3·8	+ 1·7	+ 1·9	+ 1·9	+ 1·4	+ 1·1	+11·8
,,	17	+ 3·5	+ 2·5	+ 1·0	+ 3·3	+ 1·8	+ 1·8	+13·9
9	29	+ 2·6	+ 2·8	+ 1·7	+ 1·2	+ 2·3	+ 1·4	+12·0
,,	50	+ 2·2	+ 1·5	+ 0·5	+ 1·5	+ 2·7	+ 3·2	+11·6
,,	71	+ 0·4	+ 2·2	+ 0·4	+ 2·1	+ 2·9	+ 2·1	+10 1
16	93	+ 2·3	+ 2·3	+ 2·4	+ 2·7	+ 1·3	+ 1·5	+12·5
,,	114	+ 1·9	+ 3·7	+ 1·1	+ 3·4	+ 1·9	+ 2·4	+14·4
,,	136	+ 1·7	+ 0·9	+ 0·7	+ 2·2	+ 1·2	+ 3·2	+ 9·9
23	157	+ 2·9	+ 4·0	+ 1·9	+ 2·8	+ 1·6	+ 3·7	+16·9
,,	179	+ 3·4	+ 2·7	+ 2·8	+ 0·5	+ 3·6	+ 3·7	+16·7
,,	200	+ 2·2	+ 3·0	+ 0·5	+ 0·6	+ 0·8	+ 3·2	+10·3
30	221	+ 2·8	+ 2·6	+ 2·3	+ 2·6	+ 2·8	+ 2·3	+15·4
,,	243	+ 2·6	+ 2·5	+ 1·3	+ 3·1	+ 0·7	+ 1·8	+12·0
,,	264	+ 3·3	+ 2·9	+ 2·3	+ 3·6	+ 2·9	+ 2·8	+17·8
June.........7	285	+ 3·9	+ 2·6	+ 3·0	+ 2·5	+ 3·4	− 0·1	+16·3
,,	307	+ 3·1	+ 4·5	+ 2·2	+ 2·5	+ 2·0	+ 2·2	+16·5
,,	328	+ 2·8	+ 4·9	+ 3·6	+ 3·4	+ 1·8	+ 3·9	+20·4
12	349	+ 2·7	+ 1·8	+ 2·7	+ 1·8	+ 2·4	+ 3·0	+14·4
,,	11	+ 2·8	+ 2·9	+ 1·8	+ 1·9	+ 3·4	+ 1·3	+14·1
,,	33	+ 3·4	+ 3·6	+ 1·1	+ 3·3	+ 2·2	+ 2·4	+16·0
21	50	+ 3·2	+ 4·5	+ 1·3	+ 2·5	+ 2·2	+ 2·5	+16·2
,,	71	+ 2·7	+ 3·1	+ 1·0	+ 1·8	+ 4·2	+ 2·5	+15·3
,,	93	+ 3·2	+ 5·0	+ 2·1	+ 3·2	+ 2·2	+ 4·2	+19·9

ERRORS OF EACH MICROSCOPE OF TROUGHTON'S CIRCLE—*continued.*

Day, 1847.		Pointer Reading.	MICROSCOPES.						Sum.
			A	B	C	D	E	F	
June	28	114°	+ 2″·6	+ 3″·3	+ 0″·9	+ 2″·5	+ 1″·6	+ 2″·3	+13″·2
	,,	135	+ 3·4	+ 3·7	+ 1·6	+ 2·8	+ 0·7	+ 3·4	+15·6
	,,	155	+ 3·5	+ 2·7	+ 1·0	+ 1·5	+ 1·3	+ 2·9	+12·9
July	4	177	+ 3·8	+ 3·5	+ 2·7	+ 2·4	+ 1·4	+ 3·8	+17·6
	,,	199	+ 3·5	+ 3·3	+ 3·0	+ 2·0	+ 1·5	+ 2·5	+15·8
	,,	221	+ 3·8	+ 3·8	+ 3·4	+ 3·2	+ 2·1	+ 2·3	+18·6
	12	240	+ 3·7	+ 3·5	+ 2·8	+ 3·8	+ 3·5	+ 4·3	+21·6
	,,	262	+ 3·3	+ 4·2	+ 1·3	+ 3·2	+ 2·9	+ 3·8	+18·7
	,,	284	+ 3·8	+ 4·3	+ 1·8	+ 1·2	+ 4·3	+ 2·4	+17·8
	19	297	+ 2·8	+ 2·6	+ 1·0	+ 3·8	+ 0·3	+ 1·8	+12·3
	,,	316	+ 1·9	+ 2·7	+ 0·5	+ 0·7	+ 2·0	+ 3·3	+11·1
	,,	338	+ 1·8	+ 4·7	+ 0·2	+ 1·3	+ 1·7	+ 2·2	+11·9
	26	3	+ 5·2	+ 4·1	+ 0·5	+ 1·2	+ 1·5	+ 2·1	+14·6
	,,	25	+ 2·1	+ 1·0	+ 1·3	+ 1·7	+ 0·7	+ 2·0	+ 8·8
	,,	46	+ 3·0	+ 2·0	+ 1·0	+ 2·6	+ 1·4	+ 3·3	+13·3
August	1	68	+ 3·7	+ 4·0	+ 0·9	+ 2·9	+ 3·4	+ 3·3	+18·2
	,,	89	+ 2·3	+ 4·5	+ 2·7	+ 2·2	+ 2·8	+ 1·1	+15·6
	,,	111	+ 3·1	+ 3·5	+ 3·3	+ 1·0	+ 3·8	+ 2·2	+16·9
	8	133	+ 2·3	+ 3·4	+ 1·5	+ 0·5	+ 3·0	+ 2·7	+13·4
	,,	154	+ 4·0	+ 0·4	+ 0·9	+ 1·8	+ 1·8	+ 2·6	+11·5
	,,	175	+ 2·4	+ 3·5	+ 1·3	+ 2·7	+ 2·8	+ 2·1	+14·8
	15	196	+ 4·9	+ 4·1	+ 2·2	+ 2·8	+ 2·8	+ 3·6	+20·4
	,,	218	+ 2·7	+ 2·6	+ 2·7	+ 0·3	+ 3·5	+ 3·1	+14·9
	,,	239	+ 2·4	+ 2·7	+ 2·5	+ 1·0	+ 2·1	+ 2·8	+13·5
	22	260	+ 2·9	+ 1·9	+ 3·2	+ 4·5	+ 1·2	+ 2·0	+15·7
	,,	282	+ 2·9	+ 2·5	+ 0·5	+ 3·0	+ 3·6	+ 3·1	+15·6
	,,	301	+ 1·2	+ 3·8	+ 1·4	+ 3·2	+ 1·8	+ 3·4	+14·8
	29	320	+ 3·1	+ 3·0	+ 2·9	+ 1·8	+ 3·5	+ 2·8	+17·1
	,,	341	+ 3·0	+ 2·2	+ 3·0	+ 2·3	+ 3·6	+ 2·9	+17·0
	,,	3	+ 1·7	+ 3·0	+ 1·4	+ 1·4	+ 2·6	+ 2·0	+12·1
September	6	25	+ 4·8	+ 4·3	+ 1·5	+ 3·5	+ 2·8	+ 1·5	+18·4
	,,	46	+ 3·1	+ 2·4	+ 2·7	+ 2·7	+ 2·9	+ 2·7	+16·5
	,,	68	+ 3·1	+ 2·8	+ 2·9	+ 2·3	+ 1·2	+ 2·1	+14·4
	12	89	+ 2·6	+ 3·7	+ 1·6	+ 1·7	+ 0·5	+ 0·4	+10·5
	,,	111	+ 2·6	+ 3·9	+ 2·3	+ 2·4	+ 2·9	+ 2·9	+17·0
	,,	132	+ 2·2	+ 3·4	+ 1·6	+ 1·6	+ 1·0	+ 1·9	+11·7

ERRORS OF EACH MICROSCOPE OF TROUGHTON'S CIRCLE—*continued.*

Day, 1847.		Pointer Reading.	MICROSCOPES.						Sum.
			A	B	C	D	E	F	
		°	″	″	″	″	″	″	″
September	19	153	+ 4·5	+ 3·3	+ 1·3	+ 3·7	+ 2·9	+ 1·6	+17·3
	,,	175	+ 1·0	+ 3·4	+ 0·3	+ 1·7	+ 0·2	+ 2·8	+ 9·4
	,,	196	+ 3·6	+ 3·9	+ 0·8	+ 3·2	+ 2·3	+ 2·7	+16·5
	26	217	+ 3·0	+ 3·2	+ 0·7	+ 2·6	+ 1·2	+ 0·9	+11·6
	,,	239	+ 2·7	+ 3·2	+ 0·3	+ 3·3	+ 0·8	+ 1·1	+11·4
	,,	263	+ 2·6	+ 3·8	+ 2·1	+ 2·8	+ 1·5	+ 3·5	+16·3
October	4	281	+ 2·8	+ 3·0	+ 2·0	+ 0·7	+ 1·8	+ 2·3	+12·6
	,,	303	+ 2·7	+ 2·5	+ 2·7	+ 1·2	+ 1·7	+ 3·9	+14·7
	,,	325	+ 2·8	+ 3·3	+ 1·8	+ 1·3	+ 2·0	+ 3·0	+14·2
	17	50	+ 3·0	+ 4·0	+ 0·3	+ 0·8	+ 0·4	+ 3·0	+11·5
	,,	72	+ 3·4	+ 3·2	+ 0·8	+ 1·2	+ 1·9	+ 1·4	+11·9
	,,	93	+ 2·2	+ 3·4	+ 1·0	+ 1·5	+ 1·6	+ 3·8	+13·5
	24	115	+ 2·3	+ 4·1	+ 1·6	+ 3·3	+ 1·2	+ 1·5	+14·0
	,,	136	+ 1·6	+ 3·8	+ 2·2	+ 0·3	+ 1·6	+ 3·5	+13·0
	,,	158	+ 2·8	+ 3·5	+ 1·3	+ 2·0	+ 1·4	+ 2·6	+13·6
November	1	180	+ 0·4	+ 3·5	+ 2·9	+ 2·5	+ 2·0	+ 1·0	+12·3
	,,	201	+ 2·0	+ 2·7	+ 0·3	+ 2·9	+ 2·5	+ 3·2	+13·6
	,,	223	+ 1·6	+ 3·6	+ 0·5	+ 0·5	+ 2·7	+ 2·6	+11·5
	10	245	+ 2·6	+ 3·5	+ 2·2	+ 1·8	+ 3·5	+ 2·5	+16·1
	,,	266	+ 2·7	+ 4·4	+ 2·4	+ 4·8	+ 0·8	+ 4·7	+19·8
	,,	288	+ 3·7	+ 3·8	+ 1·8	+ 1·1	+ 2·9	+ 4·3	+17·6
	15	301	+ 3·0	+ 3·4	+ 1·4	+ 3·0	+ 2·2	+ 2·0	+15·0
	,,	323	+ 2·3	+ 2·8	+ 0·7	+ 2·0	+ 1·6	+ 2·4	+11·8
	,,	345	+ 0·8	+ 2·3	+ 0·3	+ 0·4	+ 1·3	+ 1·2	+ 6·3
	21	6	+ 2·1	+ 0·1	+ 2·4	+ 1·5	+ 2·3	+ 2·5	+10·9
	,,	28	+ 2·7	+ 2·5	+ 0·7	+ 1·0	+ 2·9	+ 2·9	+12·7
	,,	49	+ 2·0	+ 3·0	+ 0·5	+ 2·6	+ 1·9	+ 1·4	+11·4
	28	70	+ 2·0	+ 3·0	+ 0·1	+ 2·2	+ 1·3	+ 2·9	+11·5
	,,	92	+ 1·2	+ 4·0	+ 0·6	+ 2·0	+ 1·0	+ 4·4	+13·2
	,,	113	+ 2·2	+ 3·5	+ 0·3	+ 2·1	+ 0·5	+ 3·5	+12·1
December	6	135	+ 4·6	+ 4·5	+ 1·5	+ 3·5	+ 1·1	+ 2·2	+17·4
	,,	157	+ 2·1	+ 2·7	+ 3·2	+ 3·5	+ 2·1	+ 3·2	+16·8
	,,	178	+ 2·9	+ 3·3	+ 1·8	+ 1·9	+ 2·6	+ 3·5	+16·0
	13	201	+ 2·1	+ 3·3	+ 3·8	+ 3·8	+ 1·3	+ 2·3	+16·6
	,,	224	+ 3·8	+ 3·0	+ 1·9	+ 2·8	+ 1·5	+ 3·3	+16·3
	,,	246	+ 1·7	+ 4·3	+ 0·9	+ 3·1	+ 2·7	+ 4·1	+16·8

ERRORS OF EACH MICROSCOPE OF TROUGHTON'S CIRCLE—*concluded.*

Day, 1847.	Pointer Reading.	MICROSCOPES						Sum.
		A	B	C	D	E	F	
December 20	269°	+ 2″·6	+ 2″·9	+ 0″·2	+ 2″·1	+ 2″·2	+ 2″·4	+12″·4
,,	291	+ 3·7	+ 3·5	+ 1·8	+ 3·6	+ 1·8	+ 2·0	+16·4
,,	314	+ 1·8	+ 3·5	+ 1·2	+ 3·5	+ 1·6	+ 1·3	+12·9
27	335	+ 1·6	+ 3·0	+ 0·2	+ 2·7	+ 2·2	+ 4·5	+14·2
,,	357	+ 0·5	+ 2·2	+ 0·6	+ 0·5	+ 1·7	+ 1·7	+ 7·2
,,	18	+ 1·1	+ 2·3	+ 0·3	+ 0·8	+ 3·3	+ 2·7	+10·5

The *eleventh* column contains the value of the correction for runs on an arc of 5′; determined, as has been before mentioned, once in every week.

The *twelfth* column contains the reading of the micrometer in the eye-piece of the telescope. It is stated in the foot-notes on each page, that 5$^{\rm r}$·000 has been assumed as the zero to which the readings are referred in the computation of their equivalents; and that, when no reading of the telescope-micrometer is given, it is understood that the reading was 5$^{\rm r}$·000.

The *thirteenth* column contains the value in minutes and seconds, of the arc measured with the telescope-micrometer. The value of one revolution of the micrometer is 53″·24, being the same as that used in previous years, and confirmed by observations contained in the Introduction to the volume for 1846.

The *fourteenth* column contains the number of the vertical wire at which the object was seen when the observation with the horizontal wire was made. The telescope of the Circle contains five vertical wires: the intervals between the wires have been ascertained by transits of stars, which (being entirely free from any sensible doubt) it is not necessary to detail here. The equatoreal interval of the wires is considered to be 20$^{\rm s}$.

The *fifteenth* column contains the correction to be applied to the circle-reading in consequence of the object not having been observed when passing the middle wire. It consists of two parts, one due to the body's change of N.P.D. (if it be the Sun, the Moon, a planet, or a comet), the other due to the difference between the small circle described by the body and the great circle of which the horizontal wire forms a part. Of the former of these no explanation is required, except that for the Moon the change is computed by the formula: change of declination for one hour of terrestrial longitude (from the section of Moon-culminating Stars in the Nautical Almanac) × sec. declination × number. (log. = 7·745) × number of intervals of wires. The latter is calculated by this formula: tan. declination × numb. (log. = 9·350) × (number of intervals of wires)^2. A table has been formed of the values of this latter correction for convenient intervals of N.P.D., and the correction for one or two intervals can always be taken out at sight. The two numbers are combined together to form the number in the *fifteenth* column.

The *sixteenth* column contains the circle-reading, as found by adding the mean of the microscope-readings (corrected for runs) to the pointer-reading, and applying the corrections from columns *thirteen* and *fifteen.*

The *seventeenth* column contains the initials of the Observers' names.

The *first* column on the right-hand page contains numbers for reference, corresponding to those in the second column of the left-hand page.

The *second* column contains the sums of the circle-readings when the same object has been observed by reflexion and directly at the same transit. These are necessary for the determination of the Zenith Point, or the circle-reading corresponding to a vertical position of the telescope. The observations being divided into groups (seldom exceeding four days), and each of these groups being subdivided into two parcels, one containing the stars which passed north of the zenith, and the other containing the stars which passed south of the zenith, the mean value of D + R for each parcel is ascertained : the mean between the two values of D + R for the two parcels is found, and is considered to be the value of D + R applicable to the whole group : this quantity is increased or diminished by 180° and divided by 2, and the result is adopted as the Zenith Point. It will be seen from this description, that the result as to the Zenith Distance of the objects comprehended in one group is entirely independent of the operations of any kind in any other group. It will also be seen, that the system of taking the means of the results from the north parcel and the south parcel, without respect to the number of stars in each parcel, supposing the zenith distances of the stars to be not very unequal, entirely eliminates the effect of any drop of the eye-end or object-end, or of any other cause which acts symmetrically on both sides of the zenith to increase or to diminish the telescope's angle with the vertical. In the daily observations, however, of 1847, care has also been taken to balance, as far as is practicable, the number of stars observed by reflexion on the north side and on the south side.

In the division of the groups, the general rule has been to divide, if possible, where a considerable interval occurs between the observations; except in cases where there is an evident change of Zenith Point between two parts of one of the selected groups; or where any recorded accident during the observations renders it necessary to make a division.

Observations of the Zenith Point have also been made systematically with an eye-piece furnished with a perforated reflector.

This eye-piece being mounted on the telescope, and the light of a lamp thrown into the telescope by its reflector, the direct image of the wire, and the image reflected from the mercury, can be seen with almost equal distinctness; and, by bringing the two images repeatedly into contact on opposite sides of each other by means of the micrometer, the reading of the micrometer for their coincidence can be obtained with great accuracy. The equivalent of this reading added to the circle-reading gives the Zenith Point. In times of unusual pressure the Zenith Points obtained by this instrument have been used, the star-observations by reflexion being discontinued for a time.

The *third* column contains the Adopted Zenith Point, determined by the rules just described.

The *fourth* column contains the Apparent Zenith Distance, which is found by subtracting the Zenith Point in the preceding column from the circle-reading: the negative sign denotes that the object is North of the zenith. When the Moon has been observed at several wires, the mean of all the concluded circle-readings is used to form the Zenith Distance.

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

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

and the correction required will be

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

If the Moon be gibbous, as is the case in the greater number of instances, draw a great circle through the center of the Moon, at right angles to the meridian passing through the Moon, and let it meet the meridian passing through the Sun; then the intersection of this circle with the Sun's meridian will determine the place of a fictitious Sun, which would equally illuminate both limbs of the Moon when on the meridian; and the elevation or depression of the true Sun above or below the great circle joining the Moon and fictitious Sun, measured in a plane at right angles to that circle, will represent the angle by which the lowest or highest part of the illuminated hemisphere is distant from the limb, and therefore the angle whose versed sine multiplied into the Moon's 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 the triangles formed by great circles joining these. Let also δ_1 be the declination of the fictitious Sun, θ_1 the arc joining the true and fictitious Suns, and θ the perpendicular arc before mentioned.

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

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

Also

$$\begin{aligned} \text{Sin}\ \theta &= \text{Sin}\ \theta_1 . \text{Sin}\ MS_1P \\ &= \sin\theta_1 \frac{\text{Sin}\ MP}{\text{Sin}\ S_1P} \\ &= \text{Sin}\ \theta_1 \frac{\text{Cos}\ \delta_m}{\text{Cos}\ \delta_1} \end{aligned}$$

Whence θ is found, and the correction required is

Moon's semidiameter × vers θ.

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

The *fifth* column contains the reading of the barometer. This instrument is by Newman: the raising of the index by which the upper surface of the mercury is read, depresses a plunger in the cistern of mercury, for the purpose of making the elevation of its surface invariable. This barometer is not fit for any delicate purpose, but is sufficiently accurate for computation of refraction.

The *sixth* column contains the reading of the exterior thermometer. This is by Troughton and Simms: it is mounted on the outside of the Observatory, at the distance of nearly four feet from the north wall, in a tinned case, with its bulb quite free to the current of air, but protected from radiation.

The *seventh* column contains the reading of the interior thermometer: it is a small thermometer suspended between the two circle-piers.

The *eighth* column contains the refraction computed by Bessel's tables in the *Tabulæ Regiomontanæ*. These tables, altered in form (but so as to give in all cases the same result) and expanded, are given in the Appendix to the volume for 1836. The exterior thermometer only is used in the computation, excepting in cases when the Zenith Distance exceeds 85°.

The *ninth* column contains the parallax. This is computed on the supposition that the earth's ellipticity is $\frac{1}{300}$. For the planets the formula is, log. parallax = log. sin (zen. dist. $- 11'.12''$) + ar. co. log. distance $+ 0{\cdot}9325$. For the Moon, the horizontal equatoreal parallax, as interpolated with second differences from the Nautical Almanac, is affected with a number from the following table, which is peculiar to the Moon's limbs. These numbers may be inferred from the investigation given in a subsequent part of this Introduction, for the Moon's parallax in Occultations, by supposing V (the angle on the Moon's limb from the vertical) = 0° or 180°.

Correction to Moon's Horizontal Parallax to be used when Parallax is to be applied to the Observation of a Limb.

Z.D.	South Limb.	Z.D.	South Limb.	Z.D.	North Limb.	Z.D.	North Limb.
°	″	°	″	°	″	°	″
30	+ 0·10	60	+ 0·15	30	— 0·03	60	— 0·08
35	+ 0·11	65	+ 0·15	35	— 0·04	65	— 0·08
40	+ 0·12	70	+ 0·16	40	— 0·05	70	— 0·09
45	+ 0·12	75	+ 0·16	45	— 0·06	75	— 0·09
50	+ 0·13	80	+ 0·16	50	— 0·06	80	— 0·09
55	+ 0·14			55	— 0·07		

The parallax is then computed by the formula: log. seconds of parallax = log. seconds of corrected horizontal equatoreal parallax + log. sin (zen. dist. – 11′.12″) + 9·9991136 + log. $\frac{\sin}{\text{arc}}$ (for hor. par.) + log. $\frac{\text{arc}}{\sin}$ (for parallax).

The logarithms of the last two factors for the computation of the parallax are taken from the following tables:

Arc.	Log. $\left(\frac{\text{Sin.}}{\text{Arc.}}\right)$	Arc.	Log. $\left(\frac{\text{Sin.}}{\text{Arc.}}\right)$	Arc.	Log. $\left(\frac{\text{Sin.}}{\text{Arc.}}\right)$
′		′		′	
50	9·9999846	56	9·9999807	61	9·9999772
51	·9999841	57	·9999801	62	·9999765
52	·9999834	58	·9999794	63	·9999757
53	·9999828	59	·9999786	64	·9999749
54	·9999821	60	·9999779	65	·9999741
55	·9999815	61	·9999772	66	·9999733
56	·9999807				

Approx. Log.	Approx. Arc.	Log. $\left(\frac{\text{Arc.}}{\text{Sin.}}\right)$	Approx. Log.	Approx. Arc.	Log. $\left(\frac{\text{Arc.}}{\text{Sin.}}\right)$
	′ ″			′ ″	
3·00	16. 40	0·0000017	3·30	33. 15	0·0000068
3·05	18. 42	·0000022	3·35	37. 18	·0000086
3·10	20. 59	·0000027	3·40	41. 52	·0000107
3·15	23. 32	·0000034	3·45	46. 58	·0000136
3·20	26. 25	·0000043	3·50	52. 42	·0000171
3·25	29. 38	·0000055	3·55	59. 8	·0000214
3·30	33. 15	·0000068	3·60	66. 21	·0000270

The distances of Flora from the Earth for the computation of the parallaxes, were taken from an Ephemeris, furnished by Mr. Hind, being computed from his Third Elements of the orbit, *Monthly Notices of the Royal Astronomical Society*, vol. VIII., No. 2, and Schumacher's *Astronomische Nachrichten*, No. 623.

The distances of Iris were taken from an approximate Ephemeris furnished by Mr. Hind.

The distances of Astræa were taken from D'Arrest's Ephemeris in No. 590 of the *Astronomische Nachrichten*.

The horizontal parallax for Neptune has been assumed to be equal to 0″·27.

The *tenth* column contains the reading of the micrometer for that limb or cusp of a planet which was not observed on the fixed wire of the telescope.

The *eleventh* column contains the semidiameter used in the reduction of the observations. That of the Sun is taken from the Nautical Almanac: that of the Moon is interpolated with second differences from the Nautical Almanac: that of Mars, Jupiter, and Saturn is half of the micrometrical measure of the diameter in the preceding column: that of Mercury and Venus is found by dividing the micrometrical measure by $1 + \cos\theta$, where θ is found by the following process. If the planet is horned, the planet's geocentric place is brought to the zenith of a celestial globe, and the quadrant of altitude being made to pass over the Sun's place, the deviation from the E. or W. point is the measure of θ. If the planet is gibbous, the planet's geocentric place is brought to the intersection of the meridian and horizon, and the point opposite to the planet's heliocentric place being marked, its elevation above or depression below the horizon is taken for θ. If the full limb has been observed with the fixed wire of the circle, the semidiameter thus obtained is to be applied: but if the imperfect limb has been observed with the fixed wire, the difference between this semidiameter and the whole micrometrical measure is to be applied.

The *twelfth* column contains the geocentric N.P.D. of the center of each object derived from every observation: found by combining the Apparent Zenith Distance with the Refraction, Parallax, Semidiameter, and assumed Co-latitude 38°.31′.21″·80.

The *thirteenth* column contains the name of the object observed; it is described in the same manner as in the third column on the left-hand page, with the omission only of the letters indicating observation with the micrometer and observation of a limb.

The *fourteenth* column contains the corrections which are to be applied to the apparent N.P.D. of the stars in order to obtain the mean N.P.D. 1847, Jan. 1. For the stars in the list of the Nautical Almanac, the correction is found by subtracting the mean declination of the Nautical Almanac from the apparent declination of the same. For stars not in the Nautical Almanac the corrections are computed by this formula,

$$E\,e' + F f' + G\,g' + H\,h' - 300''$$

which is derived from the well known formula

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

or its equivalent

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

by a process which is explained with sufficient detail in No. 11 of the 7th volume of the Notices of the Astronomical Society. The formulæ for E, F, G, H, L, have been already given: $e' = a' + 1{\cdot}2$, $f' = b' + 1{\cdot}2$, $g' = c' + 25$, $h' = d' + 1{\cdot}2$, $l' = 210 - 25 \times e' - 25 \times f' - 1{\cdot}2 \times g' - 25 \times h'$. The values of the day-constants log. E, log. F, log. G, log. H, and L, for the years from 1849 to 1860, inclusive, and the values of the star-constants log. e', log. f', log. g', log. h', and l', are given for all the stars in the "Greenwich Twelve-year Catalogue" appended to the present volume.

The sign of the computed quantity is changed before application.

§ 4. *Mean North Polar Distances of Stars deduced from each day's observations,* page (136) to (153).

The Mean North Polar Distances are found by applying to the North Polar Distances in Section 3, the corrections opposite to them in that Section.

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

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

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, WITH TROUGHTON'S MURAL CIRCLE, 1847.

Name of Star.	Approx. N.P.D.	Sec. of R.	Sec. of D.	R. — D.	No. of Obs.	
					R.	D.
	° ′	″	″	″		
γ Cephei S.P. . . .	−13. 13	15·50	18·10	+ 2·60	1	4
ε Ursæ Minoris S.P. .	− 7. 43	11·28	13·76	+ 2·48	1	1
B.A.C. 3528 S.P. . .	− 6. 40	3·13	2·95	− 0·18	1	3
δ Ursæ Minoris S.P. .	− 3. 24	14·77	14·74	− 0·03	1	1
Polaris S.P.	− 1. 30	21·96	22·41	+ 0·45	6	10
λ Ursæ Minoris S.P. .	− 1. 9	54·89	55·47	+ 0·58	1	1
Polaris	1. 30	21·94	22·20	− 0·26	7	11
Cephei 51 (Hev.) . .	2. 45	31·56	31·49	+ 0·07	2	2
δ Ursæ Minoris . . .	3. 24	16·64	15·56	+ 1·08	2	8
B.A.C. 4498	4. 27	42·54	44·72	− 2·18	2	2
B.A.C. 5352	6. 36	58·69	58·83	− 0·14	1	1
B.A.C. 3528	6. 40	5·54	4·02	+ 1·52	2	3
ε Ursæ Minoris . . .	7. 43	12·31	11·93	+ 0·38	3	3
B.A.C. 4452	8. 43	7·57	7·26	+ 0·31	3	3
B.A.C. 1276	9. 33	20·56	20·96	− 0·40	2	2
B.A.C. 4614	11. 10	9·06	9·58	− 0·52	1	1
B.A.C. 4112	11. 32	59·94	58·92	+ 1·02	1	1
ζ Ursæ Minoris . . .	11. 44	16·06	15·51	+ 0·55	5	5
θ Ursæ Minoris . . .	12. 9	37·12	35·54	+ 1·58	1	1
γ Cephei	13. 13	15·12	16·81	− 1·69	2	3
B.A.C. 3593	13. 30	7·56	6·69	+ 0·87	6	6
5 Ursæ Minoris . . .	13. 37	25·84	24·86	+ 0·98	2	2
η Ursæ Minoris . . .	13. 54	40·60	40·11	+ 0·49	3	3
β Ursæ Minoris . . .	15. 13	9·63	9·16	+ 0·47	7	9
16 Cephei	17. 33	52·70	51·94	+ 0·76	1	2
ψ^1 Draconis	17. 47	40·84	41·44	− 0·60	1	1
κ Draconis	19. 22	4·50	3·60	+ 0·90	1	1
λ Draconis	19. 50	31·70	30·32	+ 1·38	5	5
β Cephei	20. 7	36·19	37·25	− 1·06	9	9
B.A.C. 3652	20. 8	32·67	32·59	+ 0·08	3	3
B.A.C. 4589	20. 35	1·48	2·08	− 0·60	2	2
55 Camelopardali . .	21. 5	3·26	1·79	+ 1·47	1	1
B.A.C. 2439	21. 14	54·03	52·31	+ 1·72	2	2
42 Camelopardali . .	22. 16	9·95	10·05	− 0·10	3	3
9 Draconis	22. 35	35·15	35·99	− 0·84	2	3
δ Draconis	22. 36	27·23	27·64	− 0·41	4	4
38 Ursæ Majoris . .	23. 29	4·95	1·99	+ 2·96	1	1
35 Ursæ Majoris . .	23. 36	35·97	35·58	+ 0·39	1	1
ζ Draconis	24. 6	48·68	48·82	− 0·14	4	4
6 Ursæ Majoris . . .	24. 49	2·09	1·22	+ 0·87	2	2
g Draconis	25. 7	14·96	13·68	+ 1·28	1	1
49 Camelopardali . .	26. 48	31·66	29·80	+ 1·86	1	1
B.A.C. 1111	27. 17	10·26	10·02	+ 0·24	2	2
α Ursæ Majoris . . .	27. 25	28·15	27·04	+ 1·11	10	10
α Cephei	28. 4	40·62	41·39	− 0·77	13	13
η Draconis	28. 8	18·73	18·78	− 0·05	1	1
o Ursæ Majoris . . .	28. 47	36·79	35·71	+ 1·08	2	2
42 Ursæ Majoris. . .	29. 52	9·49	9·77	− 0·28	3	3
18 Lyncis	30. 6	53·04	53·26	− 0·22	1	1

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, WITH TROUGHTON'S MURAL CIRCLE, 1847—*continued.*

Name of Star.	Approx. N.P.D.	Sec. of R.	Sec. of D.	R. — D.	No. of Obs.	
					R.	D.
	° ′	″	″	″		
υ Ursæ Majoris	30. 15	43 ·13	41 ·66	+ 1 ·47	2	2
ι Draconis	30. 30	46 ·76	48 ·66	— 1 ·90	1	1
B.A.C. 1058	30. 36	54 ·65	57 ·31	— 2 ·66	1	2
37 Camelopardali	31. 3	11 ·38	11 ·09	+ 0 ·29	6	8
15 Lyncis	31. 23	5 ·72	5 ·65	+ 0 ·07	2	2
β Cassiopeiæ	31. 42	39 ·64	39 ·82	— 0 ·18	4	4
δ Ursæ Majoris	32. 7	1 ·43	0 ·74	+ 0 ·69	8	8
17 Ursæ Majoris	32. 38	44 ·41	43 ·13	+ 1 ·28	1	1
ε Ursæ Majoris	33. 13	31 ·77	30 ·41	+ 1 ·36	3	3
α Cassiopeiæ	34. 18	9 ·43	9 ·52	— 0 ·09	3	3
δ Aurigæ	35. 44	7 ·63	6 ·12	+ 1 ·51	6	6
ι Ursæ Majoris	41. 22	46 ·88	43 ·12	+ 3 ·76	1	4
B.A.C. 4287	43. 43	19 ·30	19 ·21	+ 0 ·09	1	1
Capella	44. 10	52 ·54	52 ·87	— 0 ·33	8	8
β Aurigæ	45. 5	31 ·72	31 ·73	— 0 ·01	1	1
α Cygni	45. 16	50 ·86	50 ·81	+ 0 ·05	10	15
ε Aurigæ	46. 25	34 ·80	34 ·36	+ 0 ·44	1	1
B.A.C. 3059 10 Ursæ Majoris }	47. 37	55 ·67	55 ·52	+ 0 ·15	1	1
β Canum Venaticûm	47. 49	35 ·67	36 ·26	— 0 ·59	2	2
λ Aurigæ	50. 3	36 ·66	37 ·36	— 0 ·70	2	2
12 Canum Venaticûm	50. 51	13 ·13	15 ·61	— 2 ·48	2	2
α Lyræ	51. 21	20 ·36	19 ·70	+ 0 ·66	10	15
B.A.C. 4356	52. 2	55 ·90	55 ·95	— 0 ·05	1	1
25 Canum Venaticûm	52. 55	30 ·61	30 ·00	+ 0 ·61	2	2
32 Lyncis	53. 3	57 ·09	57 ·17	— 0 ·08	1	2
ι Aurigæ	57. 5	56 ·57	57 ·19	— 0 ·62	2	2
Castor	57. 47	54 ·53	54 ·62	— 0 ·09	7	11
ρ Bootis	58. 57	16 ·13	16 ·23	— 0 ·10	3	3
η Coronæ	59. 9	23 ·97	24 ·97	— 1 ·00	3	3
26 Aurigæ	59. 36	16 ·29	17 ·35	— 1 ·06	1	1
β Coronæ	60. 22	49 ·05	49 ·26	— 0 ·21	1	1
β Tauri	61. 32	39 ·32	40 ·42	— 1 ·10	2	8
Pollux	61. 37	34 ·32	34 ·07	+ 0 ·25	8	11
α Andromedæ	61. 45	16 ·88	16 ·54	+ 0 ·34	1	5
ε Bootis	62. 17	40 ·54	41 ·18	— 0 ·64	7	7
ψ Bootis	62. 27	10 ·88	10 ·47	+ 0 ·41	2	2
ε Coronæ	62. 41	31 ·45	33 ·09	— 1 ·64	1	3
α Coronæ	62. 46	2 ·13	2 ·23	— 0 ·10	4	8
φ Geminorum	62. 51	36 ·74	35 ·37	+ 1 ·37	1	2
ε Geminorum	64. 43	24 ·50	23 ·05	+ 1 ·45	1	4
ε Leonis	65. 31	26 ·53	27 ·49	— 0 ·96	6	8
η Tauri	66. 22	21 ·37	22 ·15	— 0 ·78	3	4
α Arietis	67. 16	49 ·80	50 ·32	— 0 ·52	2	7
μ Geminorum	67. 25	49 ·44	49 ·54	— 0 ·10	3	7
δ Geminorum	67. 44	29 ·03	29 ·18	— 0 ·15	5	11
δ Leonis	68. 38	20 ·99	20 ·25	+ 0 ·74	4	10
Arcturus	70. 1	7 ·04	7 ·60	— 0 ·56	7	16
η Bootis	70. 50	0 ·19	0 ·00	+ 0 ·19	6	7

EXCESS OF REFLEXION-RESULTS ABOVE DIRECT-RESULTS, WITH TROUGHTON'S MURAL CIRCLE, 1847—*concluded.*

Name of Star.	Approx. N.P.D.	Sec. of R.	Sec. of D.	R. — D.	No. of Obs. R.	No. of Obs. D.
	° ′	″	″	″		
i Tauri	71. 26	34 ·16	31 ·90	+ 2 ·26	1	2
α Comæ	71. 40	36 ·23	35 ·99	+ 0 ·24	2	2
η Leonis	72. 30	38 ·69	37 ·29	+ 1 ·40	3	3
Aldebaran	73. 48	13 ·10	12 ·71	+ 0 ·39	3	4
β Leonis	74. 34	24 ·73	21 ·25	+ 3 ·48	1	1
α Pegasi	75. 37	1 ·37	0 ·57	+ 0 ·80	2	5
ν Pegasi	75. 40	2 ·44	2 ·97	— 0 ·53	1	5
o^1 Orionis	76. 1	33 ·46	34 ·83	— 1 ·37	2	3
o^2 Orionis	76. 44	56 ·54	56 ·11	+ 0 ·43	1	4
Regulus	77. 17	14 ·66	15 ·30	— 0 ·64	11	11
α Ophiuchi	77. 19	28 ·51	26 ·89	+ 1 ·62	5	5
ξ Leonis	78. 2	32 ·02	33 ·71	— 1 ·69	2	2
l Leonis	78. 39	48 ·90	47 ·77	+ 1 ·13	1	4
ο Leonis	79. 25	52 ·04	52 ·65	— 0 ·61	1	4
45 Leonis	79. 28	35 ·34	35 ·97	— 0 ·63	1	5
ι Ophiuchi	79. 35	40 ·75	42 ·95	— 2 ·20	1	2
ζ Pegasi	79. 58	57 ·16	56 ·94	+ 0 ·22	3	6
κ Ophiuchi	80. 23	57 ·71	59 ·71	— 2 ·00	1	1
ο Virginis	80. 25	0 ·70	1 ·13	— 0 ·43	1	5
ο Tauri	81. 31	50 ·75	49 ·45	+ 1 ·30	1	2
α Aquilæ	81. 32	53 ·91	54 ·60	— 0 ·69	5	10
χ Leonis	81. 50	16 ·52	16 ·82	— 0 ·30	1	4
ε Hydræ	83. 1	24 ·87	25 ·63	— 0 ·76	6	8
α Serpentis	83. 5	22 ·41	21 ·18	+ 1 ·23	2	8
c Virginis	85. 50	6 ·14	6 ·45	— 0 ·31	2	3
α Ceti	86. 31	51 ·49	50 ·78	+ 0 ·71	1	4
β Virginis	87. 22	22 ·05	25 ·61	— 3 ·56	1	4
ζ Virginis	89. 49	41 ·80	42 ·61	— 0 ·81	1	2
δ Orionis	90. 25	1 ·77	2 ·91	— 1 ·14	1	6
Lalande 10456 . . .	91. 16	8 ·00	7 ·75	+ 0 ·25	1	1
α Hydræ	98. 0	52 ·60	55 ·56	— 2 ·96	2	6
q Virginis	98. 36	25 ·90	27 ·03	— 1 ·13	1	4

From the above table it appears that the differences of the values of R and D follow no law for which a correction could be applied, and it is not worth while to pursue the investigation any farther by dividing them into groups and taking the means.

The results for thirty-two circumpolar stars were then used for examination of the assumed co-latitude; but the result, as in the preceding year, 1846, has not a great weight, on account of the general want of equality in the number of observations above the pole and below the pole respectively. It is believed that the co-latitude is already so accurately determined that special observations are no longer needed, though such observations as answer the purpose are combined as usual, as a matter of caution.

The computations are contained in the subjoined table; of which no explanation appears necessary, except that the weights are approximately determined by multiplying $\frac{a\,b}{a+b}$ (where a is the number of observations above the pole, and b the number below) by the number 50 for the first star, 49 for the second, 48 for the third, and so on, and assuming numbers proportional to those thus resulting.

CORRECTION OF ASSUMED LATITUDE.

Star's Name, Position, and Mode of Observation.	Number of Obs.	N. P. D. from each Group.	Number of Obs.	Concluded N. P. D. in each Position on Assumed Latitude.	Number of Obs.	Algebraic Sum of Determinations.	Weight.	Product.
		° ′ ″		″		″		″
λ Ursæ Minoris ...... D.	1	1. 8. 55·38	1	55·38	3	+ 0·20	4	+ 0·80
R.	..	.....						
S. P... D.	1	— 1. 8. 55·47	2	—55·18				
R.	1	54·89						
Polaris .... D.	11	1. 30. 22·20	18	22·10	34	— 0·14	50	— 7·00
R.	7	21·94						
S. P... D.	10	— 1. 30. 22·41	16	—22·24				
R.	6	21·96						
Cephei 51 (Hev.)..... D.	2	2. 44. 31·49	4	31·53	5	+ 0·08	5	+ 0·40
R.	2	31·56						
S. P... D.	1	— 2. 44. 31·45	1	—31·45				
R.	..	.....						
δ Ursæ Minoris ...... D.	8	3. 24. 15·56	10	15·78	12	+ 1·02	10	+10·20
R.	2	16·64						
S. P... D.	1	— 3. 24. 14·74	2	—14·76				
R.	1	14·77						
B. A. C. 4498 .... D.	2	4. 26. 44·72	4	43·63	5	— 0·98	5	— 4·90
R.	2	42·54						
S. P... D.	1	— 4. 26. 44·61	1	—44·61				
R.	..	.....						
B. A. C. 3528 .... D.	3	6. 40. 4·02	5	4·63	9	+ 1·63	12	+19·56
R.	2	5·54						
S. P... D.	3	— 6. 40. 2·95	4	— 3·00				
R.	1	3·13						
ε Ursæ Minoris ...... D.	3	7. 43. 11·93	6	12·12	8	— 0·40	8	— 3·20
R.	3	12·31						
S. P... D.	1	— 7. 43. 13·76	2	—12·52				
R.	1	11·28						
B. A. C. 4452 .... D.	3	8. 43. 7·26	6	7·42	8	— 1·50	8	—12·00
R.	3	7·57						
S. P... D.	2	— 8. 43. 8·92	2	— 8·92				
R.	..	.....						

CORRECTION OF ASSUMED LATITUDE—*continued.*

Star's Name, Position, and Mode of Observation.	Number of Obs.	N. P. D. from each Group.	Number of Obs.	Concluded N. P. D. in each Position on Assumed Latitude.	Number of Obs.	Algebraic Sum of Determinations.	Weight.	Product.
		° ′ ″		″		″		″
B. A. C. 1276 .... D.	2	9. 33. 20 ·96	4	20 ·76	5	− 2 ·34	4	− 9 ·36
R.	2	20 ·56						
S. P. . . D.	1	− 9. 33. 23 ·10	1	−23 ·10				
R.	. .	. . . . .						
B. A. C. 4112 .... D.	1	11. 31. 58 ·92	2	59 ·43	4	− 1 ·74	5	− 8 ·70
R.	1	59 ·94						
S. P. . . D.	2	−11. 31. 61 ·17	2	−61 ·17				
R.	. .	. . . . .						
ζ Ursæ Minoris ...... D.	5	11. 44. 15 ·51	10	15 ·79	11	− 2 ·04	5	−10 ·20
R.	5	16 ·06						
S. P. . . D.	1	−11. 44. 17 ·83	1	−17 ·83				
R.	. .	. . . . .						
γ Cephei .... D.	3	13. 13. 16 ·81	5	16 ·13	10	− 1 ·45	12	−17 ·40
R.	2	15 ·12						
S. P. . . D.	4	−13. 13. 18 ·10	5	−17 ·58				
R.	1	15 ·50						
β Ursæ Minoris ...... D.	9	15. 13. 9 ·16	16	9 ·37	19	− 0 ·08	12	− 0 ·96
R.	7	9 ·63						
S. P. . . D.	3	−15. 13. 9 ·45	3	− 9 ·45				
R.	. .	. . . . .						
λ Draconis .... D.	5	19. 49. 30 ·32	10	31 ·01	11	− 1 ·58	4	− 6 ·32
R.	5	31 ·70						
S. P. . . D.	1	−19. 49. 32 ·59	1	−32 ·59				
R.	. .	. . . . .						
β Cephei .... D.	9	20. 6. 37 ·25	18	36 ·72	21	− 0 ·57	12	− 6 ·84
R.	9	36 ·19						
S. P. . . D.	3	−20. 6. 37 ·29	3	−37 ·29				
R.	. .	. . . . .						
{ * R.A. $21^h.42^m.(10^s)$ D.	2	20. 43. 23 ·30	2	23 ·30	3	− 4 ·29	3	−12 ·87
(p_1) } R.	. .	. . . . .						
S. P. . . D.	1	−20. 43. 27 ·59	1	−27 ·59				
R.	. .	. . . . .						
55 Camelopardali..... D.	1	21. 5. 1 ·79	2	2 ·53	6	+ 0 ·80	6	+ 4 ·80
R.	1	3 ·26						
S. P. . . D.	4	−21. 5. 1 ·73	4	− 1 ·73				
R.	. .	. . . . .						
42 Camelopardali..... D.	3	22. 16. 10 ·05	6	10 ·00	7	+ 1 ·16	4	+ 4 ·64
R.	3	9 ·95						
S. P. . . D.	1	−22. 16. 8 ·84	1	− 8 ·84				
R.	. .	. . . . .						

CORRECTION OF ASSUMED LATITUDE—*continued.*

Star's Name, Position, and Mode of Observation.	Number of Obs.	N.P.D. from each Group.	Number of Obs.	Concluded N.P.D. in each Position on Assumed Latitude.	Number of Obs.	Algebraic Sum of Determinations.	Weight.	Product.
		° ′ ″		″		″		″
38 Ursæ Majoris ..... D.	1	23. 29. 1·99	2	3·47	4	− 1·66	4	− 6·64
R.	1	4·95						
S. P... D.	2	−23. 29. 5·13	2	− 5·13				
R.	..	.....						
6 Ursæ Majoris ...... D.	2	24. 49. 1·22	4	1·66	6	− 0·26	6	− 1·56
R.	2	2·09						
S. P... D.	2	−24. 49. 1·92	2	− 1·92				
R.	..	.....						
* R. A. 11h. 18m. (0s) .. D.	2	26. 2. 29·75	2	29·75	3	− 0·64	3	− 1·92
R.	..	.....						
S. P... D.	1	−26. 2. 30·39	1	−30·39				
R.	..	.....						
49 Camelopardali..... D.	1	26. 48. 29·80	2	30·73	6	− 0·31	5	− 1·55
R.	1	31·66						
S. P... D.	4	−26. 48. 31·04	4	−31·04				
R.	..	.....						
α Ursæ Majoris ...... D.	10	27. 25. 27·04	20	27·60	24	− 0·34	13	− 4·42
R.	10	28·15						
S. P... D.	4	−27. 25. 27·94	4	−27·94				
R.	..	.....						
α Cephei .... D.	13	28. 3. 41·39	26	41·00	31	− 0·08	16	− 1·28
R.	13	40·62						
S. P... D.	5	−28. 3. 41·08	5	−41·08				
R.	..	.....						
ο Ursæ Majoris....... D.	2	28. 46. 35·71	4	36·25	5	− 2·48	3	− 7·44
R.	2	36·79						
S. P... D.	1	−28. 46. 38·73	1	−38·73				
R.	..	.....						
42 Ursæ Majoris ..... D.	3	29. 52. 9·77	6	9·63	9	+ 0·58	7	+ 4·06
R.	3	9·49						
S. P... D.	3	−29. 52. 9·05	3	− 9·05				
R.	..	.....						
18 Lyncis .... D.	1	30. 5. 53·26	2	53·15	3	+ 0·41	2	+ 0·82
R.	1	53·04						
S. P... D.	1	−30. 5. 52·74	1	−52·74				
R.	..	.....						
υ Ursæ Majoris....... D.	2	30. 14. 41·66	4	42·40	7	− 1·42	6	− 8·52
R.	2	43·13						
S. P... D.	3	−30. 14. 43·82	3	−43·82				
R.	..	.....						

CORRECTION OF ASSUMED LATITUDE—*concluded.*

Star's Name, Position, and Mode of Observation.	Number of Obs.	N. P. D. from each Group.	Number of Obs.	Concluded N. P. D. in each Position on Assumed Latitude.	Number of Obs.	Algebraic Sum of Determinations.	Weight.	Product.
		° ′ ″		″		″		″
15 Lyncis .... D.	2	31. 23. 5·65	4	5·69	5	+ 1·03	3	+ 3·09
R.	2	5·72						
S. P..... D.	1	−31. 23. 4·66	1	− 4·66				
R.	..	.....						
ϑ Ursæ Majoris....... D.	8	32. 7. 0·74	16	1·09	18	+ 0·29	6	+ 1·74
R.	8	1·43						
S. P..... D.	2	−32. 7. 0·80	2	− 0·80				
R.	..	.....						
ϵ Ursæ Majoris....... D.	3	33. 12. 30·41	6	31·09	11	− 0·82	8	− 6·56
R.	3	31·77						
S. P..... D.	5	−33. 12. 31·91	5	−31·91				
R.	..	.....						
α Cassiopeiæ......... D.	3	34. 18. 9·52	6	9·48	8	− 0·27	4	− 1·08
R.	3	9·43						
S. P..... D.	2	−34. 18. 9·75	2	− 9·75				
R.	..	.....						

If z be the correction to be applied to the co-latitude, $2z$ + the algebraic sum of the two determinations ought to be = 0. Combining the whole with the weights above attached to them, $2z - 0''\cdot37 = 0$, or $z = +0\cdot19$. And, as the assumed co-latitude for the year was 38°.31′.21″·80, the co-latitude from this determination is 38°.31′.21″·99.

The assumed co-latitude, or 38°.31′.21″·80, has been used in the subsequent results.

§ 5. *Observations of Azimuth with the Altitude and Azimuth Instrument,* page [ii] to [xxvii].

The first *twelve* columns, on the left-hand page, as far as "Concluded Clock Time of Horizontal Transit," require little explanation. In making the observation, the instrument is clamped in azimuth, and the moderately-slow motion of the Vertical Circle is used to make the transit of the object take place over the middle of each vertical wire. When the transit is imperfect, no correction in time is applied to the mean of the wires observed.

The *thirteenth* column contains the error of the clock, as deduced from comparisons with the Transit Clock, by a process which will be explained hereafter.

By the application of this Clock Error to the Clock Time, together with the further correction $+0^{\mathrm{s}}{\cdot}30$ for Personal Equation when the observation was made by Mr. Ellis (E), the Sidereal Time in the *fourteenth* column is formed.

From the readings of the microscope-micrometers in the *last four* columns on the left-hand page, with the pointer-reading which is omitted, the Concluded Reading of Horizontal Circle in the *first* column of the right-hand page is formed in this manner:—The runs of the micrometers are examined every week. Suppose it is found that an arc of $5'$ requires $7^{\text{rev.}}{\cdot}8-p$ of micrometer a, $7^{\text{rev.}}{\cdot}7-q$ of micrometer b, $7^{\text{rev.}}{\cdot}9-r$ of micrometer c, and $8^{\text{rev.}}{\cdot}0-s$ of micrometer d. Then p, q, r, s, are very small quantities. Now suppose that the micrometer-readings in any observation are w, x, y, z: these four quantities being very nearly equal. Then the Concluded Circle Reading ought to be

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

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

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

$$w\times\frac{5'}{4\times7{\cdot}8}+x\times\frac{5'}{4\times7{\cdot}7}+y\times\frac{5'}{4\times7{\cdot}9}+z\times\frac{5'}{4\times8{\cdot}0}$$

$$+\frac{1}{4}\left\{w\times\frac{5'}{4\times7{\cdot}8}+x\times\frac{5'}{4\times7{\cdot}7}+y\times\frac{5'}{4\times7{\cdot}9}+z\times\frac{5'}{4\times8{\cdot}0}\right\}\times\frac{p+q+r+s}{7{\cdot}85}$$

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

$$w\times\frac{5'}{4\times7{\cdot}8}+x\times\frac{5'}{4\times7{\cdot}7}+y\times\frac{5'}{4\times7{\cdot}9}+z\times\frac{5'}{4\times8{\cdot}0}$$

$$+\frac{1}{100}\left\{w\times\frac{5'}{4\times7{\cdot}8}+x\times\frac{5'}{4\times7{\cdot}7}+y\times\frac{5'}{4\times7{\cdot}9}+z\times\frac{5'}{4\times8{\cdot}0}\right\}\times\text{Correction for Runs for }100''.$$

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

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

		″
Wire	1	− 598·47
	2	− 362·44
	3	− 120·77
	4	+ 120·31
	5	+ 360·92
	6	+ 600·46

These values were obtained by a process explained in the Description of the Instrument, from observations made in March and April, 1847, and are used only in 1847. When any number of wires (except the complete set of six wires) has been used in the transit, the corresponding corrections are taken from this table, and their mean is multiplied by the cosecant of Zenith Distance taken from the *second* column on the right-hand page, and thus a correction is obtained whose value is stated in the Notes. By the application of this final correction, the Concluded Reading in the *first* column on the right-hand page is formed.

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

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

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

The *twelfth* column contains the Concluded Level Indication. To 1847, November 10, this is obtained by means of tables based on the assumed values of the scale-divisions which are given at the bottom of each page. In order to diminish the magnitude of the numbers employed, the equivalents for *e*, *g*, *i*, *l*, begin from the scale-reading $0^{\text{div.}}$, and those for *f*, *h*, *k*, *m*, begin from scale-readings $150^{\text{div.}}$, $130^{\text{div.}}$, $200^{\text{div.}}$, $220^{\text{div.}}$, respectively. The Concluded Level Indication is the mean of these equivalents. From November 14, it has been assumed that each division represents one second of arc, and here the process for forming the Concluded Level Indication has been, to add the eight readings together, omitting 1000 from the sum, and to divide the remainder by 8.

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

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

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

§ 6. *Observations of Zenith Distance with the Altitude and Azimuth Instrument,*
page [xxx] to [xlix].

The *first eleven* columns require no explanation.

The *twelfth* column contains a correction which exists theoretically in all cases, but which in the Azimuths is practically insensible, although for the Zenith Distances, more especially those which are observed near the Meridian, it sometimes becomes important. The nature of it is this: In the subsequent calculations it is tacitly assumed that at the mean of the observed times of passage across the six horizontal wires (supposed free from error of observation), the body was at the point which represents the mean of all the six wires. This, however, is true only on the supposition that the vertical movement of the body is uniform. The correction is investigated in the following manner. In the spherical triangle whose sides are a, b, c, and where C is the angle opposite to c, let a and b be respectively the co-latitude of the zenith, and the north polar distance of the object, then

C is the hour-angle, and c the zenith distance. Suppose these letters to correspond truly to the position of the object when it passes the mean of the six horizontal wires: then if δC be the addition (expressed in parts of the radius) or $\delta C_s \times 15 . \sin 1''$, ($\delta C_s$ being expressed in seconds of time), which must be made to C to express the hour-angle when the object passes one wire, and δc (expressed in parts of the radius) or $\delta c_{''} \times \sin 1''$ ($\delta c_{''}$ being expressed in seconds of arc) the addition which must be made to c to give the zenith distance of the same wire, we have

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

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

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

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

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

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

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

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

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

substituting this in the last term we have

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

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

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

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

Mean of observed hour-angles in seconds of time =

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

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

Mean of the observed hour-angles in seconds of time =

$$C_s - \frac{\cot C . 15 \sin 1''}{12} . \frac{70}{100} \mathrm{I}^2$$

$$= C_s - \frac{7}{8} \sin 1'' \times \cot C \times \mathrm{I}^2$$

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

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

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

By the application of this correction to the mean of observed times, the Concluded Clock Time in the *thirteenth* column is formed. The *fourteenth* and *fifteenth* columns require no explanation, beyond that in the section of Azimuths: the quantity + $0^s{\cdot}30$ applied for Mr. Ellis's personal equation being included in the Sidereal Times, as in the section of Azimuths.

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

When the transit over any number of wires is omitted, the time of transit retained is the mean of the transits actually observed, but a correction in arc is applied, corresponding to the interval between the mean of the wires actually observed and the mean of the six wires. Calling the wires I, II, III, IV, V, VI, in the order in which a star on the west side of the meridian passes when the graduated face is Right (and remarking that the signs are to be changed when only one of these conditions is altered), the corrections applicable for each wire singly have been taken during the year 1847 from the following table (which is based upon observations made in 1847, March and April).

		″
I	−	301·00
II	−	180·40
III	−	60·00
IV	+	60·40
V	+	179·93
VI	+	301·06

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

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

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

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

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

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

The Zenith Point, whose value is given at the foot of each page, is obtained by a process which will be explained hereafter: it is sufficient here to state that it also contains implicitly the same constant depending on the assumed zeros of the Level-Scales. The Concluded Zenith Distance therefore in the *fifteenth* column, which is formed by subtracting the Zenith Point from the Corrected Reading when the graduated face is Right, and by subtracting the Corrected Reading from the Zenith Point when the graduated face is Left, is freed from this constant.

§ 7. *Comparison of Tabular Azimuths and Zenith Distances, with Azimuths and Zenith Distances Observed*, page [lii] to [xci].

The *three first* columns need no explanation.

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

The Tabular R.A. of Center in the *fifth* column is formed; for the stars of the Nautical Almanac, by applying to the places of the Nautical Almanac the mean of the corrections given in the Introduction to the Volumes for 1844 and 1845; for η Ophiuchi, by bringing up the Mean Place from the Greenwich Catalogue of 1439 stars, and applying the correction $A\ a + B\ b + C\ c + D\ d$; and for the Moon, by interpolating with second differences between the hourly places of the Moon in the Nautical Almanac, using as argument the Mean Solar *seventh* Time of the fourth column.

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

The *eighth* column contains the Tabular Geocentric N.P.D. of Center. It is formed; for the stars of the Nautical Almanac, by applying to the N.P.D. of the Nautical Almanac the mean difference of the results in the Volumes for 1844 and 1845, from the places of the Nautical Almanac: for η Ophiuchi, by bringing up the N.P.D. from the Greenwich Catalogue of 1439 stars, and applying to it the correction $A\,a' + B\,b' + C\,c' + D\,d'$, (taking a', b', &c. in the sense given to them in the Catalogue of the British Association); for the Moon, by interpolating with second differences between the hourly places of the Nautical Almanac.

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

With the Hour Angle unaltered, and the N.P D. altered (for the Moon) by the correction just described, and with the co-latitude 38°.31′.21″·80; the Tabular Azimuth in the *tenth* column of the left-hand page, and the Tabular Normal-centric Zenith Distance in the *fifth* column of the right-hand page are computed by the following formulæ:

Log tan α = log cos hour-angle + log tan Normal-centric N.P.D.
$\beta = \alpha -$ co-latitude
Log tan zenithal angle = log sin α + log. tan hour-angle − log sin β
Log cotan zen dist. = log cotan β + log cos zenithal angle.

The Correction to Azimuth for Moon's Semidiameter, in the *first* column of the right-hand page is thus computed. The semidiameter is interpolated with second differences from the Nautical Almanac, but it then requires the following corrections: First, the distance of the Moon from the foot of the normal is greater than that from the Earth's center by a × [7·71748] × cos Moon's N.P.D., and therefore her angular semidiameter is diminished in the proportion of Moon's distance to Moon's distance − a × [7·71748] × cos Moon's N.P.D., or 1 : 1 − sin hor. eq. par. × [7·71748] × cos Moon's N.P.D.: or, using the mean parallax 57′, the proportion is 1 : 1 − [5·93708] × cos Moon's N.P.D. Secondly, the Moon's tabular semidiameter is increased by 2″·5, for agreement with the results of the Greenwich Observations: and therefore the azimuthal semidiameter must be increased in the proportion of 1 : 1 + $\frac{2{\cdot}5}{9300}$. These two corrections are incorporated in the form of one factor $1 + \frac{25}{9300} - [5{\cdot}93708] \times \cos$ Moon's N.P.D., whose logarithm is taken from a small table with argument N.P.D., the number for N.P.D. 60° being 0·0011472, that for N.P.D. 90° being 0·0011658, and that for N.P.D. 120° being 0·0011844. The Correction to Azimuth is computed by the formula $\frac{\text{Corrected semidiameter}}{\text{Sine Normalcentric Zenith Distance}}$; the term depending on the difference between the sine of semidiameter and the arc being insensible.

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

The Seconds of Observed Azimuth in the *third* column are transcribed from the section of Azimuths: and the Apparent Error of Tabular Azimuth in the *fourth* column, is formed by subtracting the observed azimuth from the tabular azimuth in the last column of the left-hand page, or the second column of the right-hand page.

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

The Normalcentric Semidiameter for the Zenith Distance in the *sixth* column is formed by adding, to the semidiameter interpolated from the Nautical Almanac, the quantity $2''{\cdot}50 - 930'' \times [5{\cdot}93708] \times \cos$ Moon's N P.D. The value of this expression for N.P.D. 60° is $+2''{\cdot}46$, for N.P.D. 90° it is $+2''{\cdot}50$, and for N.P.D. 120° it is $+2''{\cdot}54$.

The place of the Moon's center having been referred to the foot of the normal, it is necessary to compute the Parallax as referred to the foot of the normal, and for this purpose, first, the Normalcentric Horizontal Parallax to be used, must be corrected so as to make it depend on the normalcentric radius, and for this purpose it must be multiplied by $\frac{\text{Normalcentric Radius of Greenwich}}{\text{Earth's semimajor axis}}$. Using the same notation as before, the factor is found to be $= \frac{1}{a \sin l} \cdot \frac{a^2}{b^2} y = \frac{a}{\sqrt{(b^2 \sin^2 l + a^2 \cos^2 l)}}$; the logarithm of which is 0·0008851. Secondly, it must be made to depend on the Moon's distance from the foot of the normal, and for this purpose it must be multiplied by $1 - [5{\cdot}93708] \times \cos$ Moon's N.P.D. Thirdly, the constant term is to be increased by $\frac{1}{2600}$ part, to make it agree with Professor Henderson's determination. These three corrections are embodied in one logarithmic table with argument N.P.D., the number for 60° being 0·0010342, that for 90° being 0·0010528, and that for 120° being 0·0010717. By the addition of this logarithm to the logarithm of the seconds of parallax interpolated from the Nautical Almanac with second differences, the logarithm in the *seventh* column is formed.

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

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

§ 8. *Computation of Clock Errors and Instrumental Errors for the observations with the Altitude and Azimuth Instrument, and of the Errors of the Moon's Tabular R.A. and N.P.D.*, page xciv to cxxii.

The comparisons of the Transit Clock and the Clock of the New South Dome used with the Altitude and Azimuth Instrument (Graham 1) are made by means of a solar chronometer (Parkinson and Frodsham 1826), the chronometer is brought close to each of the clocks, and the time of accurate coincidence of beats is noted; the chronometer-intervals between the comparisons, which is sensibly Solar Time, is converted into Sidereal Time; and the sidereal time at the comparison with the transit-clock, being found by correcting the transit-clock-time for error and rate of the transit-clock, the sidereal time at the comparison with the New 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 Reading of Horizontal Circle from observation of a high star, with Face Right and Face Left; C_r and C_l the corresponding computed azimuths; L_r and L_l the level indications; D_r and D_l the zenith distances; and let o_r, o_l, c_r, c_l, l_r, l_l, d_r, d_l, be the similar quantities for a low star. Then the true azimuth of the high star deduced from observation, face Right, is

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

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

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

The true azimuth determined from observation, face Left, is

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

and this observation therefore gives the equation,

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

Subtracting the first equation from the second,

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

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

A similar treatment of the observations of the low star gives

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

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

As 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 thought advisable to adopt the mean of the determinations of x as a quantity to be used without alteration for a considerable time.

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

$$O_r' + L_r \,.\, \operatorname{cotan} D_r - C_r = +y \,.\, \operatorname{cotan} D_r + z + w$$
$$O_l' - L_l \,.\, \operatorname{cotan} D_l - C_l = -y \,.\, \operatorname{cotan} D_l + z + w$$

$$\text{Whence } \frac{(O_r' + L_r \,.\, \operatorname{cotan} D_r - C_r) - (O_l' - L_l \operatorname{cotan} D_l - C_l)}{\operatorname{cotan} D_r + \operatorname{cotan} D_l} = y.$$

Any one star suffices for this determination, but a high star is best.

The number y, it is to be observed, corresponds strictly with the horizontal position of the Horizontal Axis of the Vertical Circle, and has no relation whatever to the Level-Zero corresponding to a vertical position of the Vertical Axis of Azimuthal Rotation; except that, supposing the workmanship of the vertical pivots to be perfectly good, and the position of the horizontal axis in its Y's to be invariable, there ought to be a constant difference between them. The latter Level-Zero is the mean of the level-indications in opposite positions of the instrument: and it has been thought sufficiently accurate for this purpose to take the mean of the level-indications for positions used in successive observations of the same object (though the instrument was not exactly reversed). The comparison of these Level-Zeros with those relating to the Horizontal Axis, gives a set of differences whose mean values have already been recorded in the description of the instrument. These mean differences are then applied to the individual Level-Zeros of the Vertical Axis, and thus another value of the quantity y is obtained, which may be combined with that found from the azimuthal transits. Usually the mean of the two is taken. The principal numbers of the whole of this work are given in the tabular part of this Section.

The comparison of the Observed Circle Reading corrected for Collimation and Level with the computed Azimuth gives the Zero of Azimuth. In adopting a mean it has been usual to consider the lower stars as much more likely to give accurate results than the high stars, and therefore double weight is always given to the low stars.

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

$$O_r - Z = \text{true zenith distance with face Right} = C_r + e$$

$$Z - O_l = \text{true zenith distance with face Left} = C_l + e$$

Subtracting the first from the second,

$$2Z - (O_r + O_l) = C_l - C_r$$

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

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

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

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

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

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

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

$$\delta . A = -r . \sin N.P.D. \times \delta . R.A. - s \times \delta . N.P.D.$$

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

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

$$\Sigma (\delta . A) = -\delta . R.A. \times \sin N.P.D. \times \Sigma (r) - \delta . N.P.D. \times \Sigma (s)$$

By solution of these equations,

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

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

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

The reductions for the year 1847, and for a large part of the year 1848, had been brought to this stage, when the necessity for a further correction, of a singular character, was discovered. On examining the results of Error of Tabular R.A., it was found that the large errors, without exception, were given by Mr. H. Breen's observations. The circumstances under which these occurred were so various, in respect of Moon's age and Moon's position in her orbit, and the intermixture of the observations had been so complete, that there was no doubt whatever that this was the result of a difference in the mode of observation. And this was not a result of personal equation usually so called: for it was known from the investigations of personal equation, as exhibited in the clock errors given by stars (which are confirmed by similar investigations made to the end of 1848), that the personal equation was small. Neither was it a different estimation of the Moon's diameter, for the difference of errors of Moon's R.A. is nearly the same, and in the same direction, whether the first Limb or the second Limb be observed. It is strictly speaking a *difference between the personal equation for the Moon, and that for the stars:* or it may be thus stated, that *the* *duration of the impression on the nerves of the eye, or the time occupied in bringing into comparison the impressions on the eye and on the ear, is not the same when the Moon is observed with the eye, as when a star is observed with the eye.* The evidence of this is given by the following numbers.

By observations of the first limb of the Moon, from 1847, May 16, to 1848, May 28:

	s
The mean of 45 errors of Moon's Tabular R.A., by Mr. Dunkin, is...	+ 0·53
The mean of 35 errors, by Mr. Breen, is........................	+ 0·99
Excess of Mr. Breen's	+ 0·46

By observations of the second limb of the Moon through the same period:

	s
The mean of 33 errors, by Mr. Dunkin, is........................	+ 0·50
The mean of 27 errors, by Mr. Breen, is........................	+ 0·80
Excess of Mr. Breen's	+ 0·30

That this is an error of *time* only will be seen from the following consideration. A little examination will show that, though an error of time will produce errors both in Azimuth and in Altitude, yet when the results of the observations have been reduced so as to exhibit errors of R.A. and N.P.D., the errors of R.A. will be affected by exactly the whole amount of the error of time, while the errors of N.P.D. will be entirely free from it. The results in North Polar Distance were therefore collected, and the following is an abstract of them.

By observations of the upper limb of the Moon, from 1847, May 16, to 1848, May 28:

	″
The mean of 33 errors of Moon's Tabular N.P.D., by Mr. Dunkin, is	− 4·07
The mean of 19 errors, by Mr. Breen, is........................	− 4·69
Excess of Mr. Breen's	− 0·62

By observations of the lower limb of Moon, through the same period:

	″
The mean of 42 errors, by Mr. Dunkin, is........................	− 0·12
The mean of 42 errors, by Mr. Breen, is........................	− 0·22
Excess of Mr. Breen's	− 0·10

These results may be considered identical for the two observers.

It now became necessary to examine which of the two persons observed the Moon rightly; or rather, which of them observed the Moon in the same way as the observers who are most trusted. For this purpose, the observations of the Moon by Mr. Henry and Mr. Dunkin with the Transit Instrument, from 1846, February 4, to July 30, were compared: they gave the following result:

By observation of the first limb,

	s
Mean of 17 errors of R.A. by Mr. Henry	+ 0·28
Mean of 21 errors by Mr. Dunkin	+ 0·24
Excess of Mr. Dunkin	− 0·04

By observations of the second limb,

	s
Mean of 10 errors by Mr. Henry	+ 0·68
Mean of 14 errors by Mr. Dunkin	+ 0·67
Excess of Mr Dunkin	− 0·01

It is evident here that Mr. Dunkin's determinations may be assumed as free from error: and that the discordance found above is to be thrown entirely on Mr. Breen's observations.

It would have been desirable to institute a similar comparison between Mr. Henry's and Mr. H. Breen's results, but the materials do not exist in sufficient amount. Three observations of the Sun by Mr. H. Breen, compared with neighbouring observations, gave a result $+0^{s}{\cdot}14$. One of the Moon appeared to give a large quantity. Venus near inferior conjunction also gave a large quantity. The observations of Saturn and Uranus also agree in the same way: but those of Mars and Jupiter tend to the opposite error. None of these investigations are fit to be put in competition with that already given.

The discordances for the two limbs are so nearly equal that it was assumed that the mean, or $+\ 0^{s}{\cdot}38$, might be used in every instance. In applying this, however, it was thought desirable to introduce a small correction for personal equation as applying to the observations of stars. By investigations of transit observations, completed about that time, it appeared that in the reduction of star-observations in the same way, an error of $+\ 0^{s}{\cdot}14$ would have been found. This was confirmed by the following investigation of Zeros of Azimuth. From 1847, May 16, to 1848, May 28, confining ourselves to those cases in which the determinations by the different observers were well intermixed, and omitting those in which the same observer was employed on the instrument for a long time, the following results were obtained:

	° ′ ″
Mean of 139 Zeros of Azimuth determined by Mr. Dunkin	10. 44. 1·75
Mean of 117 „ „ determined by Mr. Breen	10. 44. 4·18
Excess of Mr. Breen	+ 2·43

That is to say, it was necessary to turn the instrument to the West through $2''{\cdot}43$ in order that the time of instrumental transit of a star, as noted by Mr. Breen, might coincide with that noted by Mr. Dunkin; and therefore in a given position, Mr. Breen notes the time earlier than Mr. Dunkin; and, if their observations are grouped together, Mr. Breen gives the observed R.A. of a star too small, and the Errors of Tabular Place too great. The amount of the difference of Zeros of Azimuth agrees sufficiently well with the amount of personal equation in time already stated. Now the Zeros of Azimuth, actually adopted in the reductions, had been deduced from so many mixed observations of Mr. Dunkin and Mr. H. Breen, that we might say without great error that all Mr. Breen's star-observations in azimuth-transits were affected by an error $+0^{s}{\cdot}07$, and all Mr. Dunkin's by an error $-0^{s}{\cdot}07$. Therefore as regards the deduction of the Moon's errors of Tabular Azimuth, as derived from this mixed Azimuth-zero, Mr. Dunkin's observations give one error (estimated in the same direction as R.A.) corresponding to $-0^{s}{\cdot}07$ of time, and Mr. Breen's give an error of a similar kind corresponding to $+0^{s}{\cdot}31$. If the errors of Tabular Zenith Distance had corresponded to the same amounts of time; then the errors of Tabular R.A. would also have corresponded to the same amounts of time, and the excess of Tabular N.P.D. would, as depending on this cause, have been $0''{\cdot}00$. But in fact the Zenith Distances are referred to a zenith point which is free from the effect of personal equation, and therefore Mr. Dunkin's observations give an error of zenith-distance corresponding to an error $0^{s}{\cdot}00$ of time, and Mr. Breen's give one corresponding to an error $+0^{s}{\cdot}38$. Although these errors are not precisely those which give error of R.A. $-0^{s}{\cdot}07$ or $+0^{s}{\cdot}31$, and error of N.P.D. $0''{\cdot}00$, yet they approach so near that the difference will not be sensible. Hence, for the final errors in R.A., the correction $+0^{s}{\cdot}07$ has been applied to Mr. Dunkin's results, and $-0^{s}{\cdot}31$ to Mr. Breen's results: in N.P.D. no correction is applied.

§ 9. *Catalogue of the Mean Places of Stars observed in the Year* 1847, page 1 to 15.

The right ascensions in the catalogue are the means of all the separate determinations of the mean right ascension of each star, excluding only those which are contained in brackets. The annual variations for the Nautical Almanac Stars are taken from the Nautical Almanac (those in which proper motion is included being marked with an asterisk). The others are computed independently, with the elements given in the Nautical Almanac, 1834, 2nd edition, page xiii; which are taken from the *Tabulæ Regiomontanæ*, and which have been used for all the later volumes of the Nautical Almanac.

The north polar distances in the catalogue are the means of the daily results without any correction. The adopted seconds of N.P.D. are found by taking the means of the groups of direct and reflexion observations, giving to each a weight proportional to its number of observations. With regard to circumpolar stars, the following rules have been followed. For stars whose N.P.D. does not exceed 15°, the observations above and below the pole are considered equally good: from N.P.D. 15° to N.P.D. 36°, those below have the weight $\frac{2}{3}$ for each observation: from N.P.D. 36° to N.P.D. 41°, those below have the weight $\frac{1}{2}$: beyond 41° N.P.D., the observations are not combined. The annual variations are taken from the Nautical Almanac, as far as its list extends: for other stars they are computed with the elements given in the Nautical Almanac, 1834, 2nd edition, page xiii.

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

§ 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 Tables, &c.*, pages 17 to 42.

The duration of the passage of the Sun's diameter is found by subtracting the clock-time of transit of the first limb from that of the second limb in the *Transits observed, &c.*, without any further correction. The tabular duration is found by doubling the time of passage of the semidiameter given in the Nautical Almanac. The excess of the latter over the former is set down as the apparent Error of the Nautical Almanac. The mean of all the values of this error is $-0^{s}{\cdot}047$.

The Sun's vertical diameter is found by subtracting the zenith-distance of the north limb, corrected for refraction and parallax, from that of the south limb similarly corrected. The tabular diameter is found by doubling the semidiameter of the Nautical Almanac. The excess of the latter above the former is set down as the Apparent Error of the Nautical Almanac, and the mean of all the values of this error is $-2''{\cdot}98$.

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

The Moon's vertical diameter is found in the same manner as the Sun's (the correction for defective illumination having been already applied, see page lxx). The mean of nineteen values of the error is $-6''{\cdot}31$.

The vertical diameters of Venus are found by doubling the semidiameters given in the section of *Observations made with Troughton's Mural Circle.* These diameters, therefore, are not imperfect diameters, as observed in the first instance. The vertical diameters of the other planets are merely the measures corresponding to the micrometer-readings in the tenth column of the right-hand page of the same section, or are the doubles of the semidiameters in the eleventh column.

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 the Sidereal Time: the whole of these numbers being taken from the Nautical Almanac. In practice this operation is made a little easier, by putting the addition in the following form:

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

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

When any object has been observed in North Polar Distance, and not in Right Ascension, the Right Ascension at Transit (for the calculation of the Mean Solar Time) is taken from the Nautical Almanac.

The Right Ascensions of the Sun are transcribed from those in the *Transits, &c.*, with no alteration, except that, when necessary, the personal equation is applied as mentioned in a former part of this Introduction (page lviii); and that, when the first limb only has been observed, the correction $+0^{s}\cdot02$ has been applied; and when the second limb only has been observed, the correction $-0^{s}\cdot02$. The North Polar Distances of the Sun are the means of those deduced from the two limbs, in the 12th column on the right-hand page in the section *Observations with the Mural Circle:* the correction $+1''\cdot49$ has been applied when the North limb only has been observed, and the correction $-1''\cdot49$ when the South limb only has been observed.

The Right Ascensions of the Moon are taken from the *Transits, &c.*, corrected, if necessary, for personal equation: the correction $+0^{s}\cdot20$ being applied when the first limb was observed, and $-0^{s}\cdot20$ when the second limb was observed. This is the same correction which was used in all preceding years since 1836: it is fully supported by all the observations hitherto made, as appears from the following collection. The equatoreal observations for 1847 will be found in a subsequent part of this volume. With regard to these and the other equatoreal observations, it is to be noted that, on account of the greater unsteadiness of the instrument, and the smaller number of wires, one set of equatoreal observations is considered equivalent only to one transit observation.

Year.	Tabular Error.	Number of Observations in Results.	Error × Number.	
	s		s	
1836	— 0·41	3	— 1·23	Transit Observations.
1837	— 0·38	1	— 0·38	
1838	— 0·48	2	— 0·96	
1839	— 0·56	3	— 1·68	
1840	— 0·20	2	— 0·40	
1842	— 0·17	3	— 0·51	
1843	— 0·33	3	— 0·99	
1844	— 0·34	3	— 1·02	
1845	— 0·46	2	— 0·92	
1846	— 0·09	1	— 0·09	
1847	— 0·25	3	— 0·75	
1837	— 0·37	2	— 0·74	Equatoreal Observations.
1838	— 0·31	2	— 0·62	
1839	— 0·33	4	— 1·32	
1840	— 0·33	3	— 0·99	
1841	— 0·40	1	— 0·40	
1842	— 0·42	3	— 1·26	
1843	— 0·71	2	— 1·42	
1844	— 0·27	1	— 0·27	
1845	— 0·33	3	— 0·99	
1846	— 0·43	2	— 0·86	
1847	— 0·49	2	— 0·98	
		51	— 18·78	
		Mean Tabular Error =	— 0·37	

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

The North Polar Distances are taken from the *twelfth* column on the right-hand page in the section of *Observations with the Mural Circle*, the only alteration being that the correction + 2″·61 is applied when the North limb has been observed, and − 2″·61 when the South limb has been observed. This correction is deduced from the following collection of observations of the Moon's Vertical Diameter.

Errors of Moon's Tabular Vertical Diameter.

Year.	Tabular Error.	Number of Observations.	Error × Number.
	″		″
1836	− 6·23	8	− 49·84
1837	− 5·94	7	− 41·58
1838	− 5·51	11	− 60·61
1839	− 6·02	6	− 36·12
1840	− 3·56	10	− 35·60
1841	− 4·07	10	− 40·70
1842	− 3·83	26	− 99·58
1843	− 5·05	21	− 106·05
1844	− 5·50	28	− 154·00
1845	− 5·26	25	− 131·50
1846	− 5·85	28	− 163·80
1847	− 6·31	19	− 119·89
		199	−1039·27
		Mean Tabular Error =	− 5·22

When both limbs are observed, the mean is taken. There is then applied − $\frac{1}{2600}$ of the lunar parallax actually employed, for the augmentation of lunar parallax deduced by Professor Henderson, from the Observations made at the Cape of Good Hope, and compared with those made in Europe (Mem. Ast. Society, vol. x.). The tabular N. P. D. are taken from the 7th column in the section *Moon-culminating Stars* of the Nautical Almanac.

For the Right Ascensions of Venus, a correction for the error of semidiameter has been applied. From an investigation in the Introduction to the Greenwich Astronomical Observations for 1838, it appears that the error of the semidiameter in right ascension may be represented by the following formula:—

$$-0^{s}{\cdot}05 - 0{\cdot}03 \times \text{tabular semidiameter in R. A.}$$

The corrections applied in consequence are as follows:

	s		s
January 11 to May 10	+ 0·06	September 27	+ 0·11
May 17 to July 29	+ 0·07	October 7	− 0·11
July 31 to August 14	+ 0·08	November 1 to 9	− 0·09
August 25	+ 0·09	November 17 to December 7	− 0·08
September 11 to 14	+ 0·10	December 14 to 16	− 0·07

For the correction of the Right Ascension of Mars, the observations of the time of transit of his diameter, during the year 1847, have been used. From these it appears that the mean of the tabular errors of the transit of his diameter is − $0^{s}{\cdot}103$, and the mean of the tabular times of transit of the diameter is $1^{s}\cdot117$; the error of the tabular semidiameters may therefore be expressed by the formula

$$-0\cdot09 \times \text{tabular time of transit of semidiameter.}$$

The corrections which have in consequence been applied to the right ascensions, when one limb only was observed, are as follows :

	s		s
August 20 to September 1	− 0 ·04	November 1 to 18	+ 0 ·06
September 2 to 26	− 0 ·05	November 23 to December 1	+ 0 ·05
October 5 to 26	− 0 ·06	December 6 to 14	+ 0 ·04

For all other planets, the Right Ascensions are extracted from the *twelfth* column on the right-hand page of *Transits as observed, &c.*, with no alteration except for personal equation, when necessary: for all the planets, the North Polar Distances are taken from the *twelfth* column on the right-hand page of the *Observations with the Mural Circle.*

The tabular places are taken from the Nautical Almanac in all cases when they are given in that work for the days of observation.

For Flora, the tabular places were computed from an Ephemeris derived from Mr. Hind's third Elements. The first part of the Ephemeris, from 1847, October 18 to December 11, was computed by Mr. Pogson, and communicated by Mr. Hind to the Astronomer Royal; the second and third parts are printed in the Monthly Notices of the Royal Astronomical Society, for December, 1847, and January, 1848, Vol. viii., Nos. 2 and 3.

For Astræa, the tabular places were computed from D'Arrest's second Ephemeris, contained in Nos. 13, 14, and 15 of Vol. vii. of the Astronomical Society's Notices; which is the same as that in No. 590 of the *Astronomische Nachrichten,* after applying the correction for difference of longitude.

For comparison with observations of the tabular places of Juno on August 14, and of Ceres on January 11 and 15, those places were obligingly computed at my request by Lieutenant Stratford, R.N., Superintendant of the Nautical Almanac.

For Neptune, the tabular places were computed from Mr. Adams' Ephemeris, contained in Nos. 16 and 17, Vol. vii., of the Astronomical Society's Notices.

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

In the Observations of 1847, the clock-error has been obtained by means of a combination of the places of the clock-stars as observed in four preceding years, as explained in page xlvii of this Introduction. The Apparent Errors of R.A. are found by comparing the observed R.A., without any alteration, with the Tabular R.A. The Errors in Longitude and E.P.D. are formed by the use of the numbers P, Q, R, S, in the Appendix to the Greenwich Observations, 1836. For any of the small planets, whose latitude exceeded the limits of the tables, the longitude and E.P.D. were 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 gave the Errors in Longitude and E.P.D.

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

For the four small planets,

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

Then

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

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

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

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

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

For other planets, the following are used:

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

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

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

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

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

In the expressions above, different quantities are neglected for the small planets and for the other planets. For the small planets, it is not allowed to neglect the latitude in any part of the expressions; while, at the same time, their errors in general are so large that the earth may be supposed to move exactly in the orbit assigned by the tables. For the other planets, the latitude may be neglected in the formula; but it appears proper to retain the errors of the earth's place, as probably comparable in magnitude to those of the planets. A different form from that of preceding volumes has been adopted since the year 1839, for avoiding excessively large coefficients with frequent changes of sign, and for similarity with the form adopted in the published Reductions of the Planetary Observations, made at Greenwich from 1750 to 1830.

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

The Errors of the Tabular Longitude and Ecliptic Polar Distance of the Moon are deduced from the Errors of Tabular Right Ascension and North Polar Distance, for all the meridian observations, by the use of the numbers P, Q, R, S. For the observations made with the Altitude and Azimuth Instrument, the errors of Tabular R.A. and N.P.D. are extracted from the last section of computations of the observations made with that instrument, corrected for the Personal Equation of Mr. Breen.

§ 11. *Observations of γ Draconis with the Zenith Tube, and Reduction of the Observations,* page 43 to 61.

For a general description of the Zenith Tube, and an account of the steps which its construction renders necessary for the reduction of the observations, I refer to page xxix. It will be sufficient to state here, that the upper part and the lower part of the plumb-line are viewed by micrometer-microscopes, the observation with which detects and measures any inclination of the telescope to the vertical; and that the star while passing the field of view of the telescope is bisected in reversed positions of the tube by means of two wires, V and V*, in the field of view, carried by the Grand Micrometer.

The values of the several micrometer-screws used throughout the year 1847 were determined in the year 1846, and a detailed account of the observations for this determination, is given in the Introduction for that year.

The equivalents to the readings of the several micrometers are to be added together, and they will then give the star's apparent Zenith Distance (to be diminished by a certain constant or index error, called $-c$ in the printed Observations, which depends upon nothing whatever but the instrumental connexion between the object-glass, the upper plumb-line microscope, the grand micrometer, and the lower plumb-line microscope). The Zenith Distance thus deduced is estimated positive towards the north when the eye-piece is west, or towards the south when the eye-piece is east.

The tube was formerly used in reversed positions for transits of γ Draconis made on different days, till near the end of the year 1841, when it was thought desirable, on account of the still unsatisfactory nature of the results, to remove the only remaining visible source of error, by rendering the instrument capable of rapid and easy reversion, for the purpose of enabling the observer to make a complete observation in reversed positions at the same transit. The method of doing this is described above, page xxx.

The correction applicable to the reading of the Grand Micrometer for the bisection of the star with wire V* in order to reduce it to the reading for wire V, so that (omitting the entire revolutions) the observations in the two positions may be considered to have been made with the same wire, was found in the year 1843 to be $-1''\cdot374$. Observations were made for the verification of this correction in 1847, and, the resulting value being $-1''\cdot406$, no alteration has been made.

Let then z be the star's zenith distance north at the time of observation; let also s_w and s_e be the respective sums, for the two observations, of the equivalents for the micrometer-readings with the eye-piece west and east.

Then $z = s_w + c$

And $z = -s_e - c$

Hence $c = \frac{s_w + s_e}{2}$

The values of c are given explicitly for each observation, that the general steadiness of the instrument may be at once perceived, though, according to the present mode of observation, nothing whatever depends upon the change of the values from day to day.

As the tube was taken down in the summer of the year 1848, the observations for that year are given together with those for 1847.

§ 12. *Observations of the Duration of Transit of the Moon's Diameter, with the North-East Equatoreal,* pages 63 and 64.

These observations were made for the purpose of ascertaining the error in the tabular semidiameter of the Moon adopted by Burckhardt. The times selected were as near as possible to the times of opposition in right ascension. As the Moon was then at a distance from the meridian, it is necessary to examine into the influence of the hour-angle upon the duration of transit, which may be done in the following manner :—

During each transit of a diameter, the Equatoreal is fixed relatively to the earth. Suppose then the Moon to stand still in space, while the earth and the equatoreal telescope which is firmly attached to it move round. The axis of the telescope produced (or rather the plane of its meridional wire) will come in contact successively with one side and with the other side of the Moon. Produce these touching positions of the plane backwards till they intersect. Their intersection will be in a line parallel to the earth's axis: when the Moon is near the meridian, the intersection will be nearly as distant from the place of observation as the earth's axis is: when the Moon is near the six-hour angle their intersection will be near the place of observation: and generally their intersection will be at the place determined by drawing a perpendicular from the earth's axis upon the plane of the meridional wire. Consequently, the angle which the earth and telescope must describe that the plane may pass the Moon's diameter, will be found by dividing the Moon's diameter by the Moon's distance from the perpendicular dropped from the earth's axis upon the meridional plane passing through the Moon. Now, the Moon's distance here spoken of is the same as the Moon's distance from the earth's axis multiplied by the cosine of the parallax in right ascension. When the Moon is on the meridian the cosine of the parallax in right ascension is 1. Therefore the time in which the plane passes the Moon's diameter (that is, the duration of transit of the Moon's diameter) in any hour-angle, is to the duration of transit on the meridian, as unity to the cosine of the parallax in right ascension. As that parallax cannot exceed 40′, whose cosine is 0·9999323, the duration of transit cannot differ from that on the meridian by the time of transit × 0·0000677: a quantity wholly insensible. The Moon's motion in right ascension produces the same effect in all cases as if the velocity of the earth's rotation were altered in a certain proportion. The duration of transit is therefore sensibly the same at all hour-angles as if the Moon were on the meridian of the place.

The columns of the printed observations need little explanation. The correction for defect of illumination is found by estimating the Sun's perpendicular distance from the meridian passing through the Moon, produced to complete the circle; and considering the defect to be equal to the Moon's semidiameter multiplied by the versed sine of that distance. No correction for defective illumination is needed in either case. The tabular duration is interpolated for the hour-angle (formed by comparing the sidereal time with the Moon's right ascension) between the tabular durations of the Nautical Almanac, which correspond to hour-angles of 0^h and 12^h successively. The deduced diameter shews (in conformity with the results obtained in other ways) that Burckhardt's semidiameter is too small.

§ 13. *Comparisons in Right Ascension and North Polar Distance of Groombridge* 1830, *and a Neighbouring Star, made with the North-East Equatoreal*, pages 65 to 76.

The observations of the star Groombridge 1830 were undertaken for the purpose of testing the accuracy of the large parallax, supposed by M. Faye to exist in this star. The small star, compared by him with Groombridge 1830, was found to be of too low a magnitude to be observed with sufficient accuracy with the telescope of the North-East Equatoreal; another brighter star was discovered, but at a greater distance, and this star was chosen for comparison.

For determining with confidence, from the observations, the existence or non-existence of so small a quantity as annual parallax, it was thought necessary that the adjustments of the equatoreal should be examined, and that the instrument should be set as nearly correct as its construction would permit. For this purpose a series of observations was made by Mr. Main, and the results given beneath will shew that when the instrument was brought into use for the observations of Groombridge 1830, the remaining errors of adjustment were quite insignificant, and the difference of positions of the two stars would require no numerical correction on this account.

The position of the polar axis was first examined by observing the instrumental polar distances of four stars in different positions; two near the meridian above and below the pole, and two near the six-hour angles east and west.

The observations are as follows, each microscope being read for the positive and negative divisions of the declination circle, and the correction for runs being applied.

1846, November 3.

ε Pegasi.

Graduated Face of Declination Circle W.

h m ° ′ ″

At 21. 47 clock time, concluded circle-reading, 80. 46. 38 ·7

Graduated Face E.

At 21. 55 clock time, concluded circle-reading, 99. 10. 15 ·9

Applying to these readings the refractions +52″·3 and −52″·4, and taking the mean of the deduced N.P.D.'s, we obtain for the apparent N.P.D., 80°.49′.3″·3. The tabular N.P.D., from the Nautical Almanac, is 80°.49′.13″·0. Hence error of observed N.P.D. = −9″·7.

Aldebaran.

Graduated Face of Declination Circle N.

h m ° ′ ″

At 22. 3 clock time, concluded circle-reading, 106. 14. 29 ·0

Graduated Face S.

At 22. 10 clock time, concluded circle-reading, 73. 42. 3 ·8

Applying for refraction the corrections – 4′.43″·5 and + 4′·12″·0, and proceeding as before, we obtain for the observed N. P. D. 73°.48′·15″·2. The tabular N. P. D. is 73°.48′·14″·7. Hence, error of observed N. P. D. = + 0″·5.

α Ursæ Majoris S.P.

Graduated Face of Delination Circle E.

h m ° ′ ″
At 22. 25 clock time, concluded circle-reading, 27. 22. 18 ·1

Graduated Face W.

At 22. 57 clock time, concluded circle-reading, 152. 34. 26 ·5

Applying the refractions + 2′.7″·4 and – 2′.8″·7, and proceeding as before, we obtain for the observed N. P. D. 27°.26′.3″·9. Tabular N. P. D. = 27°.25′.41″·5. Hence error of observed N. P. D. = + 22″·4.

β Draconis.

Graduated Face of Declination Circle S.

h m ° ′ ″
At 23. 7 clock time, concluded circle-reading, 142. 23. 53 ·5

Graduated Face N.

At 23. 19 clock time, concluded circle-reading, 37. 32. 13 ·7

Applying the refractions – 38″·2 and + 41″·7 to these readings, and proceeding as before, we obtain for the observed N. P. D. 37°.34′.50″·1. Tabular N. P. D. = 37°.34′.38″·2. Hence, error of observed N. P. D. = + 11″·9.

It appears evident from the above observations that the position of the polar axis is very nearly correct.

The next operation was to determine the error of collimation of the line corresponding to the mean of the five wires in the eye-piece of the telescope, and the error of position of the declination-axis.

This was done by observing not far from the meridian, in reversed positions, the transit of a star not very far from the pole, and of a star very near the equator; and reading the hour-circle each time. By such observations it appeared that the position of the declination-axis needed alteration, and that the error of collimation was considerable. The declination-axis was, by repeated trials, set right by moving the screws which affect its position, and the eye-piece was taken out to find whether any means existed for altering the position of the wire frame, but none such were found. But about the same time, the object-glass was taken out, and on replacing it, and again observing stars near the equator, it was found that the error of collimation had nearly vanished.

The following observations will shew the state of the instrument with regard to the above errors during the time it was used for the observation of Groombridge 1830. Each time of transit is that across the center wire, which agrees very closely with the mean of the five wires; and each concluded hour-circle-reading is a mean of the readings of the two microscopes; the runs being very small.

1847, January 12.

α Ceti, N. P. D. = 86°. 31′

Graduated Face of Declination Circle W.

Time of transit	$3^{h}.\ 21^{m}.\ 18^{s}\cdot8$
Concluded hour-circle-reading..	$186^{\circ}.\ 47'.\ 21''\cdot3$
Or	$12^{h}.\ 27^{m}.\ \ 9^{s}\cdot4$
Hence R. A .... =	$2^{h}.\ 54^{m}.\ \ 9^{s}\cdot4$

Graduated Face E.

Time of transit	$3^{h}.\ 26^{m}.\ 14^{s}\cdot7$
Concluded hour-circle-reading..	$8^{\circ}.\ \ 2'.\ 15''\cdot7$
Or	$0^{h}.\ 32^{m}.\ \ 9^{s}\cdot1$
Hence observed R. A .... =	$2^{h}.\ 54^{m}.\ \ 5^{s}\cdot6$

Hence error of collimation $= \dfrac{9^{s}\cdot4 - 5^{s}\cdot6}{2} = 1^{s}\cdot9$

31 Cassiopeiæ, N. P. D. = 22°. 2′

Graduated Face of Declination Circle W.

Time of transit	$3^{h}.\ 54^{m}.\ \ 8^{s}\cdot5$
Concluded hour-circle-reading..	$223^{\circ}.\ 26'.\ 46''\cdot9$
Or	$14^{h}.\ 53^{m}.\ 47^{s}\cdot1$
Hence observed R. A .... =	$1^{h}.\ \ 0^{m}.\ 21^{s}\cdot4$

Graduated Face E.

Time of transit	$3^{h}.\ 58^{m}.\ \ 3^{s}\cdot3$
Concluded hour-circle-reading..	$44^{\circ}.\ 28'.\ 22''\cdot5$
Or	$2^{h}.\ 57^{m}.\ 53^{s}\cdot5$
Hence observed R. A .... =	$1^{h}.\ \ 0^{m}.\ \ 9^{s}\cdot8$

Hence the combined effect of the error of collimation and of that of the position of declination-axis is $\dfrac{21^{s}\cdot4 - 9^{s}\cdot8}{2} = 5^{s}\cdot8$.

Hence if c be the error of collimation in time = error in space divided by 15, and l the error of declination axis in space, we have

$$c \times \operatorname{cosec} 22^{\circ}.\,2' + \frac{l}{15} \times \cot 22^{\circ}.\,2' = +\,5^{s}\cdot8,$$

and, c being $= +\,1^{s}\cdot9$, we get $l = +\,4''\cdot5$.

Hence the errors are sufficiently small to prevent the necessity of numerical corrections.

The following explanation of the observations and reductions will be sufficient, in addition to that given in the foot-notes.

The seconds only of the observed transit of each star over the five wires are set down, and the concluded transit, or that deduced from the mean of wires, is given for each star. There are only two cases in which it was necessary to apply corrections to the mean of the observed wires on account of the transits being imperfect. These cases occur on 1847, Dec. 14, and for their reduction the following table of the distance of each wire from the mean of wires was formed by selecting several of the best observed perfect transits.

Calling the wires in the direction in which the star moves when the Graduated Face of the Declination Circle is Right, A, B, C, D, and E, the following are the intervals in time from each wire to the mean of wires for the star Groombridge 1830.

	s
For A	+ 25·192
B	+ 12·582
C	+ 0·032
D	− 12·618
E	− 25·188

The corrections for reduction to mean R.A. and mean N.P.D., 1847, Jan. 1, are computed by the constants given in the Nautical Almanac and in the British Association Catalogue. The corrections for difference of refraction of the two stars in R.A. and N.P.D. were computed from a table deduced from formulæ derived from the following process.

In the usual triangle PZS (where P, Z, S, represent the pole, the zenith, and the position of the star) draw an arc of a great circle ZQ, from Z perpendicular to PS; and use the symbol $\triangle$ to denote the star's N.P.D., and M for the modulus of common logarithms $= 0{\cdot}43429448$.

Then refraction in seconds in N. P. D. $= \alpha \,.\, \tan ZS \,.\, ZSQ = \alpha \,.\, \tan QS = \alpha \,.\, \tan (\triangle - PQ)$.

$$\text{Therefore } \frac{d\,(\text{refraction in sec. in N. P. D.})}{d\,\triangle} = \frac{d\,\alpha}{d\,.\,ZS} \,.\, \frac{d\,.\,ZS}{d\,\triangle} \tan(\triangle - PQ) + \alpha \,.\, \frac{d}{d\,\triangle} \tan(\triangle - PQ)$$

$$\text{But } \qquad \frac{d\,\alpha}{d\,.\,ZS} = \alpha \,.\, \frac{d\,(\log_e \alpha)}{d\,.\,ZS} = \alpha \,.\, \frac{1}{M} \,.\, \frac{d\,(\log_{10} \alpha)}{d\,.\,ZS}$$

$$\text{Then } \frac{d\,(\text{refraction in N. P. D.})}{d\,\triangle} = \alpha \left\{ \frac{1}{M} \,.\, \frac{d\,.\,\log_{10} \alpha}{d\,.\,ZS} \,.\, \frac{d\,.\,ZS}{d\,\triangle} \tan(\triangle - PQ) + \frac{1}{\cos^2(\triangle - PQ)} \right\}$$

$$\text{But } \qquad \frac{d\,.\,ZS}{d\,\triangle} = \cos ZSQ = \frac{\tan.\,(\triangle - PQ)}{\tan ZS}$$

$$\text{Therefore } \frac{d\,(\text{refraction in N. P. D.})}{d\,\triangle} = \frac{\alpha}{\cos^2(\triangle - PQ)} \left\{ 1 + \frac{1}{M} \,.\, \frac{d\,.\,\log_{10} \alpha}{d\,.\,ZS} \,.\, \frac{\sin^2(\triangle - PQ)}{\tan ZS} \right\}$$

and δ (refraction in N. P. D.) $= \delta\,.\,\text{N. P. D.} \times \dfrac{\alpha}{\cos^2(\Delta - PQ)} \left\{ 1 + \dfrac{1}{M} \cdot \dfrac{d\,.\,\log_{10}\alpha}{d\,.\,ZS} \cdot \dfrac{\sin^2(\Delta - PQ)}{\tan ZS.} \right\}$

When the differences are given to 1°, $\dfrac{d\,.\,(\log_{10}\alpha)}{d\,.\,ZS} = \dfrac{\text{diff.}\log_{10}\alpha}{3600 \times \sin 1''}$

" " $30'$, $\dfrac{d\,.\,(\log_{10}\alpha)}{d\,.\,ZS} = \dfrac{\text{diff.}\log_{10}\alpha}{1800 \times \sin 1'}$

" " $10'$, $\dfrac{d\,.\,(\log_{10}\alpha)}{d\,.\,ZS} = \dfrac{\text{diff.}\log_{10}\alpha}{600 \times \sin 1'}$

Again, Refraction in R. A. in arc $= \dfrac{\alpha\,.\,\tan ZS\,.\,\sin ZSP}{\sin PS}$

But $\tan ZS\,.\,\sin ZSP = \dfrac{\sin ZS\,.\,\sin ZSP}{\cos ZQ\,.\,\cos QS} = \dfrac{\sin ZQ}{\cos ZQ\,.\,\cos(\Delta - PQ)} = \dfrac{\tan ZQ}{\cos(\Delta - PQ)}$

Therefore Refraction in R. A. in time $= \dfrac{1}{15} \cdot \dfrac{\alpha \tan ZQ}{\sin\Delta\,.\,\cos(\Delta - PQ)}$

and $\dfrac{d\,(\text{refraction in R. A})}{d\,\Delta} = \dfrac{\alpha}{15} \cdot \dfrac{1}{M} \cdot \dfrac{d\,.\,\log_{10}\alpha}{d\,.\,ZS} \cdot \dfrac{\tan(\Delta - PQ)}{\tan ZS} \cdot \dfrac{\tan ZQ}{\sin\Delta\,.\,\cos(\Delta - PQ)}$

$$- \frac{\alpha}{15} \cdot \frac{\tan ZQ\,.\,\cos\Delta}{\sin^2\Delta\,.\,\cos(\Delta - PQ)} + \alpha \frac{\tan ZQ\,.\,\sin(\Delta - PQ)}{\sin\Delta\,.\,\cos^2(\Delta - PQ)}$$

The two last terms of this expression may be replaced by

$$\frac{\alpha \tan ZQ}{15\,.\,\sin\Delta\,.\,\cos(\Delta - PQ)} \left\{ - \frac{\cos\Delta}{\sin\Delta} + \frac{\sin(\Delta - PQ)}{\cos(\Delta - PQ)} \right\}$$

or by $\dfrac{\alpha \tan ZQ}{15\,.\,\sin\Delta\,.\,\cos(\Delta - PQ)} \left\{ - \dfrac{\cos(2\Delta - PQ)}{\sin\Delta\,.\,\cos(\Delta - PQ)} \right\}$

and the whole expression then becomes

$$\frac{\alpha\,.\,\tan ZQ}{15 \sin\Delta\,.\,\cos(\Delta - PQ)} \times \left\{ \frac{1}{M} \cdot \frac{d\,(\log_{10}\alpha)}{d\,.\,ZS} \cdot \frac{\tan(\Delta - PQ)}{\tan ZS} - \cot\Delta + \tan(\Delta - PQ) \right\}$$

Call the co-efficient of tan $(\Delta - PQ)$ in the first term of the expression, V; then

$$\delta\,(\text{refraction in R. A}) = \frac{\delta\,.\,\Delta}{15} \times \frac{\alpha\,.\,\tan ZQ}{\sin\Delta\,.\,\cos(\Delta - PQ)} \left\{ (1 + V) \tan(\Delta - PQ) - \cot\Delta \right\}$$

To use the above formulæ, it would be necessary to tabulate the values of V and of tan ZQ for different values of the Zenith Distance.

For small values of the Zenith Distance, V will not be appreciable.

By means of these formulæ the following table has been formed of the corrections to be applied to the differences of observed R.A. and N.P.D. of the comparison star in the observations of which we are treating; assuming the N.P.D. of the comparison star to be greater by 317″ than that of Groombridge 1830.

Table of the Corrections for Refraction, of Observed Difference of R. A. and N. P. D.; in the Comparison of Groombridge 1830 and Neighbouring Star.

To be applied to the Observation of the Neighbouring Star.

Sidereal Time.	Correction in R.A.	Correction in N. P. D.	Sidereal Time.	Correction in R.A.	Correction in N. P. D.
h m	s	″	h m	s	″
1. 44	+0·261	+10·191	15. 14	+0·002	+ 0·109
2. 4	·199	6·766	15. 44	·001	0·117
2. 24	·143	4·386	16. 4	·001	0·125
2. 44	·102	2·905	16. 24	+ ·001	0·135
3. 4	·073	1·967	16. 44	·000	0·149
3. 24	·053	1·371	17. 4	— ·001	0·167
3. 44	·038	0·980	17. 24	·002	0·191
4. 4	·027	0·718	17. 44	·004	0·224
4. 24	·020	0·540	18. 4	·007	0·269
4. 44	·014	0·417	18. 24	·010	0·331
5. 4	·010	0·331	18. 44	·014	0·417
5. 24	·007	0·269	19. 4	·020	0·540
5. 44	·004	0·224	19. 24	·027	0·718
6. 4	·002	0·191	19. 44	·038	0·980
6. 24	+ ·001	0·167	20. 4	·053	1·371
6. 44	·000	0·149	20. 24	·073	1 967
7. 4	— ·001	0·135	20. 44	·102	2·905
7. 24	·001	0·125	21. 4	·143	4·386
7. 44	·001	0·117	21. 24	·199	6·766
8. 14	·002	0·109	21. 44	—0·261	+10·191
8. 44	·002	0·103	22. 4		
9. 14	·002	0·099	22. 24		
9. 44	·001	0·097	22. 44		
10. 14	·001	0·095	23. 4		
10. 44	— ·001	0·094	23. 24		
11. 14	·000	0·093	23. 44		
11. 44	·000	0·093	0. 4		
12. 14	·000	0·093	0. 24		
12. 44	+ ·001	0·094	0. 44		
13. 14	·001	0·095	1. 4		
13. 44	·001	0·097	1. 24		
14. 14	·002	0·099	1. 44		
14. 44	·002	0·103			

The factor for annual parallax is the quantity $A\,a + B\,b$ or the aberration of the star computed for a time when the Sun's longitude was greater by 90° than at the time of observation. The final result will therefore require to be multiplied by the constant of aberration used in the reductions of the Catalogue of the British Association; or, in the case of Right Ascensions, the result for parallax must be multiplied by $\frac{20{\cdot}42}{15}$ or by 1·361; and, in the case of N.P.D., by 20·42.

The value of a revolution of the micrometer (*b*) that has been used is 31″·214. This result is derived from observations on 1846, Nov. 2, of which the following is an abstract. Each microscope was read on the positive and negative division in every instance, and the positive readings are set down beneath together with the corrections for runs.

Micrometer Reading.	Declination Circle.			Mean of Seconds.	Correction for Runs for 5′ on mean of Microscopes.	Concluded Circle Reading.	Differences.		Values of one Revolution.
	Pointer.	A	B				Micrometer Difference.	Arc measured.	
r	° ′	′ ″	″	″	″	° ′ ″	r	′ ″	″
85	93. 55	1. 36 ·3	40 ·6	38 ·45	— 2 ·8	93. 56. 37 ·55	30	15. 38 ·15	31 ·272
115	93. 40	0. 56 ·8	62 ·8	59 ·80	— 1 ·8	93. 40. 59 ·40			
93	93. 50	2. 31 ·0	29 ·8	30 ·40	— 2 ·3	93. 52. 29 ·20	15	7. 48 ·65	31 ·243
108	93. 40	4. 40 ·0	45 ·5	42 ·75	— 2 ·3	93. 44. 40 ·55			
91	93. 50	3. 32 ·2	32 ·6	32 ·40	— 1 ·5	93. 53. 31 ·30	16	8. 19 ·60	31 ·225
107	93. 45	0. 11 ·0	12 ·8	11 ·90	— 3 ·6	93. 45. 11 ·70			
92	93. 50	2. 60 ·0	58 ·3	59 ·15	— 1 ·6	93. 52. 58 ·15	14	7. 15 ·75	31 ·125
106	93. 45	0. 40 ·8	44 ·6	42 ·70	— 2 ·7	93. 45. 42 ·40			
94	93. 50	1. 57 ·3	57 ·8	57 ·55	— 2 ·9	93. 51. 56 ·35	11	5. 43 ·05	31 ·186
105	93. 45	1. 13 ·2	15 ·0	14 ·10	— 3 ·4	93. 46. 13 ·30			
96	93. 50	0. 53 ·8	54 ·2	54 ·00	— 1 ·7	93. 50. 53 ·71	13	6. 45 ·37	31 ·182
109	93. 40	4. 9 ·1	12 ·7	10 ·90	— 3 ·0	93. 44. 8 ·40			
97	93. 50	0. 22 ·2	21 ·4	21 ·80	— 2 ·5	93. 50. 21 ·60	13	6. 44 ·05	31 ·077
110	93. 40	3. 36 ·7	41 ·2	38 ·95	— 1 ·9	93. 43. 37 ·55			
92	93. 50	3. 0 ·6	2 ·0	1 ·30	— 2 ·4	93. 52. 59 ·90	10	5. 13 ·85	31 ·385
102	93. 45	2. 46 ·6	49 ·5	48 ·05	— 3 ·5	93. 47. 46 ·05			
98	93. 45	4. 52 ·2	55 ·3	53 ·75	— 2 ·5	93. 49. 51 ·35	5	2. 35 ·95	31 ·190
103	93. 45	2. 15 ·6	18 ·2	16 ·90	— 3 ·2	93. 47. 15 ·40			
90	93. 50	4. 2 ·2	4 ·0	3 ·10	— 0 ·5	93. 54. 2 ·70	20	10. 25 ·15	31 ·258
110	93. 40	3. 34 ·6	42 7	38 ·65	— 1 ·6	93. 43. 37 ·55			

The values in the last column agreeing so closely, and the arc measured in each case being sufficiently great, it is sufficient to take the mean of them; this is 31″·214, which has been used.

§ 14. *Right Ascensions and North Polar Distances of Hind's Second Comet and Neighbouring Stars, observed with the South-East Equatoreal,* pages 77 to 81.

The methods of observation and reduction are essentially similar to those for all previous equatoreal observations. The following remarks will include all the explanation which is necessary.

In regard to Right Ascension, the clock (Earnshaw) was generally compared with the Transit Clock at each set of observations, and also (on the usual system of comparison) every week; and no sensible doubt remains as to the amount of clock-error.

The hour-circle-readings are not sufficiently accurate to give reliance on observations of the Comet that depend at all on them. If the observations be made carefully, and the verniers read with all possible accuracy, the error may vary from 2^s to 4^s. The relation between the hour-circle-reading and the hour-angle, when the object is West of the meridian, is

$$\text{Hour-circle-reading} - \text{Hour-angle West} = 6^h,$$

and when the object is East of the meridian, the relation is

$$\text{Hour-circle-reading} + \text{Hour-angle East} = 18^h.$$

The refractions and parallaxes used in reducing all the equatoreal observations in this volume (and in all the preceding volumes from 1836) are computed by the following formulæ :—

For refraction. From Z, the zenith, draw a great circle ZQ, perpendicular to PS, the meridian passing through the pole P and the object S. Then, assuming vertical refraction $= 57'' \times \tan$ zen. dist., the refraction in N.P.D. $= 57'' \times \tan(PS - PQ)$, and the refraction in R.A. $= \frac{57^s}{15} \times \frac{\tan ZQ}{\sin PS \times \cos(PS - PQ)}$. Tables are prepared, containing the values of PQ and $\tan ZQ$ for different values of the hour-angle; and the computation for each instance is then very easy.

For parallax. From Z', the geocentric zenith, draw $Z'Q'$ perpendicular to PS: let r be the ratio of the geocentric radius for Greenwich to the equatoreal radius : then the whole parallax = hor. eq. parallax $\times\, r \times \sin Z'S$, and it is in the direction of $Z'S$: the parallax in N.P.D. = hor. eq. par. $\times\, r \times \cos Z'Q' \times \sin(PS - PQ')$, and the parallax in R.A. = hor. eq. par. $\times \frac{r \sin Z'Q'}{15} \times \frac{1}{\sin PS}$. Tables are prepared containing the values of PQ', $r \cos Z'Q'$, and $\frac{r \sin Z'Q'}{15}$, with which the calculation is easily made.

The distances of the Comet from the Earth were taken from Mr. Hind's Ephemeris in the *Astronomische Nachrichten*, No. 593. This Ephemeris extends only to February 28, and the distance for March 11 was obtained from it by extending the Ephemeris by second differences.

The following are the mean places of the stars of immediate comparison for 1847, January 1; the R.A. and N.P.D. of p_1, and the N.P.D. of Groombridge 4207, being obtained from the catalogue of stars in the present volume, and the R.A. of Groombridge 4207 being deduced from the Oxford Observations for 1846 :

	Mean R. A. Jan. 1, 1847.	Mean N. P. D. Jan. 1, 1847.
	h m s	° ′ ″
* (p_1)...........	21. 42. 10 ·87	20. 43. 24 ·37
Groombridge 4207	23. 55. 18 ·40	48. 6. 13 ·74

The corrections to apparent R.A. and N.P.D. are computed by the formulæ equivalent to A a + B b + C c + D d and A a′ + B b′ + C c′ + D d′.

The apparent correction for index-error is found by subtracting the corrected instrumental R.A. of the stars from the assumed R.A.

When the Comet and the star are observed in the same series, the adopted index-correction applied to the observed R.A. of the Comet is always that deduced from the star in that series. In other cases the selection of stars for the adoption of index-correction is explained in the notes.

The value of one division of the sector-arc which has been used for all the equatoreal observations of this year, is $5'.33''\cdot00$; the observations on which this result is founded will be found in the Introduction to the Greenwich Observations for 1845.

The value of a revolution of the micrometer of the sector-arc is the same as that used for De Vico's Third Comet in 1846, viz., $19''\cdot143$.

The rules for the adoption of the index-corrections in N.P.D. are precisely similar to those used for the observed R.A. of the Comet previously mentioned.

The mean solar times for the observations in N.P.D. are the same, without exception, as for the observations in R.A.

§ 15. *Eclipses, Occultations, and Transits of Jupiter's Satellites, compared with the Nautical Almanac; and Occultations of Stars by the Moon, with the Equations deduced from the Occultations,* page 83 to 89.

The observations of Jupiter's Satellites require no explanation additional to that which is given in the notes. The clock used is compared with the Transit Clock at the time of the observation, and the mean solar time is computed in the usual way.

For the computation of the Occultations, the star's place is taken from the "Elements for facilitating the Computation of Occultations" in the Nautical Almanac. The Moon's geocentric place, semidiameter, and hor. eq. parallax, are interpolated with second differences from the Nautical Almanac for the observed instant of the occultation. The correction to be applied to the parallax of the Moon's center to obtain that for the point of the limb at which the occultation takes place, is investigated in the following manner.

Let P = Moon's horizontal equatoreal parallax; S = semidiameter in arc; V = angle from the vertical at which the occultation takes place, as seen in an inverting telescope; and Z the apparent Zenith Distance of that point. (V is taken from the Nautical Almanac, and Z is found by means of a celestial globe.) Let also r = the earth's radius for Greenwich. This radius produced will form an angle with the astronomical vertical equal to $11'.12''$. Draw a plane through it and through the point of the Moon at which the occultation takes place. The radius of the section of the Moon thus formed will be (in terms of the Earth's radius) $\frac{r}{\sin P} \cdot \sin S . \cos V$; $\frac{r}{\sin P}$ being the distance between the earth and Moon's center. Now let two lines, one from the Earth's center and the other from the place of observation touching this section of the Moon, intersect each other and form an angle p. Then the whole length of the tangent from the earth's center will be seen to be,

$$\frac{r . \sin Z}{\sin p} + \text{rad. of Moon's section} \times \tan \frac{p}{2}$$

$$= \frac{r . \sin Z}{\sin p} + \frac{r . \sin S}{\sin P} . \cos V . \tan \frac{p}{2}$$

which is also plainly equal to

$$\cos \text{Moon's radius in arc} \times \text{dist. between centers of Earth and Moon}$$

$$= \frac{r}{\sin P} \cos S = \frac{r}{\sin P} \sqrt{1 - \sin^2 S}$$

Equating these two expressions, and multiplying each term by $\sin P . \sin p$, we have,

$$\sin P . \sin Z + \sin S . \cos V . \sin p . \tan \frac{p}{2} = \sin p . \sqrt{1 - \sin^2 S}$$

in which the second term is of an order inferior to the others, and, in a first approximation, may be neglected, as well as the difference between the factor $\sqrt{1 - \sin^2 S}$ and unity.

An approximate solution is therefore

$$\sin p = \sin P . \sin Z$$

$$\text{whence } \tan \frac{p}{2} = \frac{1}{2} \sin P . \sin Z \text{ approximately.}$$

Substituting these expressions in the above equation, and, for $\sqrt{1 - \sin^2 S}$, writing $1 - \frac{1}{2} \sin^2 S$, we get

$$\sin P . \sin Z + \frac{1}{2} \cos V . \sin S . \sin^2 P . \sin^2 Z = \sin p . (1 - \frac{1}{2} \sin^2 S)$$

whence $\sin p = \sin P . \sin Z + \frac{1}{2} \sin^2 S . \sin P . \sin Z + \frac{1}{2} \cos V . \sin S . \sin^2 P . \sin^2 Z$ which is erroneous only in the fourth dimensions of the parallax and semidiameter.

The correction to the Moon's horizontal parallax, P or $\sin P$, will be, therefore,

$$\frac{1}{2} \sin^2 S . \sin P + \frac{1}{2} \cos V . \sin S . \sin^2 P . \sin Z$$

of which the following table is formed, using the mean values of P and S, viz. 57′.3″ and 15′.33″.

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

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

Let now δ and θ be the N.P.D. and hour-angle of the star; δ' and θ' those of the corresponding point of the limb as seen from the Earth's center; and l the geocentric latitude of the place; and imagine the spherical triangles in which P is the pole of the heavens, Z the zenith, and S and S' the geocentric and apparent positions of the point of the Moon's limb in the same vertical circle.

$$\text{Then } \sin SS' = \sin p = \sin \text{corrected hor. par.} \times \sin Z.$$

$$= \sin P' \times \sin Z \text{ suppose;}$$

$$\text{and } \sin SPS' = \sin(\theta - \theta') = \sin p \, \frac{\sin ZS'P}{\sin SP}$$

$$= \frac{\sin P' \times \sin Z \times \sin ZS'P}{\sin SP}$$

$$= \frac{\sin ZP \times \sin ZPS'}{\sin SP} \cdot \sin P'$$

$$= \frac{\cos l \sin \theta}{\sin \delta'} \cdot \sin P'$$

and, to adapt this for computation,

$$\text{seconds of } \frac{\theta - \theta'}{2} = \frac{\theta - \theta'}{\sin(\theta - \theta')} \times \frac{\cos l \,.\, \sin \theta}{2 \sin \delta'} \times \frac{\sin P'}{P'} \times \text{seconds of } P'.$$

Again; $$\cos S'ZP = \frac{\cos\delta - \cos ZS' . \sin l}{\sin ZS' . \cos l} = (\text{also}) \frac{\cos\delta' - \cos ZS . \sin l}{\sin ZS . \cos l}$$

or, $$\frac{\cos\delta - (\cos\theta . \cos l . \sin\delta + \sin l . \cos\delta)\sin l}{\dfrac{\sin\theta . \sin\delta}{\sin S'ZP}} = \frac{\cos\delta' - (\cos\theta' . \cos l . \sin\delta' + \sin l . \cos\delta')\sin l}{\dfrac{\sin\theta' . \sin\delta'}{\sin S'ZP}}$$

whence, by reduction,

$$\frac{\cos\delta . \cos l - \cos\theta . \sin\delta . \sin l}{\sin\theta . \sin\delta} = \frac{\cos\delta' . \cos l - \cos\theta' . \sin\delta' . \sin l}{\sin\theta' . \sin\delta'}$$

$$\text{or, } \cot\delta \frac{\cos l}{\sin\theta} - \cot\theta . \sin l = \cot\delta' \frac{\cos l}{\sin\theta'} - \cot\theta' . \sin l$$

Then, substituting for $\cos l$ its value $\dfrac{\sin\delta'}{\sin\theta} . \dfrac{\sin(\theta - \theta')}{\sin P'}$

(previously deduced) and reducing, we get—

$$\sin\delta' \left\{ \frac{\cot\delta'}{\sin\theta'} - \frac{\cot\delta}{\sin\theta} \right\} = \frac{\sin l}{\sin\theta'} \sin P'$$

$$\text{or, } \sin\delta . \cos\delta' . \sin\theta - \cos\delta . \sin\delta' . \sin\theta' = \sin l . \sin\delta . \sin\theta . \sin P'$$

which may be put under the form

$$\frac{1}{2}\left\{ \sin(\delta - \delta') . (\sin\theta + \sin\theta') + \sin(\delta + \delta') . (\sin\theta - \sin\theta') \right\} = \sin l . \sin\delta . \sin\theta . \sin P'$$

$$\text{whence, } \sin(\delta - \delta') = \frac{2 \sin l . \sin\delta . \sin\theta . \sin P'}{\sin\theta + \sin\theta'} - \frac{\sin(\delta + \delta') . (\sin\theta - \sin\theta')}{\sin\theta + \sin\theta'}$$

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

or, in a form adapted for computation,

$$\text{seconds of } (\delta - \delta') = \frac{(\delta - \delta')}{\sin(\delta - \delta')} . \frac{\sin l . \sin\delta . \sin\theta}{\sin\frac{1}{2}(\theta + \theta') . \cos\frac{1}{2}(\theta - \theta')} . \frac{\sin P'}{P'} \times \text{seconds in } P'$$

$$- \frac{\delta - \delta'}{\sin(\delta - \delta')} \cot\tfrac{1}{2}(\theta + \theta') . \sin(\delta + \delta') \frac{\tan\frac{1}{2}(\theta - \theta')}{\frac{1}{2}(\theta - \theta')} \times \text{seconds in } \tfrac{1}{2}(\theta - \theta')$$

The following quantities are then formed :—

F = log. sin star's hour-angle + log. seconds of corrected eq. hor. parallax + 9·4942187.

G = log. sin star's N. P. D. + log. sin star's hour-angle + log. seconds of corrected eq. hor. parallax + 9·8913921.

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

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

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

$$+ \text{ log. } \frac{\text{arc}}{\text{sine}} \text{ for } (\theta - \theta')$$

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

$$+ \text{ log. } \frac{\text{arc}}{\text{sine}} \text{ for } (\delta - \delta') - \text{log. sine } \tfrac{1}{2}\,(\theta + \theta')$$

$$\text{log. 2nd number} = \text{log. } \tfrac{1}{2}\,(\theta - \theta') \text{ in seconds} + \text{log. } \frac{\text{tan}}{\text{arc}} \text{ for } \tfrac{1}{2}\,(\theta - \theta')$$

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

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

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 center is thus found, by means of a subsidiary angle ψ.

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

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

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

log. 1st number = 2 log. diff. R. A. + log. sine (sum of N. P. D.) − log. dist. + 4·0835.
log. 2nd number = log. diff. N. P. D. − log. distance.

Coefficient of variation of greater N. P. D. = 1st number + 2nd number.
Coefficient of variation of smaller N. P. D. = 1st number − 2nd number.
Log. coefficient of variation of diff. R. A. =

log. diff. R .A. + log. sin δ' + log. sin Moon's N. P. D. − log. distance.

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

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

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

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

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

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

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

The variation of the R. A. of the Moon's center is $x'' + t$ × 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 in N. P. D. by the quantity f'' will alter the N. P. D. of the corresponding point by f'' nearly.

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

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

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

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

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

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

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

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

§ 16. *Measures of Distance of the Double-star γ Virginis; and of the Diameters of Planets; made with a Double-image Micrometer upon the South-East Equatoreal,* page 91 to 93.

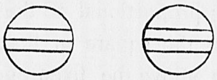
The eye-piece with which these observations are made is a four-glass erecting eye-piece, in which the lenses are so arranged that the axis of the pencil of rays, from each point of an observed object, passes through the center of the lens which is second (as measured from the object-glass), or third (as measured from the eye). This lens is divided by a plane passing through the axis of the telescope. One half of the lens is fixed, the other is moved by means of a micrometer-screw with graduated head. The whole eye-piece is made to revolve round an axis coinciding sensibly with the axis of the telescope, by a toothed-wheel-and-pinion movement: the position circle is graduated so that the readings increase when the eye-piece revolves in the direction opposite to that of the hands of a watch.

The power of the eye-piece is altered by using different lenses in the position nearest to the eye, without alteration of the other three lenses.

Since the axis of the pencil of rays, coming from any object or any point of an object, passes through the center of the divided lens, it is evident that one half of that lens receives the light which comes from one half of the object-glass, and the other half receives the light which comes from the other half of the object-glass. When the moveable half of the lens is in that position in which its surface is continuous with the surface of the fixed half (or in the position corresponding to the zero point of its scale), the axis of every semi-pencil on either half passes through that part of the lens in which the surfaces are parallel; but when the moveable half is moved from that zero position, the axis of the semi-pencil incident on that half falls upon a part in which the two surfaces are not parallel, their inclination being proportional (with sufficient accuracy) to the distance through which that half of the lens has been slid, and the plane which is perpendicular to both surfaces being the plane passing through the line of division and the axis of the telescope. This semi-pencil therefore emerges, inclined to the other; the plane of inclination being the plane just mentioned, and the extent of inclination being proportional to the movement of the moveable half-lens. On tracing the effect of this upon the image viewed by the eye-glass, it is seen that two images of the same object are formed by the light from the two halves of the object-glass, the line joining them being (sensibly) parallel to the dividing line of the lens, and their apparent distance being (sensibly) proportional to the movement of the half-lens, in whatever part of the visible field of view they may be.

The following circumstances are worthy of remark, in estimating the value of a construction like that now described.

1. The image formed by each semi-pencil is really formed by light from only one half of the object-glass, and therefore has all the defects of an image formed by a half-lens. But one of the images is formed by one half, and the other by the other half. Suppose now that the object-glass has sensible dispersion (from which no object-glass that I have ever seen is free). It is well known, in the use of an entire object-glass, that by selecting as the point for the effective image a place intermediate to the points at which the most refrangible and least refrangible rays converge, the most refrangible rays from one half of the object-glass will be mingled with the least refrangible from the other half, and their general effect of colour will be almost destroyed. But in the separate images formed by a divided lens of this construction, no such compensation of colour exists with regard to the direction *perpendicular* to the plane of division: because if the semi-pencil be examined with reference to this direction, it evidently comes from half an object-glass, without any opposed half whose colour may be mingled with it. If, however, the semi-pencil be examined with reference to the direction *parallel* to the plane of division, it is easily seen that each half of the semi-pencil on one side is balanced by a half on the opposite side, whose colours will be mingled with it. Thus, the two images of the object may appear very much coloured, but they will be coloured only on those sides which are measured from the center of each image transversely to the line of separation. For instance, suppose Jupiter to be observed, and suppose the two images to be separated as in the accompanying figure.



Then, in the first image the top may be red and the bottom blue, while in the second, the top will be blue and the bottom red; but the sides will be no more and no less coloured than when the whole object-glass is used to form a single image; and thus, in spite of the colour which immediately catches the eye, the images are (for the purposes of measurement of distance) as good as it is possible to have.

2. With reference to the measurement of angle of position of the two images, the circumstance that has been mentioned may cause some uncertainty, or even some difference as estimated by different eyes, which are differently sensitive to the different colours. The last inconvenience, however, is completely overcome by the method of double observation, of which we shall presently speak; and ceases to exist on applying the method of putting the eye-piece in focus, to which we shall shortly advert.

3. In regard to the effects of diffraction on each image, the image of a star is not round, but is elongated in the direction perpendicular to the line of separation of the images. This distortion operates nearly in the same manner as that described above: it produces no uncertainty whatever on the estimation of distance, but it does introduce uncertainty in the estimation of direction of separation of images.

4. From these remarks it will be gathered, that a divided eye-piece of this construction is particularly advantageous for the estimation of the distances of objects, but it is not particularly advantageous for the estimation of their position. From the statements of Sir J. Herschel, it appears that the distance is usually the more inaccurate co-ordinate, and therefore that this eye-piece, and others on the same general principle, supply what was formerly a defect. The angles, however, are also observed, as I believe, with great accuracy.

5. The method used for putting the eye-piece (practically) in focus is founded on the following consideration, it being premised that the eye-piece tube is so constructed that on sliding the eye-piece it receives no sensible rotation. Suppose the images to be separated right and left; one of them (for instance, the fixed image) is then formed by light coming from the upper half of the object-glass, and the other (the moveable image) by light coming from the lower half. Suppose the eye-piece to be drawn away from the object-glass; then the center of the section of the pencil forming the fixed image (not the center of the semi-circular outline, but the center of the general mass of light), which is viewed at the distance of distinct vision by the eye-piece, and on which the visible place depends, falls lower; and the center of the section of the pencil forming the moveable image, on which the visible place of the moveable image depends, rises higher. And this rise and fall may amount to a very sensible quantity within the limits in which the alteration of the visible size of the image is nearly insensible (the former being proportional to the movement of the eye-piece, while the latter is nearly proportional to the square of that movement). Thus it is possible to make the moveable image slide above the fixed one, or through it, or below it. And these different appearances may present themselves to different eyes in the same state of the eye-piece, according to the difference of sensitiveness of the eyes to different colours. If (as may happen) one of the halves of the lens is brought by the instrument-maker a very little too near to the other, or a very little too far from it (which, separately considered, would make the moveable image slide above or below the fixed image), advantage may be taken of this principle to correct that defect by thrusting in or drawing out the eye-piece. The principle therefore upon which the adjustment to focus is determined is, to adjust the eye-piece so that the moveable image shall pass as accurately as possible *through* the fixed image: and the practical method of using this principle is, to adjust it so that the angle of position of a double star (determined as hereafter mentioned) shall be the same when the observation is made by bringing the moveable image to the right of the fixed one, as when it is made by bringing it to the left of the fixed one. If there is error of adjustment, it affects both equally, one + and the other − ; and the rule therefore is: determine the apparent values of the angles of position in the two directions of separation; the mean of these is the correct value; place the position-circle of the eye-piece in the position corresponding to that correct value; then thrust in or draw out the eye-piece until the line of separation of

the images concides with the line joining the two individual stars of the double star; the adjustment to focus is then completed. But after all precautions are taken, it is thought prudent always to observe angles of position with the moveable image on both sides of the fixed image, and to take the mean.

6. As the separation of the images is affected by a species of prismatic refraction, it will be different for rays of different colours, and the moved image will therefore be changed into a spectrum, in which (beyond a certain distance) the colours will be sensible. And, as the lenses of the eye-piece will produce a certain degree of distortion, it will happen that where the object observed is large, or where its images are separated widely, the apparent magnitude is slightly altered, and the line of position of the two stars of a double star is sensibly altered. The extent, at which these combined causes begin to operate sensibly, can only be judged from experience. My impression from my own observation is, that the separation ought in no case to exceed ninety seconds of arc.

These remarks on the general properties of the eye-piece being premised, I shall now proceed to describe the method of making fundamental determinations for reduction.

7. To determine the reading of the position-circle, corresponding to that position of the eye-piece in which the separation of the two images takes place in the direction of the celestial meridian passing through any object.

A tube is prepared, containing only one lens (the eye-glass, or lens nearest to the eye), and furnished with a single wire in the focus of that eye-glass. It slides upon the tube containing the other three lenses of the eye-piece (namely, the divided lens and one on each side of it), and is held safely upon it, in the same manner as the other change-tubes with eye-glasses of different powers, by two pins and bayonet notches. This tube, however, has four bayonet notches, which permit it to be mounted, so that the wire may be placed either in the direction of separation of the images or in the direction perpendicular to that, the notches being sufficiently long to allow of considerable motion for adjustment. To determine the reading of the position-circle corresponding to separation in the direction of the astronomical meridian, the eye-tube is attached with its wire nearly parallel to the direction of separation, the telescope is directed to a star, and the clock-work of the equatoreal is put in action; then the micrometer-screw is turned through a considerable number of revolutions backwards and forwards, and the eye-tube is turned by hand (without moving the rest of the eye-piece), till the moveable image of the star, as moved by the micrometer-screw, runs well upon the wire. Thus the position of the wire is made to correspond accurately to the direction of separation. Then the clock-work is stopped, the star passes the field of view by its diurnal motion, and the position-circle is turned (without independent movement of the eye-glass tube), till the diurnal motion makes the star run well along the wire; then the position of the wire, and consequently the direction of separation, coincides accurately with the direction of diurnal motion: and the reading of the position-circle, increased or diminished by 90°, is therefore the reading corresponding to the separation in the direction of the meridian, or is the Polar point.

8. To determine the value of one revolution of the micrometer-screw.

The eye-glass tube carrying the wire is placed in such a position that the wire is nearly perpendicular to the line of separation (extreme accuracy is not necessary). Then, by moving the position-circle, the line of separation is made to coincide pretty accurately with the direction of diurnal movement; the telescope is directed to a single star, and by turning the micrometer through a known number of revolutions, this single star is converted into two stars, which in the diurnal motion follow each other across the field of view, and whose transits across the wire can be separately observed. The interval in time is converted into arc, and is multiplied by the sine of the star's N. P. D., and thus the arc is found which corresponds to a known number of revolutions of the micrometer.

The value of one revolution of the micrometer is that determined in 1842 and used in previous years, viz. 17″.

By observation of one of the stars of γ Virginis on 1847, May 31, the value of the Polar point, or zero of position, was found to be 4°.36′, and this value has been used throughout the year.

In the reduction of the observations of Mars and Jupiter, corrections have been applied for defective illumination (supposed to apply to the equatoreal diameter), which are computed thus:—The angle made at the planet by lines drawn to the Sun and the Earth (the difference of the planet's geocentric and heliocentric longitudes) being ascertained, the correction to the equatoreal diameter is, observed semidiameter × versed sine of this angle.

For Jupiter the diameters thus measured and corrected are compared with those computed from Struve's elements in the Memoirs of the Astronomical Society, vol. III. page 301, namely,

	″
Equatoreal diameter................	38·327
Polar diameter.....................	35·538

The distance of Jupiter being 5·20279

$$\text{Ellipticity} = \frac{38\cdot327 - 35\cdot538}{38\cdot327} = \frac{1}{13\cdot7}$$

The polar and equatoreal diameters at the times of observation are computed from these by the inverse proportion of distance.

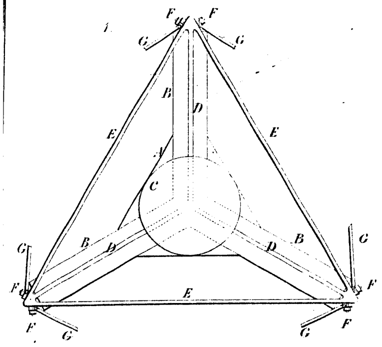
The comparison of results seems to shew that Struve's ellipticity is too large.

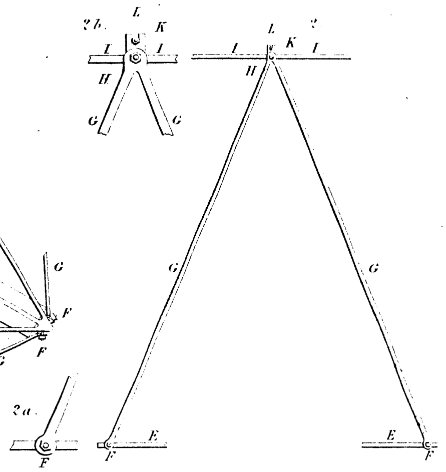
From the observations for the years 1840 to 1846 inclusive, the mean value of the ellipticity of Jupiter appeared to be 0·05654 or $\frac{1}{17\cdot7}$, and to this result the weight 358 is attached. The ellipticity deduced from three observations of Jupiter in 1847 is 0·05721 with the weight 30. Combining this value with that previously given, we find for the ellipticity deduced from all the observations from 1840 to 1847, 0·05659, or $\frac{1}{17 \cdot 7}$.

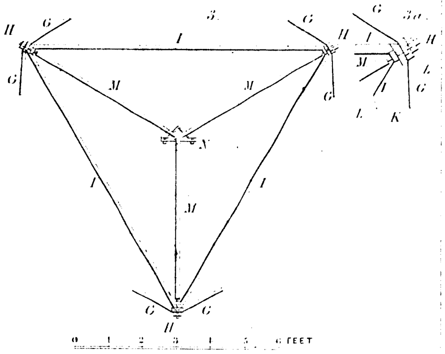
As a general remark, applying to every class of observation above mentioned, I may state that the original entries of observations are in all cases preserved. The greater part of the regular observations are entered in small memorandum books, in which the entries are written with a metallic pencil, whose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

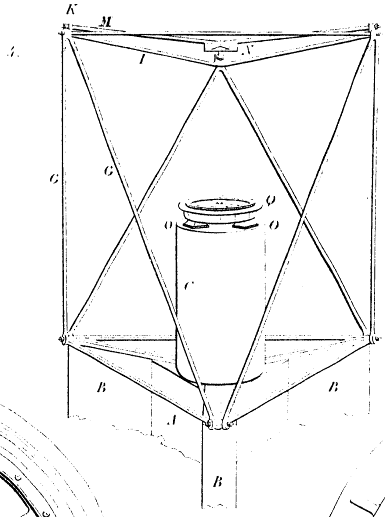
Greenwich Astronomical Observations 1847. Altitude and Azimuth Instrument.

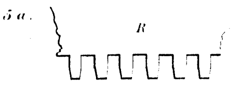
Pl. I

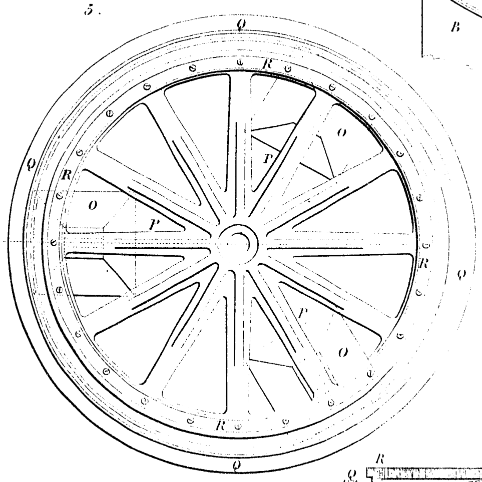


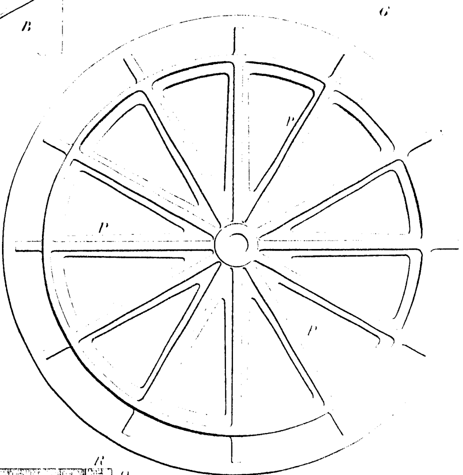


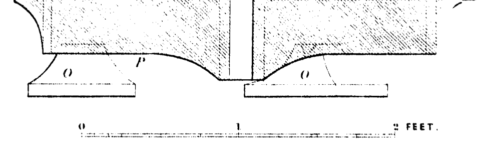












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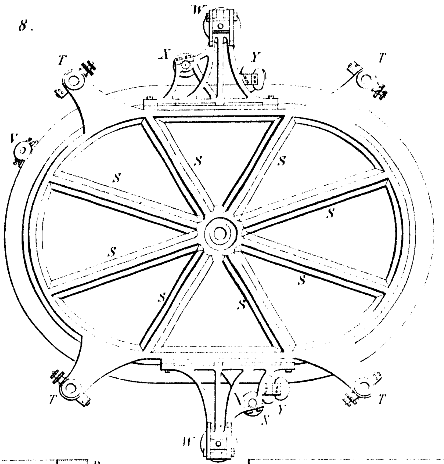

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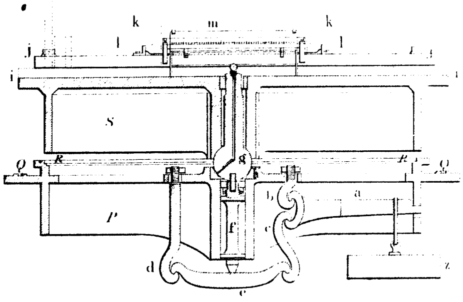

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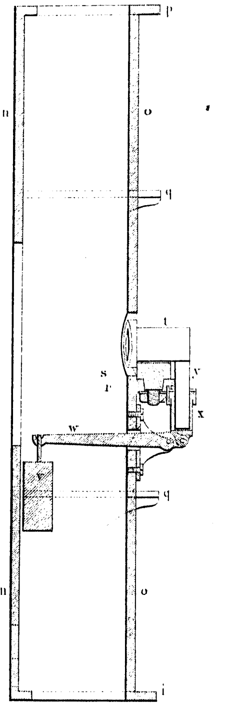

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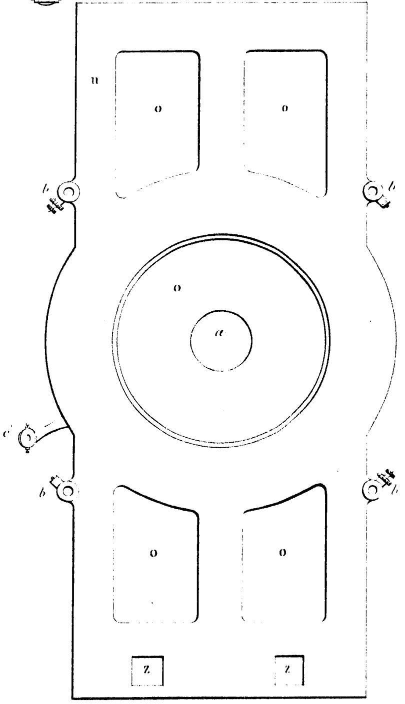

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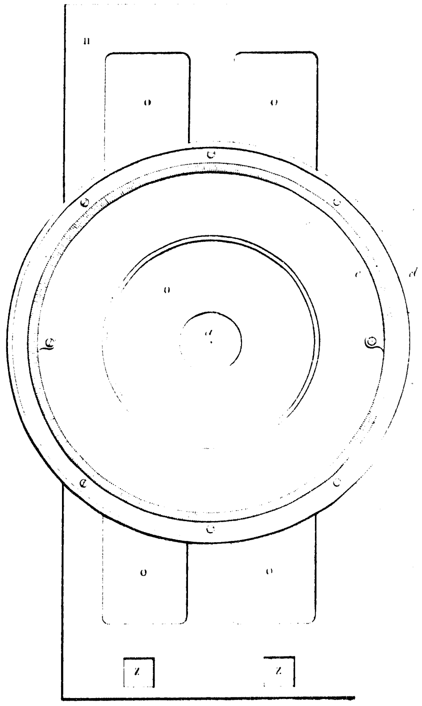

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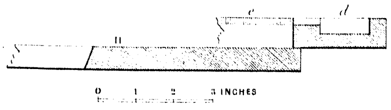

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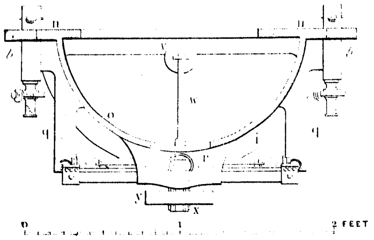

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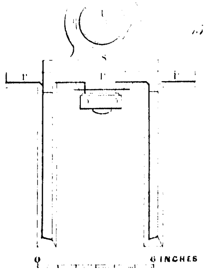

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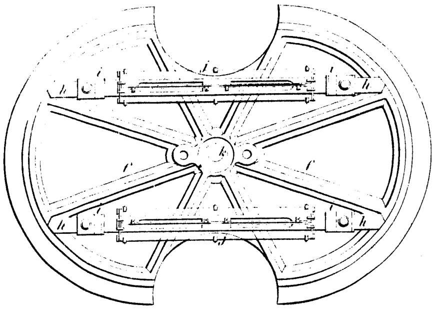

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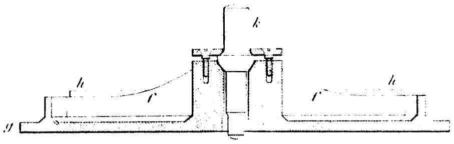

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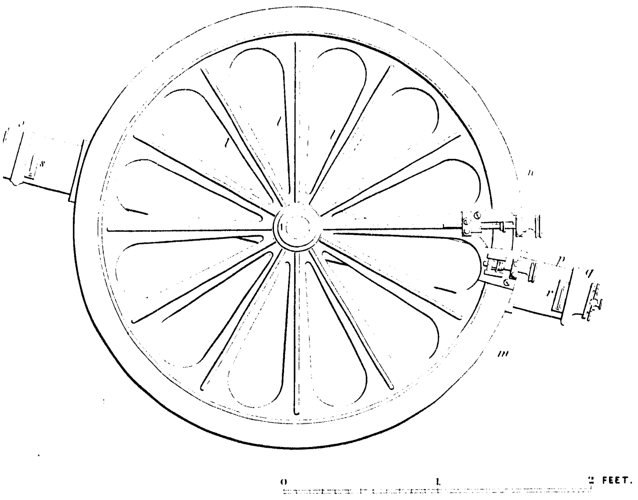

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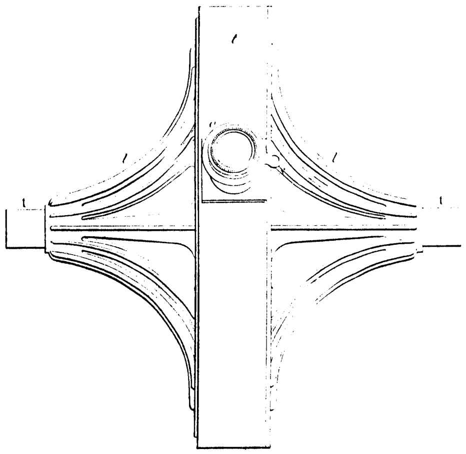

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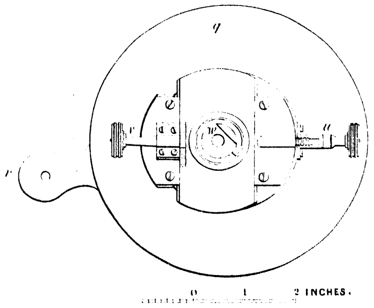

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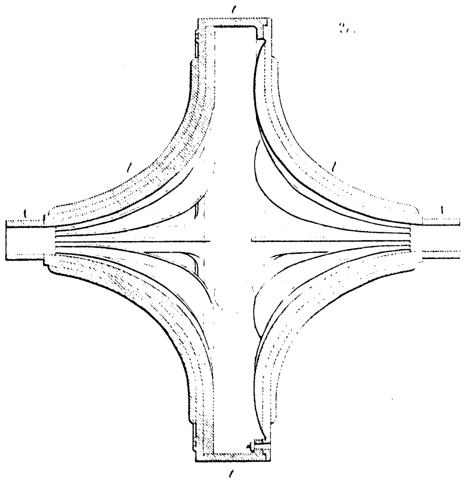

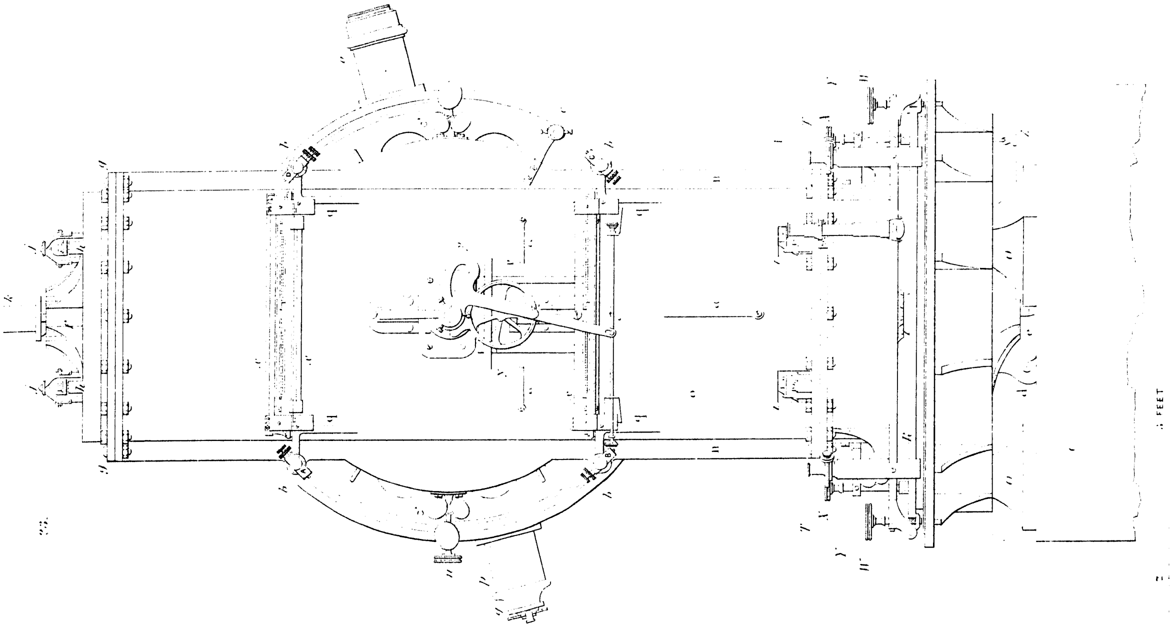
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