

MADRAS MERIDIAN CIRCLE OBSERVATIONS OF
FIXED STARS DURING 1862 TO 1887

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The meridian circle observations of fixed stars, considered in this paper, were taken at the old Madras Observatory during the years 1862 to 1887 variously by four observers C. Sashoo Iyengar, C. Ragoonatha Chary, T. Mootoosawmy Pillay and P. Raghavachari under the direction of Norman Robert Pogson, Government Astronomer at Madras. The results of these observations, after due reductions, were published in several volumes between 1887 and 1894¹, the last three volumes being supervised by C. Michie Smith who succeeded Pogson as Government Astronomer upon the latter's death in 1891.

Pogson was an accomplished observer who, before joining the Madras Observatory in 1861, had worked at the Radcliffe Observatory, Oxford and a few other places in Great Britain and specialized in the study of variable stars. 'Robert Norman Pogson', observed Michie Smith, 'was already well known as an ardent and skilful astronomer when, in 1861, he arrived in Madras to take charge of the Government Observatory there. During the following thirty years he pursued his work with characteristic energy and success without taking leave for a single day'². In developing his plan of work at Madras Pogson was deeply influenced by the astronomical work of Friedrich Argelander (1799-1875), particularly by his *Astronomische Beobachtungen* and *Durchmusterung*.³ In his introductory volume he observed, 'My intention was to have only a small catalogue of stars observed by the native assistants with the Meridian Circle, pending completion of the first few maps of the Southern Survey, and as soon as the approximate catalogues, similar to those of the Bonn "*Durchmusterung*" were available, to have all the stars they contained observed in zones with the new instrument, just as the "*Durchmusterung*" itself has been since dealt with by the northern observatories'.⁴

Of the four observers C. Sashoo Iyengar was the oldest and worked at the observatory from 1837 till his death in March 1863. Sashoo Iyengar 'was scrupulously careful and accurate and was warmly commended by every astronomer'. C. Ragoonatha Chary who succeeded Sashoo was a better mathematician with a greater general aptitude for science. He was intimately associated with practically the whole period of meridional circle observations at Madras, in the course of which he

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contributed papers to the Royal Astronomical Society on the determination of personal equation, and discovered new variable stars such as R. Reticuli and V. Cephei. On the recommendation of Pogson and E. B. Powell, then Director of Public Instruction at Madras and an authority on double stars, Ragoonatha Chary was elected a Fellow of the Royal Astronomical Society. T. Moottoosawmy Pillay, also 'a very trusty, painstaking' observer, contributed his share to the meridional circle observations. All these three observers worked with the old transit instruments of the observatory, used by Pogson's predecessors, as also with the Troughton and Simms meridional circle with which these new set of observations were accomplished. P. Raghavachari, as first observatory assistant, became associated with the project from 1874, as is evident from Michie Smith's record : 'The observers for the years 1874, '75 and '76 were Moottoosawmy Pillay and a new observer P. Raghavachari who is now First Observatory Assistant.'⁵

Pogson had originally intended to engage European observers and even approached Prof. Argelander and Mr. Hind for recommending suitable names for appointment. The Madras Government warmly supported his plan for a German or English assistant, but it was eventually turned down by the India Office in London. Pogson was naturally disappointed, for he had misgivings as to whether Indian Assistants, 'though good for slow methodical processes of ordinary meridian observations', would be able to handle the more sophisticated Troughton and Simms transit circle. His misgivings were dispelled after Sashoo, Ragoonatha and Moottoosawmy were allowed a year's practice with the new instrument. 'All three', wrote Pogson, 'had used the old meridian instruments, but it was not until after more than a year's practice with the new Transit Circle that I dare trust them to determine all their own instrumental corrections in the ordinary course of the night observations,...'⁶ In another place Pogson admitted that Indian observers 'have greater and more constant personalities of observation than generally prevail among Europeans'⁷.

MERIDIAN OBSERVATIONS BEFORE 1862

In positional astronomy work the Madras Observatory had already attained distinction in the first half of the nineteenth century due largely to the work of Goldingham, Taylor, Jacob and Worster. The meridional observations had commenced at the Observatory on January 9, 1793, within a year of its foundation 'with a little twenty-inch transit instrument, by Stancliff, and a twelve-inch altitude and azimuth instrument, by Troughton'. With these instruments which did not contain an object glass of any aperture, observations were taken upto the year 1829, but were not reduced. The results of the first nineteen years' observations were copied out and despatched to the Board of Directors of the East India Company in the hope that some day these would see the light of day. The results for the years 1812 to 1825, consisting of observations on the Sun, Moon, planets and brighter fixed stars were published by J. D. Goldingham in two bulky volumes, now only of historical importance.⁸

The next phase of development took place under T. G. Taylor, responsible for the famous *Madras Catalogue* of 11, 015 stars. The observations of fixed stars incorporated in it were carried out during 1831 with the help of a new 5 ft transit instrument and a 4-ft mural circle, both made by Dollond and set up by Taylor. The idea of having a quadrant fixed in the plane of the meridian which goes back to the time of Ptolemy or earlier, was successfully used by Tycho, but does not appear to have been popular in the 17th century for right ascension determinations. Around 1690 Romer developed the idea of fixing a telescope at right angles to a horizontal axis set in the direction of east and west and resting firmly on fixed supports. This concept enabled the telescope to revolve freely in the plane of the meridian.

The invention of the altitude and azimuth instrument for measuring vertical and horizontal angles was also due to Romer. In 1704, Romer further hit upon the idea of combining a vertical circle with his transit instrument in order that both the coordinates could be determined at the same time. While this concept was soon taken over on the continent and the transit circle, in various designs, appeared in European observatories, the mural circle in combination with the transit instrument continued to be the principal instrument for positional astronomy work in the United Kingdom and her colonies and dependencies till the middle of the 19th century.⁹

The mural circle set up at Madras had large instrumental errors which Taylor tried his best to reduce.¹⁰ His *Madras Catalogue* was reduced for the year 1835 and was well received in European circles of astronomers. The existing demand for a revised edition of this catalogue was another reason for Pogson's programme of surveying the sky. He wrote : '... its value at the present date may be inferred from the circumstance of a new edition being now called for by European astronomers. It is scarcely necessary to mention that I shall respond to this call with great pleasure as soon as the results of my own labours have been laid before the world, and time permits of the investigation of the remaining errors, both casual and systematic, which still require correcting in the former catalogue.'¹¹

The original observatory building which housed the old transit instruments, the mural circle, *etc.* and later on the Troughton Simms meridional circle employed for the observations of 1862-87, was constructed in 1792. It was a single room, 40 ft x 20 ft x 15ft high with massive walls 2 ft thick. The instrumental base was a solid masonry pyramid (frustum), 45 ft x 12 ft at the base, 37 ft x 6 ft at the top and 6 ft high. In the centre of the top was placed a conical granite pier, 4 ft in dia at its base, 2 ft dia at the top, with a total height of 18 ft ; it was used to support Troughton's altitude and azimuth instrument. The observatory floor was detached from the pyramidal basement and made to rest on beams supported by the walls.

Around 1845 the old observatory building received extensions in the eastward and westward directions for the accommodation of a magnetic observatory with its various instruments, manuscripts and computational work, and storage of

instruments and other property. The original building while retained for transit circle observations as before was extended upwards for celestial photography with a Browning reflector.

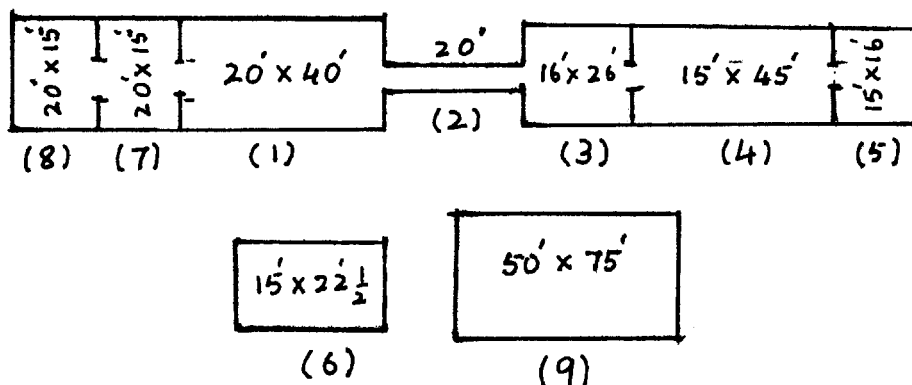


Fig. 1

Plan of the Madras Observatory as it existed in 1887, reconstructed on the basis of Pogson's description.

1. Ground floor-Transit room, housing transit instrument, mural circle, meridional circle. First floor-3-rooms for celestial photography with 9" Browning reflector.
2. 20 ft long covered passage.
3. Dip-circle room.
4. Magnetic room housing bifilar, vertical force, declination magnetometers.
5. Transit theodolite room.
6. Room for absolute horizontal force determination.
7. Computing and manuscript room.
8. Store room for instruments and other property.
9. Astronomer's residence accommodating Library on the ground floor, Astronomer's private office on the first floor, anemograph, 8 "equatorial and 6" equatorial on 3 rooms on the roof.

} Magnetic
Observatory

The Browning reflector was used by J. F. Tennant at Guntur to photograph the total solar eclipse of August 18, 1868. In 1872, three additional rooms were constructed on the first floor of the old observatory building for celestial photography. The building for Astronomer's residence stood at about 120 yards south-west of the observatory building. It was a spacious building with a plinth area of 75 ft x 50 ft, and contained 18 rooms, 8 on the ground floor, 7 on the first and 3 on the roof. The ground floor housed the Library and electric clock and telegraphic

appliances for giving true time signals to local shipping ; the first floor accommodated the private office and living quarters of the Astronomer, and rooms on the roof were used for observations with an 8 inch equatorial by Troughton and Simms and a 6-inch equatorial by Lelebour and Secretan. The latter was used by Capt. Jacob for his study of double stars and Saturn's satellites.

THE TRANSIT CIRCLE

In the system of coordinates, right ascension (R. A) and declination or polar distance (P. D), the right ascension of a star, expressed in time, equals the sidereal time of its meridional transit. The star's declination equals the sum of its meridian zenith distance and the latitude of the observatory. The sidereal time can be ascertained from the signals of a sidereal clock at the instant of the star's transit and the meridian zenith distance read off the graduated circle of the transit instrument. The transit circle which combines the functions of a transit instrument and a mural circle in one instrument and enables both coordinates of a celestial object to be observed and determined at the same time and by the same person, superseded the older instruments on the continent from 1818-1819. The firms of Repsold, Reichenbach, Pistor and Martins came into prominence as makers of transit circles. In England, Edward Troughton, in 1806, constructed a modern transit circle for Groombridge's Observatory at Blackneath, but gave up the construction of his model in the face of the improved models developed and perfected by Repsold and Reichenbach.¹² In 1850, the Royal Observatory at Greenwich, at the initiative of the Astronomer Royal (then Professor) G. B. Airy, installed a transit circle of which the telescope had an eight inch object glass and a divided circle 6 ft in diameter. Two years later Troughton and Simms of England constructed for R. C. Carrington of Redhill a transit circle 'similar in all essential points to the new one at Greenwich'. The instrument was later transferred to the Radcliffe Observatory at Oxford. The success of the Troughton and Simms transit circle at Redhill and Radcliffe led the Madras Observatory to place an order for a similar instrument with the same firm ; in this case also Carrington acted as the expert consultant in the execution of several alterations necessary for an instrument of this type.¹³ The transit circle finally reached Madras in March 1858, but was not installed for astronomical observations before 1862, that is, until after Pogson assumed charge of the Observatory. A schematic diagram and a fuller sketch of the transit circle are shown in Figs. 2 and 3.

In Fig. 2. ST-represents the telescope. It consists of two slightly conical tubes screwed to the central cube of the axis. The object glass had a clear aperture of $5\frac{1}{2}$ inches and a focal length of about 50 inches. The eye-pieces had three magnifying powers engraved one on each, *e.g.* 105, 147 and 230, the middle power being used throughout the observations. Moreover, a Bohnenberger's eye-piece of power 106 was also supplied with the instrument for finding the nadir point and the level error.

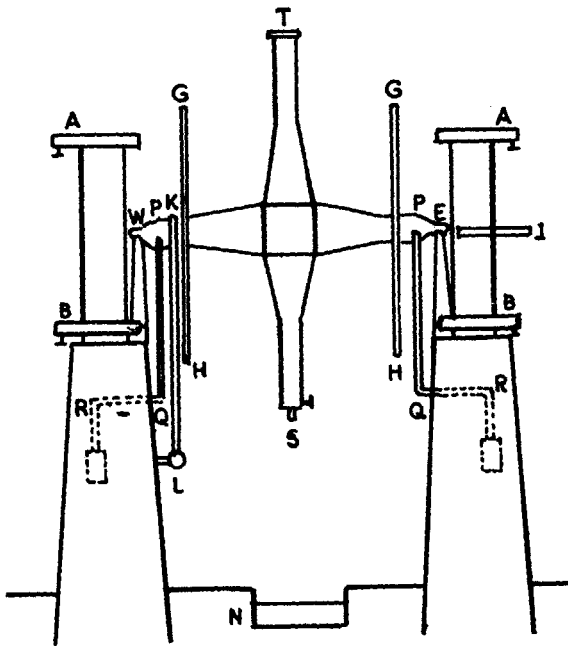


Fig. 2 →

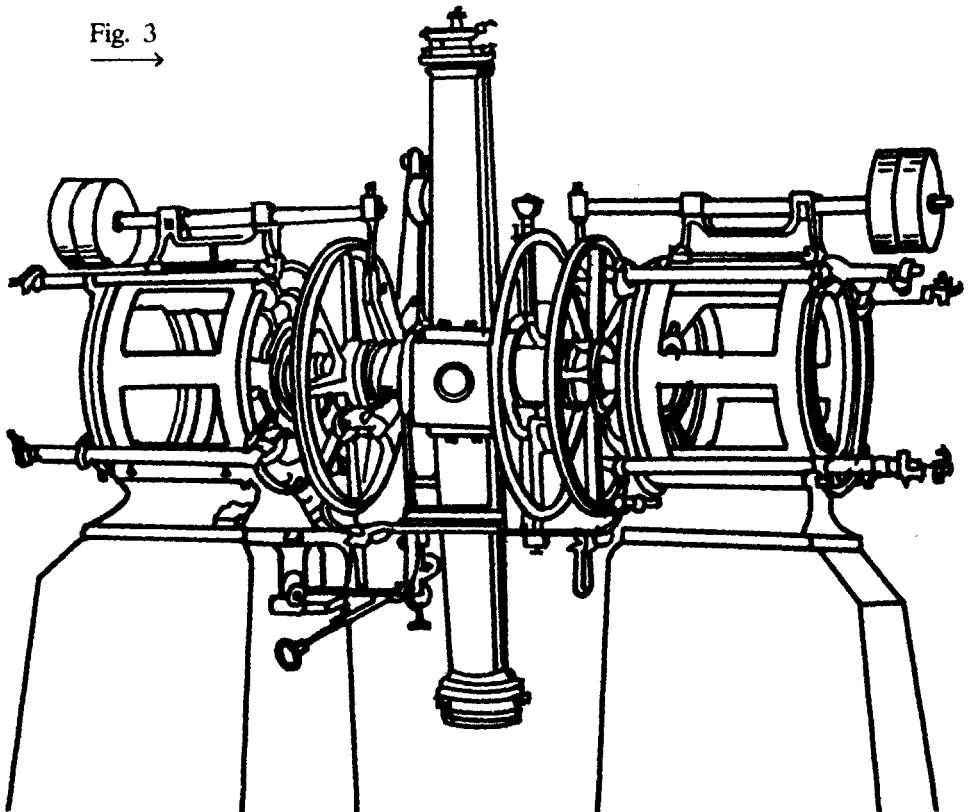


Fig. 3 →

At the focal plane of the objective within the telescope tube was fitted a framework containing seven vertical and one horizontal spider lines, movable by micrometer screws. For actual working the single horizontal line was replaced by a pair separated by 12" in order to enable the image of the star (bisection) to coincide exactly with the midway between the pair at the time of crossing the central vertical line. This arrangement was 'better than tangential contacts of a single line with either north or south limb'.

WPPE—hollow rigid horizontal axis consisting of a central cube and two cones, one on either side. The central cube was 12 inches on each side and each of the two cones had a diameter of 10 inches at the cube being made of one casting of gun-metal and tapering off at their extremities into cylindrical pivots, 3 inches in diameter and also made of gun-metal. The two ends of the telescope were each screwed to the cube by 12 stout bolts. This connection should be as firm and the tube as stiff as possible to minimize the flexure of the tube which affects the declinations deduced from observations.

FF—The piers containing the Y's for supporting the axis ; the Y's were made of brass and adjustable vertically by screw motion. Furthermore, the Y's were enclosed in brass boxes to exclude dust and moisture.

PP, QQ and RR—PP are friction rollers which relieve the pivots from the weight of the instrument by means of the levers QQ attached to the friction rollers and the counterpoise RR placed within the piers. By this arrangement the residual pressure of the pivots upon each Y did not exceed 10 or 12 lbs. Small additional weights were used to lift the axis out of its bearings for cleaning purposes.

GH—two graduated circles attached to the axis at each end. The two circles were nearly similar, 42 inches in diameter, made of gun-metal and firmly secured to the conical axes by means of screws and flanges. The clear space between the two circles was 30 inches. The eastern circle was coarsely divided to 10' only for setting purposes and the western circle carried a rim of gold inclined at 12° to the plane of the circle for proper illumination and easy reading ; the precision graduations were upto 5'.

LK—a bar for slowly rotating the telescope and then firmly clamping the axis, further slow motion being done by horizontal tangent screw at L.

AIB—compound microscopes for reading the graduations of the circles GH. Generally four, but in this Troughton and Simms instrument, six microscopes of considerable magnifying power were used for each circle to read off their divisions. The microscopes were so placed as to bring their micrometer eye-pieces within a circle of 30 inches diameter, the lower microscope being used to read zenith distances. In the earlier instruments the microscopes used to be fixed in holes drilled through the pier. In the later plans adopted by Repsold and Simms the piers were made short and the microscopes were carried in an iron framework in order to avoid exposure of the circles to the radiations from the piers. About the fixing of the 6 microscopes, we have the following brief

statement of Pogson, from which the actual arrangement is not very clear : "The greatest source of delay and difficulties in mounting the instrument was in regard to the fixing of the six microscopes. It was obviously intended that they should be placed as they now are, for the lower one to read zenith distance, and the hole for it to look through was drilled for the lower part of the western pier in readiness. This however caused the upper microscope, in the cap-stone above, to come immediately above the flame of an argand lamp, provided for lighting up the field of view, or the wires in a dark field, and for the general illumination of the limb opposite to each microscope.¹⁴

In the Reichenbach circles verniers were used in place of microscopes ; these verniers were attached to an immovable alidade circle.

N—Mercury trough for determining the nadir point.

The setting of the instrument and various adjustments called for the services of an expert instruments mechanic, generally supplied by the manufacturers themselves. In September 1861, luckily for the observatory, a German mathematical instruments maker of the name F. Doderet was available. Doderet had recently arrived in Madras with an assignment to set up 'workshop for the repair of levels, theodolites, etc. for the Public Works Department', and his services were made available for the setting up of the transit circle. An excellent lathe, made by Holtzaffel, which Tennant had purchased for starting a small workshop at the observatory, now proved of inestimable value. All modifications required, the microscope arrangements and the setting up of the instrument in all its details were completed in May 1862 'when complete observations were first steadily commenced'.¹⁵

CLOCKS AND CHRONOGRAPH

An old Shelton pendulum clock had been used as a transit clock from 1792 till 1859 for astronomical observations at the observatory. The clock's gridiron pendulum admitted of as near perfection as possible. Mention may be made of another old clock, made by Haswall, which was used by Goldingham in his pendulum experiments in 1821 and for transit observations with the old mural circle, but was not used in meridional circle observations of 1862-87. In 1859, the old Shelton clock was replaced by a new one by Dent, equipped with a mercurial pendulum whose compensation was hardly better than the Shelton's gridiron. Nevertheless the Dent clock gave louder and more convenient beat and worked quite reliably throughout the observations ; Pogson remarked that 'no better could be desired as a standard sidereal regulator'.¹⁶ In 1872, the observatory acquired a meantime electrical clock by Shepherd and Son. Although its performance during testing at the India Stores Department for Instruments at Lambeth attracted criticism, it worked well in Madras. The clock had a magnetic contrivance for the daily rectification of its error, a common practice for electrical motor clocks, which was the source of indifferent functioning during its trial in London. In Madras, the

defect was rectified by introducing a simple gravitation adjustment. In Pogson's words : 'As soon however as a simple gravitation adjustment was substituted, consisting of a small brass weight of 159 grains, which when placed upon a shelf about 18 inches below the point of suspension of the pendulum makes the clock gain a hundredth of a second per minute, or lose at the same rate when placed on another shelf below the pendulum jar, all irregularities ceased and no further difficulty was experienced'.¹⁷

In 1863, Pogson tried to obtain a barred chronograph for telegraphic longitude determinations and finding the solar parallax constants, but failed to receive any reply from the sanctioning authorities in London until after several years when a French fillet recorder was despatched too late for the purpose for which it had been requested.

INSTRUMENT CORRECTIONS

Transit instruments and clocks require a number of corrections to be applied to the observations of the transit of stars for obtaining their true right ascensions and polar distances.¹⁸ The right ascension involves the following corrections : (a) error and rate of astronomical clock, (b) personal equation of the observer, and (c) errors of adjustment of the transit circle, which generally include (i) collimation error, (ii) level error, (iii) azimuth error, (iv) pivot form irregularities and (v) errors due to verticality and wire intervals. Declinations or polar distances must be corrected for (a) flexure errors, (b) imperfect centering of circles and errors of graduations and (c) errors of 'runs' in reading microscopes. A few of these corrections as discussed by Pogson may be referred to.

Clock errors are determined by observing the transits of stars of known R. A.'s and declinations. For clocks of no errors transit times would equal the stars' known R. A.'s and declinations ; otherwise the error would be the star's R. A. minus the observed time of transit, provided the instrument was free from other types of error. Pogson and his team used standard nautical almanac stars for finding clock corrections, *e.g.*, Bootis and Polaris, ρ Bootis and Polaris, δ Urs. Minor and Altair, α Orionis and Urs. Min., Z Pegasi and 79 R.P.L., *etc.*

The error made by an observer in estimating the time of transit is his personal equation. This may vary from person to person, one observer estimating the time too late, another too soon. If the same observer determines the clock error, the personal equation for transit of a star would be compensated by the clock error. For two persons differing in their equations, the difference should be taken into account. Personal equations of the first three observers were determined as follows : Sashoo Iyengar, $-0^s.75$; Ragoonatha Chary, $-0^s.35$; and Moottoosawmy Pillay, $-0^s.23$. All three Indian observers had negative personal equation as opposed to the positive equation of their leader Pogson.

The principal errors of the transit circle are the collimation, the level and the azimuth error. When the line of collimation, that is the line through the optical

centre of the objective and perpendicular to the axis of rotation, makes a small constant angle with the meridian this angle is the collimation error. The level error is the angle which the axis of rotation makes with the horizon. The azimuth error is the horizontal angle which the axis of rotation makes with the true east-west line or the prime vertical plane. The collimation error is determined by using two telescopes, called collimators, which are directed to each other, one due north and the other due south. By placing the transit telescope in the vertical position and by piercing two holes in the central cube, the cross wire of one collimating telescope is observed through the other collimator and the two wires are brought into coincidence. The transit telescope is then directed to each collimator in turn and adjustment with the collimator cross mark is made with a graduated screw. The mean of the two readings of the graduated screw gives the line of collimation agreeing with the meridian.

The collimation error being thus eliminated, the level error is then determined by pointing the transit telescope downwards over a trough of mercury. In this case, a Bohnenberger eye-piece is used. (Fig. 4) This eye-piece contains a plate glass at 45°

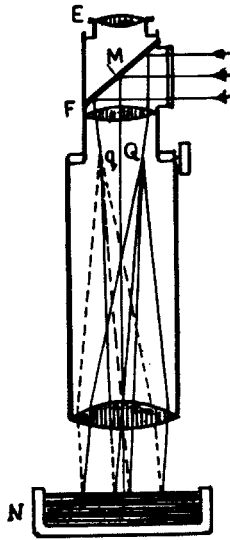


Fig. 4

and admits light through a side hole to be reflected by the plate glass down the telescope tube on to the mercury trough. The result will be the reflected image of the telescope, which, to all intents and purposes, will act as a second collimator, as in the case for determining collimation error. If the middle cross wire of the telescope coincides with its reflected image, the collimation line is vertical. If not, there is a level error, which can be found by turning the graduated screw and reading off the angle.

The azimuth error is determined from the observed times of the upper and lower transit of a circumpolar star.

In the Madras circle, the collimation error was determined by two 35 inch telescopes with $2\frac{3}{4}$ inch object glass. The original idea was to use the collimators from outside the transit room, for which purpose two square rooms were built 20 ft north and south of the transit circle. But the passage of rays over such a long distance marked by unequal temperatures made the cross wires appear 'faint and tremulous'. This led Pogson to place the collimators inside the transit room at a distance of 57 inches from the object glass of the telescope. The centre of the cube was pierced by two 4 inch circular apertures in order to enable the cross wires of each collimator to be viewed when the transit telescope was in the vertical position. On the instrumental basement one foot below the boarded floor were placed two movable mercury troughs, besides a fixed circular one, vertically below the transit circle, for the determination with the use of Bohnenberger eye-piece of the level error and the nadir point. The collimation and inclination or level corrections for the Madras transit circle were found as follows :—

(a) Collimation correction— $1^{\circ}.771$ (zero of collimation—adopted reading— 0.073)

(b) Inclination correction— $1^{\circ}.771$ (zero of Coll—coincidence reading)

It has already been stated that the two telescope tubes, one containing the objective and other the eye-piece, should be firmly fixed with the central cube. The telescopic tube may develop a flexure which affects the declinations deduced from observations. The flexure in the horizontal position of the tube is determined with the help of the two collimators placed horizontally with the meridian, as in finding the collimation error. In the set of observations as published in the first volume of the series a flexure correction of $1''.72 \times \sin$ Zenith Distance was applied provisionally to Polar Distance. In the next volume Pogson reported that the flexure correction finally adopted was $0''.85 \times \sin$ Zenith Distance.¹⁹ In the previous observations, a further error was introduced by applying twice the value of the flexure correction needed. In the volume giving observations for 1865-67, a table of corrections was furnished for amending Polar Distances from 0° to 150° .

A select list of various instrumental corrections adopted in 1862, 1863 and 1864 is given in Table 1 by way of illustration.

TABLE 1
Instrumental Corrections Adopted in 1862, 1863 and 1864 (Selected).

Date	Index	Run in 5'	Clock Rate	Inclination	Collimation	Meridian	Determining stars
1862	"	"	s	s		s	
June 2	-5.0	+0.8	-0.32	0.00		+0.53	ρ Bootis and Polaris
Aug 20	+4.2	0.0	-0.52	+0.01		+0.09	δ Urs. Min & Altair
Oct 6	+0.8	+0.5	+0.14	-0.31		-0.01	150 RPL & Piscium
Dec 11	+0.6	+0.1	-0.25	+0.17		+0.18	Polaris & α Arietis

1863							
Jan 6	+0.8	+0.2	-0.23	+0.14		+0.13	43 R.P.L.g Eridani
March 17	-0.4	0.0	-0.05	+0.32		-0.09	60 R. P. L. & Hydrae
May 18	+4.0	+0.2	-0.29	+0.03		-0.21	3 Virginis Polaris
July 10	+0.8	-0.2	-0.08	+0.09		0.00	131 RPL α^2 Librae
Sept 12	+2.1	-0.2	-0.38	-0.11	0.00	0.13	λ Urs. Min & β Aquilae
Nov 18	+2.2	+0.2	-0.29	-0.17	-0.03	+0.03	Polaris Achemar
Dec 8	+6.2	-0.2	-0.55	-0.05	-0.01	+0.32	40 67 R.P.L
1864							
Jan 19	-1.7	-0.1	-0.06	-0.21	-0.04	-0.92	51 Cephei δ Urs. Min.
Feb 3	-3.0	-0.1	+0.14	-0.22	0.00	-0.03	α Orionis δ Urs. Min.
April 11	-0.7	+0.1	+0.03	+0.09	0.00	-0.24	γ Urs. Maj Polaris
June 14	+1.0	-0.1	-0.19	+0.04	-0.01	-0.16	η Bootis & Polaris
Aug 23	+0.5	+0.2	0.00	-0.08	-0.07	-0.29	λ Urs. Min & 51 Cephei
Oct 21	+6.1	+0.2	-0.23	-0.44	-0.06	-0.22	3 Pegasi & 79 R.P.L.
Nov 29	+7.1	+0.1	+0.01	-0.28	+0.04	+0.12	Polaris & Achemar

FOLIO DAY BOOKS

Folio Day Books for recording the observations and carrying out their reductions were maintained in the following form :—

Left side—Polar Distance :

12 Columns

1. Reference number.
2. Date and Observer.
3. Barometer.
4. Thermometer.
5. Name of object.

6. Deduced circle reading :—
i.e. Zenith Distance counted round through south nadir and north upto 360° ; the means of the six microscopes, corrected, for index, run of micrometers, and curvature if not observed at the centre of the field.

7. Refractions, computed by

Right side—Right Ascension :

17 Columns

1. Reference number
2. Name of object.
3. Number of wires.
4. Estimated magnitudes.
5. Mean of wires : The clock time of transit over the mean of the seven wires being meant in all cases, and every object observed over a less number being reduced thereto by the adopted intervals of the wires noted.
6. Inclination correction.

7. Collimation correction.

"Bessel's Tables" as modified and expanded in an appendix to the Greenwich Observations for 1853.

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|--|--|
| 8. Apparent Polar Distances, assuming the latitude as given in the Nautical Almanac ; viz., 13° 4' 8" 1 north. | 8. Meridian correction. |
| 9. Reductions to January 1st ; using the "Day Numbers" of the Nautical Almanac and Constants Calculated for every star not in the N. A. list for the year. | 9. Personal equation of the observer. |
| 10. Mean Polar Distances of stars. | 10. Sum of columns 6, 7, 8 and 9. |
| 11. Apparent Polar Distance by Ephemeris. | 11. Corrected clock time of transit. |
| 12. Correction to Ephemeris. | 12. Clock correction applied. |
| | 13. Apparent Right Ascension. |
| | 14. Reduction to January 1st. Calculated as in column 9 of the Polar Distance page |
| | 15. Mean Right Ascension of stars. |
| | 16. Apparent Right Ascension by Ephemeris. |
| | 17. Correction to clock or Ephemeris. |

In view of the practice of publishing only the results of observation folio day books, although they constituted the basic documents, were seldom published except by national observatories. The Madras folio day books were bound for preservation in the observatory, and a copy of them was prepared for better preservation in England on account of climatic conditions in the tropics.

OBJECTS SELECTED FOR OBSERVATION

The plan of observing the fixed stars and other objects with the new Troughton and Simms transit circle included the bright stars inclusive, down to the 5th magnitude ; the moon and moon-culminating stars given in the Nautical Almanac ; Mars and the stars observed with him at successive oppositions, on the meridian, as well as those used east and west, with the Equatorial, for parallax investigations ; minor planets in opposition, if not under the 10th magnitude ; comparison stars used for differential observations for comets and planets from 1861 ; all known variable stars ; zero stars for maps of those objects in hand, and as many others, not below the 9th magnitude, as time would permit, between 130° and 150° Polar Distances, as determining stars for the zones of the southern survey, in extension of the late Prof. Argelander's great Northern Survey, which with that distinguished

astronomer's warm approval and advice I had intended to make my chief personal labour at Madras' ²⁰ Pogson's southern survey plan received a setback presumably due to opposition from his authorities and advisers in England, who preferred to apportion the work to a number of observatories. He started the work in 1863, early in his programme, but gave it up due to such unexpected opposition. He recorded his disappointment as follows : 'The very extraordinary opposition met with to this work, from a quarter whence such was least expected, partitioning out in portions to other observatories the work I had undertaken as a whole, compelled me to abandon any participation in its accomplishment at the end of 1863, after it had been fairly commenced in that year'.

The Madras meridian circle observations as published between 1887 and 1894 gave only the results for the fixed stars. For observations on the Moon, Mars and minor planets, and comets, separate volumes of planetary and cometary discoveries were envisaged. On variable stars Pogson spent a considerable part of his time and energies with the help of his Indian assistants and planned an *Atlas of Telescopic Variable Stars*. Michie Smith recorded in 1892 that the manuscript of this Atlas had been nearly completed when he laid it aside to take up the publication of the volumes on fixed stars. On Pogson's death, the manuscript and related papers passed on to the care of his nephew. Nevertheless, his catalogue of fixed stars contains a large number of variable stars of which a sample is given in Table 6.

In the catalogue of fixed stars, the stars have been designated by Flamsteed's numbers and Bayer's Greek letters, while in the case of principal stars, their familiar names have been retained. For stars not covered by the above, designations have been made by reference to Taylor's *Madras Catalogue*, Baily's edition of *Lalande, Bessel's Zones* as compiled by Weisse, and *Argelander's Zones* as compiled by Celtzen. For polar stars, the nomenclature used in the *Catalogue of 164 Stars Within 6° of the North Pole*, given in Vol XVI of the *Radcliffe Observations*, was used. The values of proper motions have generally been given from the results published in the *Memoirs of the Royal Astronomical Society* (Vols. 19, 28 and 33), *Greenwich Catalogue*, *Stone's Catalogue*, and the *Cape Catalogue of 12,441 Stars* and a few others referred to in the foot-notes. In the volume for observations for the years 1871-73, proper motion data were taken from Auwer's *Neue Reduction der Bradley'schen Beobachtungen*.

For the variable stars Pogson used his own nomenclature after consultation with Prof. Argelander, Sir John Herschel and other authorities. His plan was to use the name of the constellation followed by Var. 1, Var. 2, etc. to indicate 'the order of proved variability of each star in such constellation'. The system did not make any distinction between periodical and temporary stars—those which are subject to more or less regular changes and those which have only once risen to a maximum. Pogson explained this by the following example : 'Thus in Cassiopea, we have Gemma's Nova of 1572, known as β Cassiopea α Cassiopea Var. 2; R Cassiopea Var 3, etc.'²¹

The catalogue contains the separate results of observations for each star often

over several nights by more than one observer and the mean positions of stars observed in each year. In the latter only complete observations are included so as to render the mean date the same for both coordinates. The tables of fixed stars given in this paper are all taken from the catalogue of mean positions. To give an idea as to how the separate results were recorded, Table 2 is reproduced from the results of observations for the years 1865, 1866 and 1867.

TABLE 2
SEPARATE RESULTS OF OBSERVATIONS FOR FIXED STARS-PLAN OF RECORDING, (R-RAGOONATHA CHARY ;
M-MOOTTOOSAWMY)

No. and Date	Mag.	Mean Rt. Ascension 1865' h m s	No. of Wires	Mean Polar distance " ' "	Obsers	No. & date	Mag	Mean Rt. Accen-sion. h m s	No. Of Wires	Mean polar Dis-tance " ' "	Obsers
9		88 Pegas γ		Algenib				60 α Eridani,		Achernar	
Oct 5	0 6	17.8	75	34 2.8	M	Oct 31	1 32	41.25	147	55 26.4	R
	6	17.21		34 1.9	M	No 3	32	41.24		55 25.2	M
	7	17.20		34 3.0	M	22	32	41.06	6	55 26.7	R
	27	17.18		34 2.6	R	27	32	41.13		55 28.0	R
						30	32	41.09		55 26.6	M

The number of annual mean positions of fixed stars as on January 1st for the years 1862-1887, as given in the catalogue, is shown in Table 3.

TABLE 3
NUMBER OF ANNUAL MEAN POSITIONS OF FIXED STARS AS ON JANUARY 1ST BETWEEN
THE YEARS 1862-1887.

Year	No. of Stars	Year	No. of Stars	Year	No. of stars
1862	227	1869	688	1876	218
1863	782	1870	628	1883	480
1864	1000	1871	496	1884	222
1865	1063	1872	918	1885	51
1866	957	1873	680	1886	55
1867	1016	1874	590	1887	58
1868	837	1875	310		
				Total :	11,276

From the catalogue of mean positions, a select list of bright stars is given in Table 4, a select list of stars with Polar Distances greater than 90° in Table 5, and a select list of variable stars in Table 6. While Tables 4 and 5 do not call for comments, a few remarks may be made on variable stars.

VARIABLE STARS

In Table 6, the period of brightness fluctuations is given with the exception of a few cases. The period ranges from the minimum value of 3.95 days to the maximum value of 658 days. If we arrange the periods according to the classification adopted by Chandler and Roberts²² two classes of variable stars, *e.g.*, long-period and short-period, are readily recognizable.

TABLE 4
MEAN POSITIONS OF BRIGHT STARS

No.	Star	Mag.	Mean R. A.			Mean Polar Distance			Observer	
			h	m	s	°	'	"		
<i>For 1865 January 1st</i>										
9	88 Pegasi γ (Algenib)	3.0	0	6	17.16	75	34	2.3	5M	2R
28	Cassiopeae α Var	22.2	0	32	51.73	34	12	14.6	2R	
49	1 Ursae Minoris α (Polaris)	2.2	1	9	37.58	1	24	38.2	3M	2R
60	α Eridani, (Achemar)	1.0	1	32	41.15	147	55	26.6	3R	2M
75	13 Arietis α	2.0	1	59	34.07	67	10	41.0	6M	5R
122	33 Persei α	1.9	3	14	41.76	40	37	21.6		1R
157	87 Tauri α (Aldebaran)	1.0	4	28	10.58	73	45	56.3	6M	2R
188	13 Aurigae α (Capella)	0.2	5	6	43.14	44	8	36.6		1R
225	58 Orionis α Var. 2 (Betelgeux)	0.9	5	47	51.84	82	37	17.0	5M	4R
257	α Argus (Canopus)	1.0	6	20	57.41	142	37	23.6		R
279	9 Canis Maj (Sirius) α	1.4	6	39	11.78	106	32	1.5	1M	1R
<i>For 1866 January 1st.</i>										
339	66 Geminorum α^2 (Castor)	2.0	7	26	2.74	57	49	17.1	4M	2R
345	10 Can. Min. α^2 (Procyon)	0.5	7	32	17.12	84	26	4.7	3R	11M
352	73 Geminorum (Pollux)	1.1	7	37	6.77	61	39	13.1	1P,4R,11M	
441	65 Cancri α	4.3	8	51	9.34	77	37	35.3	1M	3R
472	30 Hydrae α Var 2	2.0	9	21	0.11	98	4	46.7	8M	1R
514	32 Leonis α (Regulus)	1.4	10	1	13.95	77	22	46.3	9M	4R
568	50 Ursa Majoris α (Dubhe)	2.0	10	55	26.08	27	31	33.9	1M	
618	94 Leonis β (Deneb)	2.2	11	42	13.32	74	40	46.7	6M	3R
686	67 Virginis α (Spica)	1.2	13	18	8.14	100	27	40.2	1M	4R
716	16 Bootis α (Arcturus)	0.0	14	9	33.04	70	7	8.6	3R	8M
722	α Centauri... 1st	1.0	14	30	31.24	150	16	55.3	3R	
741	5 Cor. Bor. α (Alpheta)	2.4	15	29	0.89	62	49	59.0	1M	3R
<i>For 1867 January 1st.</i>										
769	1 Ophiuchi δ	2.8	16	7	22.62	93	20	59.5	1M	1R
778	21 Scorpii α (Antares)	1.1	16	21	15.38	116	8	1.4	1R	

806	55	Ophiuchi α	2.2	17	28	45.61	77	20	28.0	6R	2M
835	3	Lyræ α (<i>Vega</i>)	0.2	18	32	26.04	51	20	19.3	3R	2M
845	41	Sagittar π	3.1	19	1	51.16	111	13	56.5	1M	
858	50	Aquilæ γ	2.8	19	39	56.08	79	42	31.5	3R	3M
890	50	Cygni α (<i>Deneb</i>)	1.5	20	36	53.82	45	11	38.8	3M	1R
924	8	Pegasi ϵ	2.4	21	37	39.11	80	44	0.3	3R	5M
970	53	Pegasi β Var. 1 (<i>Scheat</i>)	2.6	22	57	19.89	62	38	17.4	1M	
993	17	Piscium τ	4.3	23	33	6.60	85	5	39.7	7M	2R
1008	28	Piscium ω	4.2	23	52	28.93	83	52	23.1	1M	2R

For 1883 January 1st.

29	43	Andromedæ β	2.2	1	3	10.92	54	59	58.7	2R	
37	1	Urs. Min. α (<i>Polaris</i>)	2.2	1	15	50.44	1	18	54.4	5R	9M
45		α Eridani (<i>Achernar</i>)	1.0	1	33	21.53	147	49	54.4	1R	
58	13	Arietis α	2.0	2	0	34.70	67	5	29.9	6R	11M
107	33	Persei α	1.9	3	15	58.29	40	33	23.5	3M	
127	87	Tauri α (<i>Aldebaran</i>)	1.0	4	29	12.46	73	43	37.5	5R	3M
136	13	Aurigæ α (<i>Capella</i>)	0.2	5	8	2.65	44	7	19.6	5M	4R
137	19	Orionis β (<i>Rigel</i>)	0.3	5	8	54.85	98	20	16.2	8R	

For 1884 January, 1st.

43	21	Canis Majoris ϵ	1.5	6	54	4.01	118	48	53.4	1M	
46		Canis Min. α (<i>Procyon</i>)	0.5	7	33	13.74	84	28	42.5	1M	
68	32	Leonis α (<i>Regulus</i>)	1.4	10	2	11.61	77	27	55.7	3R	
82	94	Leonis β	2.2	11	43	8.59	74	46	45.7	1R	
87	2	Corvi ϵ	3.1	12	4	9.43	111	58	25.6	1R	
97	67	Virginis (<i>Spica</i>) α	1.2	13	19	4.82	100	33	18.2	1R	
102	16	Bootis (<i>Arcturus</i>) α	0.0	14	10	22.21	70	12	45.6	1M	2R
111	5	Cor. Bor. (<i>Alpheta</i>) α	2.4	15	29	46.52	62	53	38.7	1R	6M
118	21	Scorpii (<i>Antares</i>) α	1.1	16	22	17.75	116	10	24.6	2M	
146	3	Lyræ (<i>Vega</i>) α	0.2	18	33	0.47	51	19	23.7	2M	4R
174	53	Aquilæ (<i>Altair</i>) α	1.0	19	45	7.41	81	26	13.1	1M	2R
182	6	Capricorni α^2	3.8	20	11	37.16	102	54	9.8	2R	
191	50	Cygni (<i>Deneb</i>)	1.5	20	37	28.48	45	7	58.7	1R	4M
211	34	Aquarii α	3.2	21	59	49.58	90	52	59.6	1M	
218	24	Pis. Atls. (<i>Fomalhaut</i>) α	1.3	22	51	14.28	120	14	12.3	2M	

TABLE 5
 MEAN POSITIONS OF A SELECTED LIST OF STARS WITH POLAR DISTANCES GREATER THAN 90°
 (R = C. Ragoonatha Chary ; M = P. Moottoosawmy Pillay)

No.	Star	Mag.	Mean R. A.			Mean Polar Distance			Observer
			h	m	s	°	'	"	
	<i>For 1868 Jan. 1st.</i>								
3	Lacaille 9757	7.0	0	4	37.48	131	6	27.8	1M
4	Lacaille 3	6.9	0	6	18.72	148	38	57.8	1M
7	Taylor 64	7.1	0	14	19.84	129	58	18.4	1M
13	Lacaille 88	7.8	0	19	42.86	130	22	43.8	2M
17	Taylor 148	6.0	0	28	10.49	143	6	10.6	1R
26	Lacaille 234	7.2	0	45	5.86	129	14	48.1	1M
42	Brisbane 203	8.0	1	15	9.38	150	46	2.3	1R
43	45 Ceti θ'	3.8	1	17	25.51	98	51	56.3	8M, 2R
46	Taylor 496	8.0	1	25	51.12	140	34	56.8	1M
50	Taylor 539	5.9	1	31	54.34	148	56	42.3	1M
54	Lacaille 550	8.1	1	46	45.90	129	23	55.9	2M
68	Taylor 697	7.0	2	1	54.27	145	42	48.3	1M
85	Taylor 940	7.9	2	40	24.68	128	43	31.9	1R
86	Taylor 978	7.3	2	47	28.25	147	44	12.5	2M
87	Lacaille 941	6.8	2	50	33.47	146	25	7.1	2M
88	Taylor 991	7.6	2	50	42.58	129	11	12.0	2M
92	Taylor 1052	6.0	3	0	30.45	150	15	4.7	1R
97	Taylor 1112	8.0	3	10	26.01	129	29	27.6	1R
105	Lacaille 1159	6.9	3	30	21.30	151	27	46.1	1M
108	Lacaille 1192	7.9	3	35	4.22	147	43	1.2	1M
109	Lacaille 1193	7.6	3	35	21.44	146	34	27.9	1M
114	Lacaille 1242	7.3	3	41	50.75	147	4	31.9	1R
117	34 Eridani γ'	3.0	3	51	52.30	103	53	10.2	3M, 3R
120	Taylor 1392	6.5	3	55	53.15	147	28	41.9	1R
127	Lacaille 1425	6.0	4	13	4.72	152	31	28.1	1M
128	ε Reticuli	5.0	4	14	12.72	149	37	16.0	1M, 1R
129	Taylor 15 13	6.3	4	14	21.97	151	16	26.2	1M, 1R
135	Taylor 1582	7.0	4	23	15.88	151	32	17.4	1R
137	R Reticuli Var. 1	9.8	4	32	10.98	153	18	11.4	1R
138	Lacaille 1551	5.5	4	32	11.93	153	5	45.7	1R
140	Lacaille 1567	5.0	4	35	13.90	152	20	19.2	1R
	<i>For 1869 Jan. 1st.</i>								
115	Taylor 1764	6.6	4	50	31.69	129	50	27.3	1R, 1M
121	2 Leporis	3.3	4	59	54.92	112	32	57.4	1R, 6M
123	Taylor 1852	6.5	5	2	16.23	144	35	7.8	1R
124	Lacaille 1739	7.6	5	2	56.85	146	57	29.5	1M

127	Lacaille 1824	7.8	5	17	7.90	129	37	44.8	1M
130	Taylor 1973	6.5	5	19	4.80	129	48	5.9	1R, 1M
136	Taylor 2057	8.0	5	38	4.53	151	55	21.9	1R
140	Lacaille 1916	8.8	5	32	33.80	121	8	29.2	1R
142	α Columbae	2.7	5	34	54.47	124	8	44.1	3 M, 2R
162	Lacaille 2104	6.9	5	54	27.67	143	26	19.3	1M
165	Taylor 2301	6.6	5	58	34.74	148	6	17.1	1M
178	Lacaille 2273	8.0	6	17	5.61	153	58	34.0	1M
179	α Argus (<i>Canopus</i>)	0.4	6	21	2.74	152	37	31	1R
181	Lacaille 2312	7.0	6	22	11.16	153	36	47.9	1R
183	Lacaille 2321	7.0	6	23	31.80	153	20	53.4	1M
184	Taylor 2524	9.0	6	23	36.96	131	3	14.8	1R
185	Taylor 2529	7.1	6	24	30.99	130	59	28.3	1R, 1M
186	Lacaille 2348	7.7	6	26	34.71	152	3	54.8	2M
204	Lacaille 2500	7.5	6	47	9.60	130	23	42.5	1M
208	21 Canis Majoris ϵ	1.5	6	53	28.66	118	47	44.6	4R. 6M
213	Taylor 2840	8.8	6	59	6.54	150	57	16.4	1R
217	Lacaille 2678	8.0	7	6	15.89	148	9	43.2	1M
237	Taylor 3293	7.8	7	46	38.29	144	44	50.3	1M
243	Taylor 3373	7.3	7	55	21.11	144	12	42.1	1M
246	Taylor 3380	8.4	7	55	55.33	144	11	22.4	1M, 2R
248	15 Argus	2.9	8	1	57.92	113	55	42.6	7 M, 7R
258	Taylor 3599	7.1	8	20	24.39	144	53	44.3	1M
264	Lacaille 3475	6.7	8	34	59.38	152	23	39.4	1M
267	Taylor 3767	7.0	8	36	26.45	149	51	17.0	1M
304	Taylor 4337	7.4	9	42	0.75	148	26	38.6	1M
334	Taylor 4824	7.3	10	36	17.48	148	59	36.5	1M
<i>For 1870 Jan. 1st</i>									
352	Taylor 4852	7.9	10	39	5.85	148	53	38.2	2M
354	Brisbane 3194	8.0	10	39	32.46	149	3	21.2	1R, 1M
358	Lacaille 4502	8.2	10	46	45.39	141	6	39.1	1R
364	Taylor 4945	7.3	10	49	10.79	144	55	37.5	1M
377	Taylor 5088	7.1	11	5	10.31	149	40	45.4	1M
380	12 Crateris δ	3.9	11	12	50.49	104	4	31.8	5M, 1R
392	Lacaille 4850	6.0	11	34	43.57	144	51	12.9	1M
397	Lacaille 4956	8.0	11	51	27.47	154	35	57.3	1M
401	2 Corvi ϵ	3.1	12	3	26.42	111	53	47.4	9M
414	Taylor 5710	6.5	12	20	20.36	147	35	49.5	2R, 1M
417	Taylor 5785	8.0	12	28	6.30	151	1	24.7	1M
435	Taylor 6057	6.0	13	4	12.11	149	13	42.4	1M
437	Lacaille 5434	8.0	13	6	20.54	152	53	30.9	1M

440	67 Virginis α (<i>Spica</i>)	1.2	13	18	20.71	100	28	54.7	10M, 2R
450	Taylor 6374	7.0	13	38	8.39	151	56	15.9	1R
457	Taylor 6570	8.8	14	0	26.75	149	57	45.1	1M
470	Brisbane 5069	7.9	14	41	46.87	131	18	15.6	1M
481	Taylor 7242	7.0	15	24	47.78	130	2	45	1M
499	21 Scorpii α (<i>Antares</i>)	1.1	16	21	26.35	116	8	27.3	2R, 2M
512	Lacaille 7517	7.0	17	52	55.92	149	10	28.3	1R
520	Taylor 8527	6.0	18	23	49.21	108	29	20.5	1R
<i>For 1871 Jan. 1st.</i>									
355	Lacaille 7919	8.5	18	48	12.10	129	4	39.4	1M, 1R
369	Lacaille 8074	6.7	19	13	6.66	132	15	14.8	1R
376	Lacaille 8173	8.0	19	32	10.42	143	14	37.4	2R
386	Lacaille 8370	7.7	20	7	34.43	152	18	1.0	1M
401	Lacaille 8571	7.5	20	43	27.24	150	11	24.5	1R
405	Lacaille 8630	7.5	20	51	50.86	126	37	35.8	1R
413	Lacaille 8748	8.3	21	10	18.31	145	5	58.3	1R, 1M
423	Taylor 10032	6.3	21	31	10.34	142	56	23.9	2M
433	Lacaille 8948	7.3	21	45	27.85	127	30	0.4	1M
438	Lacaille 9006	7.5	21	56	34.81	129	29	52.2	1M
443	Lacaille 9047	7.5	22	4	21.51	128	56	18.7	2M
465	24 Piscis Aus α (Fomalhaut)	1.3	22	50	31.01	120	18	19.8	2M, 1R
470	Lacaille 9372	7.7	23	0	48.47	150	25	57.0	1M
473	Lacaille 9423	7.0	23	10	20.64	151	42	19.3	1M
480	Lacaille 9514	8.9	23	26	15.91	131	33	27.7	1M
489	Lacaille 9650	9.0	23	49	27.45	129	45	51.3	1R

* Misprinted 450.

TABLE 6

VARIABLE STARS OBSERVED BY MADRAS MERIDIAN CIRCLE

(S=C. SASHOO IYENGAR; R=C. RAGOONATHA CHARY; M=T. MOOTTOOSAWMY PILLAY; P=POGSON; INV=INVISIBILITY; IRRG=IRREGULAR; NUMBER BEFORE S, R, M, P.

MEANS NUMBER OF OBSERVATIONS CARRIED OUT BY EACH.)

No.	Star	Period	Magnitude		h	Mean			Mean			Observer
			Mean	Range		R. A.	m	s	P. D.	"	"	
<i>Observations during 1862</i>												
<i>Mean Positions for 1862 Jan 1st.</i>												
52	68 Ceti * Var. 1	331 days	5.7.	2-10	2	12	22.52	93	36	22.1		1R, 2M
71	35 Tauri λ Var. 1	3.95 "	45	3.4-4.3	3	53	2.16	77	54	10.5		IS
124	S Ophiuchi Var. 3	234 "	—	9-inv.	16	26	18.98	106	52	3.1		1S
127	R Ophiuchi Var. 2	302 "	—	7-inv.	16	59	50.59	105	54	20.1		3S
129	64 Herculis Var. 1	ing.	3.0	3-4	17	8	21.31	75	26	58.6		1P, 3S, 1M
153	R Scuti Var. 1	71 "	4.4	5-8.5	18	40	6.76	95	51	10.9		2M
156	10 Lynae β Var. 1	12.9 "	3.9	3.5-4.5	18	44	59.09	56	47	44.3		5S
157	13 Lynae Var. 2	46 "	—	4.2-4.6	18	51	8.15	46	14	3.2		3S
211	53 Pegasi β Var. 1	ing.	2.5	2.2-2.7	22	57	5.33	62	39	53.5		1M
225	R Cassiopeae Var. 3	426 "	6.0	5-inv.	23	51	24.70	39	22	48.8		1R
<i>Observations during 1863;</i>												
<i>Mean positions for 1863 Jan. 1st.</i>												
7	R Andromedae Var 1	405 "	8.4	6-13	0	16	48.16	52	10	55.4		3R, 2M
14	18 Cassiopeae Var. 1	ing.	3.0	2.2-2.8	0	32	45.04	34	12	54.1		2M
42	R Piscium Var. 1	345 "	10.2	7.5-12	1	23	34.40	87	49	43.4		1R
66	68 Ceti * Var. 1	331 "	7.8	2-10	2	12	25.64	93	36	8.6		1R
107	35 Tauri λ Var. 1	3.95 "	4.5	3.5-4.3	3	53	5.59	77	54	7.4		2M
137	7 Aurigae ϵ Var. 1	ing.	3.5	—	4	52	8.56	46	23	0.7		2R

140	R Leporis Var. 1	438	"	6.3	6-9	4	53	22.12	105	0	54.4	5M
156	34 Orionis δ Var. 1	irr.	"	2.0	2.3-2.7	5	25	0.51	90	24	14.0	1M, 6R
169	58 Orionis α Var. 2	irr.	"	1.0	1.0-1.5	5	47	45.30	82	37	18.5	12R
181	7 Geminorum η Var. 6	229	"	3.5	3-4	6	6	36.42	67	27	26.8	3R
204	43 Gem. 3 ² Var. 1	10.16	"	4.0	3.7-4.5	6	55	58.86	69	13	56.7	1M, 3R
206	R Geminorum Var. 2	371	"	7.7	7-inv	6	59	6.33	67	5	20.3	3R
210	R Canis Minoris Var. 1	335	"	8.4	7.5-11	7	1	10.40	79	45	46.5	3R
228	S Canis Minoris Var. 2	332	"	9.8	7.5 inv	7	25	16.94	81	23	36.4	3R
242	T Geminorum Var. 4	228	"	8.3	8.5-inv	7	41	4.50	65	55	40.7	2R
264	R Cancri Var. 1	354	"	7.7	6-12	8	9	0.61	77	51	21.7	2R, 1P
284	S Cancri Var. 2	9.48	"	8.5	8-10.5	8	36	6.39	70	28	32.6	4R
291	S Hydrae Var. 3	256	"	10.2	8-13	8	46	25.20	86	24	59.2	3R
294	T Cancri Var. 3	484	"	9.4	8-10.5	8	48	50.44	69	37	45.1	2R, 1M
295	T Hydrae Var. 4	289	"	9.7	7-12	8	48	59.93	98	37	15.5	1R
323	30 Hydrae α Var. 1	irr.	"	2.3	2-2.5	9	20	51.25	98	4	0.1	6M, 7R
342	R Leonis Var. 1	312	"	8.6	5-10	9	40	11.14	77	56	16.3	3M, 2R
369	R Ursa Majoris Var. 1	303	"	7.0	6-13	10	34	54.01	20	30	25.3	4M, 1R
465	R Virginis Var. 2	146	"	9.1	6.5-11	12	31	32.83	82	15	27.4	2M, 1R
472	S Ursae Majoris Var. 2	225	"	8.5	7-12	12	37	54.71	28	9	19.6	1R
529	U Bootis Var. 4	uncertain	"	9.7	8.7-12	14	4	18-65	79	32	14.1	1R
548	R Bootis Var. 1	223	"	8.2	6-12	14	31	9.02	62	40	3.1	3R
568	S Serpentis Var. 3	361	"	10.3	8-12.5	15	15	14.94	75	11	28.9	1R
584	R Coronae Borealis Var. 1	323	"	7.4	6-13	15	42	55.81	61	25	16.9	1R, 1M
585	R Serpentis Var. 2	658	"	9.4	6-11	15	44	22.70	74	26	27.0	1R
596	R Scorpis Var. 1*	223	"	10.5	9-inv	16	9	29.32	112	36	12.5	3P, 1R
601	U Scorpis Var. 4*		"	9.0		16	14	37.24	107	33	6.6	2R

* A new temporary star (Nova)

611	S Hercules Var. 3	303	"	7.9	6-12	16	45	39.68	74	49	31.9	1P, 2M
618	64 Hercules α Var. 1	irrg.	"	3.5	3-4	17	8	24.07	75	27	4.2	2P, 4R, 3M
635	'Sagittarii Var. 6	7-59	"	5.5	5-6	17	56	16.20	119	34	56.7	1M
648	10 Lyrae β Var. 1	12.91	"	4.0	3.5-4.5	18	45	1.25	56	47	40.6	3M, 1R
650	13 Lyrae Var. 2	46	"	4.3	4.2-4.6	18	51	9.74	46	13	59.4	1R
655	R Aquilae Var. 2	345	"	9.3	6.5-11	18	59	46.23	81	58	36.2	1R
658	T Sagittarii Var. 3	381	"	9.0	7.5-inv	19	8	19.76	107	12	28.3	2R, 2M
659	R Sagittarii Var. 1	270	"	8.9	7-inv	19	8	39.23	109	32	43.8	1R, 2M
659	R Cygni Var. 3	425	"	10.3	7-inv	19	33	10.30	40	4	55.5	1R
673	X Cygni Var. 2	406	"	5.7	4-inv	19	45	17.88	57	25	51.3	1R
674	55 Aquilae η Var. 1	7.17	"	5.0	3.5-4.7	19	45	29.50	89	20	36.6	1R, 1M
679	R Capricorni Var. 1	347	"	9.9	9-inv	20	3	37.14	104	40	13.6	1R, 1M
682	R Sagittae Var. 1	70.4	"	9.7	8.3-10.3	20	7	49.50	73	41	10.8	1R, 1M
685	34 Cygni Var. 1	Many	"	5.9	3-6	20	12	44.35	52	23	30.3	1R, 2M
690	24 Cephei (Hev) Var. 4	Many	"	7.9	5-11	20	28	56.11	1	17	22.1	1M
694	S Capricorni Var. 2	—	"	9.2	9-12	20	33	53.85	109	32	34.3	1R, 1M
697	S Delphini Var. 2	276	"	8.9	8-12	20	36	46.06	73	24	9.9	1M
706	R Vulpeculae Var. 2	137	"	10.0	7.5-13	20	58	23.33	66	42	54.9	2R
719	μ Cephei Var. 1	irrg.	"	5.4	4-6	21	39	18.86	31	50	51.5	1R, 2M
733	27 Cephei Var. 2	5.36	"	5.6	3.7-4.8	22	24	5.38	32	17	9.6	1R, 2M
744	S Aquarii Var. 2	279	"	8.8	8-inv	22	49	48.58	111	4	26.7	2R
750	53 Pegasus Var. 1 (Scheat)	6 weeks	"	'2.0	2.0-2.5	22	57	8.24	62	39	36.2	1M
778	R Cassiopeae Var. 3	426	days	9.5	5-inv	23	51	27.44	39	22	30.2	1R
Observations during 1864, Mean Position for												
1864 January, 1st.												
56	V Piscium Var. 5	—	—	10.0	6-9	1	47	7.59	81	53	9.4	1R
71	68 Ceti α Var. 1 (Mira)	331	days	8.0	2-10	2	12	28.68	93	35	52.2	1M, 2R
101	25 Persei ρ Var. 2	irrg	"	4.0	3.5-4.3	2	56	27.54	51	41	23.1	1M
132	35 λ Tauri ν Var. 1	3.95	"	6.3	3.5-4.3	3	53	8.92	77	53	48.7	1R

148	U Tauri Var. 7	unknown		9.7	9-10.5	4	13	53.65	70	30	42.4	1R
149	T Tauri Var. 6		"	10.4	9-13	4	14	3.84	70	47	26.0	2R
157	R Tauri Var. 2	325	"	9.9	8-inv.	4	20	51.07	80	8	37.7	2R
163	R Reticuli Var. 1	281	d	8.5	7-inv	4	32	8.35	153	18	40.4	1M
307	S Canis Minoris Var. 2	382	days	8.3	8.5-inv	7	25	20.43	81	23	41.7	1R
383	U Cancri Var. 4	306	"	9.7	9-inv	8	27	58.93	70	35	20.4	2R
505	η Argus Var. 1	irrg.		—	1-9	10	39	47.45	148	58	13.4	2R,1M
611	T Ursae Majoris Var. 3	255	"	8.3	7-12	12	30	11.19	29	45	49.5	2R, 1M
628	U Virginis Var. 3	207	"	9.3	8-13	12	44	11-78	83	42	20.5	3R
644	W Virginis Var. 1	irrg.		8.4	7-10.5	13	6	54.18	105	49	54.7	3R, 1M
654	V Virginis Var. 7	251	"	9.3	7-13	13	20	46.90	92	27	59.2	1R
655	R Hydrae Var. 1	15	Mths	5.5	4-10	13	22	17.30	112	34	38.9	1M
659	S Virginis Var. 6	374	days	7.0	6-12	13	25	53.98	96	29	41.9	1M, 1R
705	R Camelopardi Var. 1	266	"	10.8	8-12	14	28	9.31	5	33	16.5	1R
714	β Ursae Minoris Var. 1	irrg.		2.0	2-2.5	14	51	8.11	15	17	19.1	1R
802	T Herculis Var. 4	165	days	8.2	7.5-12	18	3	57.37	58	59	52.7	1R
840	S Vulpeculae Var. 3	67.5	"	9.6	8.5-9.5	19	42	49.26	63	3	1.8	2R
852	S Aquilae Var. 4	147	"	9.1	9-11.5	20	5	21.88	74	46	56.4	1R, 1M
875	7 Aquarii Var. 4	203	"	8.7	7-12.3	20	42	45.58	95	38	58.1	3R, 1M
932	27 Cephei δ Var. 1	5.366	"	4.0	3.7-4.8	22	24	7.58	32	16	51.0	1M

TABLE 7
LONG-PERIOD AND SHORT-PERIOD VARIABLE STARS

Period in days	0 to 50	50 to 100	100 to 150	150 to 200	200 to 250	250 to 300	300 to 350	350 to 400	400 to 450	450 to 500	500 to 550	550 to 600	600 to 650	Total
Stars														
Madras Catalogue (Pogson) Chandler & Roberts.	14	3	3	1	9	8	15	7	5	1	0	0	1	67
	73	8	12	22	41	45	49	50	20	6	1	2	1	330

The long-period variables cluster in the range between 200 to 450 days with the maximum in the range 300 to 350 days. The short-period variables have their periods between 0 and 50 days, the majority (in this case 9) with a period less than 10 days. Chandler and Roberts, who had a much larger number of variables for statistical analysis in 1896, arrived at similar conclusions, namely that (a) variables tended to fall within two categories, the long and the short, (b) that the long-period variables range from 200 to 450 days with a maximum at 300-350 days, and (c) the short-period variables have periods less than 50 days, the majority having less than 10 days. In his discussion of the results of meridian circle observations Pogson, however, did not discuss the classification of variable stars into such categories.

Among the long-period variables the best known is 68 Ceti o Var.1 which Pogson and his group observed several times. The period is given as 331 days, range between 2-10 mag., the mean magnitude varying in different years. Known as Mira or o Ceti, this was the first variable star to be discovered in 1596 by David Fabricius and systematically studied ever since, later on by the more powerful spectroscopic method. χ Cygni with a period of 406 d is another variable star of this class. Its magnitude varies from invisibility to 4 at which it is 4000 times as bright as when it is just visible; the mean magnitude is 5.7. Pogson's own discovery among the long variables includes R Ursa Majoris, Var 2, period 303 d, S Ursa Majoris, Var 2, 225 d, T Sagittarii, Var 3, 381 d, R Sagittarii, Var 1, 270 d, R Cygni, Var 3, 425 d, and R Cassiopeae, Var 3, 426 d:

The short variables are marked by a small range, the maximum and minimum exceeding 2 magnitudes (in our table only S Cancri var 2, 9.48d has a range of 8-10.5 mag.) The typical short-period variables are represented by Algol (β Persei), β Lyrae, ζ Geminorum and δ Cephei. Variability of Algol (not shown in our Table) was discovered by John Goodricke in 1783, with a period of 2d.20h.49m. We now know its variability is due to partial eclipse of a star by its dark companion. The

variable star 10 Lyrae β , period 12.9 days, range 3.5-4.5 mag, was also discovered by Goodricke in 1784. Goodricke noticed maximum magnitude of 3.4 while the minimum was at one time 3.9 and at another 4.5 ; he estimated the period at 12d. 22h. The Geminorum type of variable is represented by 43 Gem. z^2 , Var. 1, 10.16 d, 3.7-4 range. The fourth type is 27 Cephei δ Var. 1, 5.366 d with a range of 3.7 to 4.8 mag. The short variable U Scorpii, Var 4, discovered by Pogson, was a new temporary star or nova.

Pogson and his team of observers worked indefatigably over their cherished programme of meridional observations of fixed stars with their new transit circle. Pogson's interest in astronomy was so deep and abiding that he worked almost to the last day of his life in complete disregard of medical advice. Michie Smith observed : "Mr. Pogson's interest in Astronomy never flagged and even after the doctors had told him that he had only a short time to live he devoted all the little strength he had to pushing on his work and so arranging it that others might take it up. By his death astronomy lost one of her most devoted disciples—an observer of remarkable skill and one whose knowledge was full and accurate—while those who knew him well lost a true friend on whom they could always depend and one ever willing to help them to master what had been to him a life-long study and a life-long source of pleasure²³

POSTSCRIPT

After communicating the paper my attention was drawn to two papers by R. K. Kochhar, one dealing with the early history of the Madras Observatory and the other its buildings and instruments²⁴. The papers contain sketches of the observatory building from Goldingham's manuscript (1792) and the volume containing Taylor's observations (1848) and further details of some early instruments used in the observatory.

NOTES AND REFERENCES

- 1 Results of observations of the Fixed Stars made with the Meridian Circle at the Government Observatory, Madras under the direction of Norman Robert Pogson, printed at Madras at the Lawrence Asylum Press for the years 1862, 1863 and 1864 in 1887 ; for the years 1865, 1866 and 1867 in 1888 ; for the years 1868, 1869 and 1870 in 1890 ; for the years 1871, 1872 and 1873 in 1892 (supervised by Mickie Smith) ; for the years 1874, 1875 and 1876 in 1892 (supervised by Mickie Smith) ; and for the years 1883, 1884, 1885, 1886 and 1887 in 1894 (supervised by Mickie Smith). The volumes are abbreviated as 'Madras Meridian Circle Observations'.
- 2 Madras Meridian Circle Observations, 1871-73, i.

3. Friedrich Wilhelm August Argelander (b. March 22, 1799) studied at the University of Königsberg and started his astronomical studies under F. W. Bessel. After directing the work of the observatories of Åbo and Helsingfors during 1823 and 1837, he joined the University of Bonn as Professor of Astronomy and worked in that capacity till his death in 1875. His important publications include *Observationes Astronomicae Aboae Factae* (3 vols, 1830-32), *Stellarum Fixarum Positiones Mediae* (1835), *Astronomische Beobachtungen auf der Sternwarte zu Bonn* (1846-1869), and *Durchmusterung* (vols. 3-5, 1859-1862) in which he reviewed the positions of 324198 stars from the north pole to -2° dec. [*Encyclopaedia Britannica*, 11th ed. (1910-11), vol. 2, p. 457.]
- 4 Madras Meridian Circle Observations, 1862-64, xiv.
- 5 Madras Meridian Circle Observations, 1874-76, i.
- 6 Madras Meridian Circle Observations, 1862-64, xv.
- 7 Madras Meridian Circle Observations, 1868-70, i.
- 8 Goldingham, J. D., *Astronomical Observations Made in the Honourable East India Company Observatory at Madras*, Vols. III and IV, 1824-25.
- 9 *Encyclopaedia Britannica*, 11th edition, vol. 27, p. 181.
- 10 Taylor, T. G., 'Determination of the Errors of Division of the Mural Circle at the Madras Observatory', *The Journal of the Asiatic Society*, 3, 403-408, 1834.
- 11 Madras Meridian Circle Observations, 1862-64, iii.
- 12 *Encyclopaedia Britannica*, 11th edition, vol. 27, p. 311.
- 13 Madras Meridian Circle Observations, 1862-64, v.
- 14 Madras Meridian Circle Observations, 1862-64, ix.
- 15 Madras Meridian Circle Observations, 1862-64, x.
- 16 Madras Meridian Circle Observations, 1862-64, xii.
- 17 Madras Meridian Circle Observations, 1862-64, xiii.
- 18 For methods of investigating the errors of transit circle, Brunnow's and Chauvenet's *Manuals of Spherical Astronomy*, may be consulted. For a simple account Barlow and Bryan's *Elementary Mathematical Astronomy*, as revised by Harold Spencer Jones, University Tutorial Press, London, will be useful.
- 19 Madras Meridian Circle Observations, 1865-67, xiv.
- 20 Madras Meridian Circle Observations, 1862-64, xiv.
- 21 Madras Meridian Circle Observations, 1862-64, xli.
- 22 Chandler S. C., 'Third Catalogue', *Astrophysical Journal*, vol. xvi, 1896 ; Roberts, A. B., 'Supplementary List of Southern Variables', *ibid*, vol. xxi. See also *Encyclopaedia Britannica*, 11th edition, 'Star' by A. S. Eddington.
- 23 Madras Meridian Circle Observations, 1871-73, i.
- 24 Kochhar, R. K., 'Madras Observatory : the beginning' and 'Madras Observatory : buildings and instruments,' *Bull. Astr. Soc. India*, 13, 162-168; 287-302, 1985.