REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1899 *June* 3.

GREENWICH OBSERVATIONS, 1898.

THE BOARD OF VISITORS.

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The President of the Royal Astronomical Society.	Prof. Sir R. S. Ball.
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The Report here presented refers to the year from 1898 May 11 to 1899 May 10, and exhibits the state of the Observatory on the last-named day.

I.—Buildings and Grounds, Movable Property, and Library :—

The new Observatory Building which has been in progress since 1891, was completed last March, by the addition of the East and West wings. This handsome building, which has been skilfully designed by Mr. Crisp, under the superintendence of the Director of Works of the Admiralty, provides much needed accommodation for the Observatory Staff, for the photographic records and books of calculations, and for the library, which had long outgrown the rooms hitherto available for it. In the new Observatory Building—which is cruciform in shape, having four wings of three storeys, with a central tower carrying the Thompson Equatorial and Dome—the Staff occupies the principal floor, the library will be placed in the ground floor of the North, East, and West wings, the ground floor of the South wing being fitted up as a workshop, and the upper floor will accommodate the photographic and other records and the stock of publications of the Observatory. Office furniture for the whole building has now been supplied through the Director of Stores, and as regards the library,

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records, publications, &c. arrangements have been made with Messrs. Lucy & Co. for the supply of their patent adjustable book-stacks to provide the shelf space required.

The completion of the new Observatory Building, which at three points breaks into the existing boundary fence, makes it desirable that the boundary of the Observatory should be enlarged in order to show off the handsome new building, and a proposal to give effect to this is under the consideration of the Admiralty. In the meanwhile, as a temporary measure, the existing wooden fence has been repaired where necessary.

Several sheds and outbuildings which encumbered the grounds have lately been removed consequent on the completion of the new building, in which provision is made for their contents.

The new Magnetic Pavilion, in an enclosure in Greenwich Park, at a distance of about 350 yards from the Observatory, on the East side, was completed at the end of last September, and the magnetic instruments for absolute determinations have been installed there. The greatest care has been taken to exclude all iron in building the Magnetic Pavilion, and the site has been selected so that there is no suspicion of magnetic disturbance from iron in the neighbourhood. The enclosure also provides a good meteorological station, where the standard thermometers and rain-gauges have been mounted.

The balcony round the building in which the 28-inch telescope is mounted was completed at the end of September, and is found very useful by the observers in doubtful weather, as giving an all round view of the sky.

The new Accumulator House, to take the place of the shed in which the accumulators are now placed, has been built as a basement on the north-west side of the new Observatory Building. It was completed at the end of March.

The electric light installation has been extended to the East and West wings of the new Observatory, and provision has been made for the renewal and enlargement of the accumulators, which will, as soon as practicable, be placed in the new Accumulator House and connected with the dynamo and electric mains.

The room formerly used as the Astronomer Royal's Official Room has been converted into an additional Chronometer Room, and has been fitted up with long tables or shelves to accommodate 140 chronometers.

The principal movable instruments are thus distributed:—

At Greenwich—

Transits B, C, D, E, and the transit with axis view.

Altazimuth D.

Equatorials (6-inch).—Cooke No. 2; Simms No. 1; Hodgson and Corbett. (The telescopes are mounted respectively on the Thompson and 28-inch Equatorials.)

Photoheliographs.—No. 3, complete. The tube of No. 2, and the driving clock (in use for the Personal Equation Machine).

Detached Telescopes (on tripod stands).—Two 4-inch (Simms Nos. 1 and 2), two 4-inch (R.O. Nos. 1 and 2), two $3\frac{1}{2}$-inch (R.O. Nos. 3 and 4).

Two Hilger Chronographs.

A single prism Spectroscope.

On loan—

Transit.—A, at the Cape Observatory.

Altazimuths.—A, at the Science Schools, South Kensington; B, at the Cape Observatory; E, at the Royal Naval College, Greenwich.

Equatorials.—Lee (6-inch) at Hong Kong Observatory; Simms No. 2 (6-inch), lent to the Science and Art Department.

Photoheliographs.—No. 1, complete, at the Cape Observatory; No. 5, complete, and No. 2 (without the driving clock), lent to the Science and Art Department; No. 4, complete, at the Madras Observatory.

Clocks.—Dent No. 1916, and Dent No. 2013, at the Cape Observatory; Dent No. 2011, at the Kew Observatory; Dent No. 2010, at Devonport; and Arnold 2, at the University Observatory, Oxford.

Anemometer.—Whewell's Anemometer, formerly (1843–1862) mounted above the roof of the Octagon Room of the Royal Observatory, lent for exhibition at South Kensington Museum.

The annual comparison of books in the Libraries with the catalogue has been made, and 7 books are reported missing, besides 9 books which were reported missing

last year. Five of the books missing last year have since been found. It is probable that some of the books now missing have simply been misplaced, the shelves being overcrowded. This state of things will, happily, not exist much longer, as the books will shortly be removed to the new rooms on the ground floor of the new Observatory Building, as explained in a previous paragraph. The opportunity will be taken at the time of the removal to re-arrange and re-organize the library, and it is proposed to make a new card catalogue to replace the existing slip catalogue.

II.—Astronomical Observations:—

Transit Circle.—The Sun, Moon, planets, and fundamental stars have been regularly observed on the meridian as in previous years. The number of observations made from 1898 May 11 to 1899 May 10, is as follows:—

Transits, the separate limbs being counted as one observation	11,764
Determinations of collimation error	298
Determinations of level error	694
Circle observations	10,830
Determinations of nadir point (included in the number of circle observations)	665
Reflexion observations of stars (similarly included)	560

The number of stars observed in 1898 is about 5,000.

The number of meridian observations in the first three months of 1899 was unusually large, being 1,200 more than the average of the three preceding years. The excess was entirely in January and February, for which months the number of observations was double the average number. This unusually large number of observations has caused great pressure on the computing staff in that branch, and it is much to their credit that the reductions have fallen so little behind.

The transits are completely reduced (so as to exhibit Mean R.A. 1899·0) to March 11. Apparent R.A. is formed to April 4, and the instrumental and clock errors are found to May 7.

The circle observations are completely reduced to March 11. Apparent N.P.D. is formed to April 9. Star corrections are computed for R.A. and N.P.D. to March 20.

The copy for press of the transits and zenith distances for 1898 is in the printer's hands.

The investigation of personal equations is completed for 1898.

The correction for R–D discordance, the error of the assumed colatitude, and the position of the ecliptic have been investigated for 1898; and the whole of the planetary reductions are complete.

The apparent correction for discordance between the nadir observations and stars obtained by reflexion for 1898 was found to be $-0''.36$. The results of recent years are as follows:—

	Mean.	Range.
	″	″ ″
1880–1885	−0·34	From −0·29 to −0·45
1886–1891	+0·03	„ −0·12 to +0·09
1892–1898	−0·30	„ −0·25 to −0·36

New steel screws for the microscope micrometers were introduced in 1886; and in 1891 October, the object glass was repolished, and a new steel telescope micrometer screw was introduced. Both microscope and telescope micrometer screws have been examined, but show no errors which would account for this discordance.

The zenith-point correction is derived when possible from the mean of two reflexion observations of north stars, two of south stars, and the nadir observations, so that the weight given to the nadir observations is one-fifth. When no reflexion observations of stars are secured a correction of $-0''.25$ has been applied since 1897 January 1 to the observations of the nadir in forming the zenith-point. In other cases no correction is necessary, as the discordance in the nadir observation is virtually corrected through the constant term in the R–D correction, so that the zenith-points depend essentially on reflexion observations of stars distributed over a large range of zenith-distance.

Observations of level and nadir have, when practicable, been made three or more times on the same day. The results of the observations from 1895 to 1898 are given in a paper communicated to the Royal Astronomical Society, *Note on the Diurnal Variations of the Nadir and Level of the Transit Circle.* (M.N. Vol. LIX. pp. 351–353.) The observations of level made within three hours of noon and of midnight give

corrections of + 0″·25 and + 0″·18 respectively, to those made within three hours of 6 p.m. Similarly the observations of nadir near noon and midnight give corrections of + 0″·17 to those made within three hours of 6 p.m.

The small value of the correction for the R–D discordance found for 1897, viz., +0″·068 +0″·104 sin Z.D. is confirmed by the result for 1898, viz., +0″·082 +0″·102 sin Z.D. The coefficient of sin Z.D. was about 0″·6 from 1881 to 1894, diminished to 0″·41 and 0″·37 in 1895 and 1896, and has diminished further to 0″·10 in 1897 and 1898.

The observations of the zenith distances of pairs of stars directly and by reflexion, alternately on alternate nights, have been continued, and 41 pairs have been observed in the year ending 1899 May 10. The following table gives a comparison of the results in 1898 with those obtained from the ordinary reflexion observations :—

Mean Z.D.	R. and D. observations on different nights taken in 1898.	R. observations taken immediately before D. in 1897 and 1898.	No. of pairs of observations on different nights.
°	″	″	
+62	+0·67	+0·56	4
+48	+0·23	+0·43	11
+25	−0·08	+0·07	5
−25	+0·02	+0·30	4
−49	−0·23	+0·06	8
−63	−1·12	−0·20	4

The colatitude of the transit-circle, as found from observations of about 600 stars in 1898, is 38° 31′ 21″·75, differing by − 0″·15 from the adopted value. The effect of Chandler's latitude variation was computed for each of these stars within the limits 10° and 35° N.P.D. The following table, exhibiting the effect of Chandler's correction to the colatitude on the means of groups arranged for each hour of right-ascension, shows how entirely its influence is eliminated from the resulting colatitude.

R.A.	Correction.	R.A.	Correction.	R.A.	Correction.	R.A.	Correction.
h.	″	h.	″	h.	″	h.	″
0	0·00	6	·00	12	·00	18	·00
1	·00	7	+ ·01	13	− ·02	19	·00
2	+ ·02	8	+ ·02	14	− ·03	20	·00
3	+ ·03	9	+ ·01	15	·00	21	·00
4	+ ·01	10	+ ·02	16	− ·01	22	·00
5	·00	11	+ ·03	17	− ·02	23	+ ·04

The correction to the tabular obliquity of the ecliptic from solar observations in 1898 is $+0''\cdot40$. The discordance between the results from summer and winter solstices is $0''\cdot00$, indicating that the observations of the Sun are in exact accord with the adopted colatitude and refractions. The apparent correction from the observations of the Sun to the right ascensions of the clock stars is $+0^s\cdot085$.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is $-0^s\cdot143$ in R.A. and $+0''\cdot14$ in N.P.D. deduced from 104 observations. These are equivalent to an error of $-2''\cdot23$ in longitude and $+0''\cdot21$ in ecliptic north polar distance.

As proposed in the last report, a new determination of the division errors of the transit circle was made in 1898, June–September. An account of this investigation is given in a paper by Mr. Dyson and Mr. Thackeray, published in the Memoirs of the R. Astron. Soc., Vol. LIII., "New values of the division errors of the Greenwich Transit Circle and their effect upon the Observed North Polar Distances." Two determinations of the 5° divisions were made; in the first 5°, 25°, 45° were taken as primary divisions, and in the second 15°, 35°, 55°. These were combined with a determination made in 1856, in which 0°, 20°, 40° were taken as primary divisions, and one in 1871, in which 10°, 30°, 50° were taken as primary divisions, the determination made in 1851 being rejected. Combination of these four results gives a symmetrical determination of the 5° divisions in which each is determined with equal accuracy. The errors of the single-degree divisions were also re-determined; the result was combined with the determinations of 1851 and 1856, which were re-reduced with the newly determined values of the terminal five-degree divisions in each case. The errors of the 5′ divisions used in the nadir observations and for close polars were re-determined and previous observations collected and re-reduced and combined with the new determinations.

The copy for press of the New Ten-Year Catalogue of Stars, 1887–1896, which contains 6,950 stars, is nearly completed. The magnitudes of the stars and the notes are not yet inserted. Comparisons with other Catalogues are in progress as a final check on the numerical accuracy of the work.

With the new division errors, the accordance of the observations above and below Pole is very satisfactory, as is shown in the following table:—

Limits of N.P.D.	Observed Excess of N.P.D. above Pole, Bessel's Refractions. Colat. 21″·90.	Weight.	Number of Stars.	Correction for Pulkova Refractions. Colat. 21″·90.	Observed Excess of N.P.D. above Pole, Pulkova Refractions. Colat. 21″·75.
° °	″			″	″
0 to 5	−0·08	812	63	+0·24	−0·14
5 „ 10	+0·06	1,600	182	+0·26	+0·02
10 „ 15	+0·09	1,634	181	+0·29	+0·06
15 „ 20	+0·02	2,146	274	+0·30	+0·02
20 „ 25	+0·02	1,922	273	+0·33	+0·05
25 „ 30	−0·02	1,687	289	+0·37	+0·05
30 „ 35	−0·19	1,491	344	+0·44	−0·05
35 „ 40	−0·28	1,006	280	+0·54	−0·04
40 „ 45	−0·56	141	56	+0·65	−0·21

It is hoped that the Catalogue will be printed by the end of the present year.

The New Altazimuth.—After the date of the last Report it was found that the readings of the several microscopes varied systematically with the direction in which the instrument was swung. As this pointed to a constraint in the axis, several modifications were made in the arrangements for counterpoising the instrument. Rollers were introduced instead of ball-bearings, but these were not found to be satisfactory, and ultimately improved ball-bearings with balls of larger diameter in a hardened steel ring, freely suspended by a chain, were found to be quite successful. It was not till November 18 that these improvements were completed, and that regular observations could be commenced. It is now found that the direction of swing of the telescope has no effect on the readings of the several microscopes, but discordances in the results in reversed positions of the telescope as compared with the transit-circle observations indicated weakness in the attachment of the telescope tube to the axis, or of the object-glass and eye-end to the telescope tube. On examination it was found on December 14 that several of the screws were loose, and, subsequently, bolts were substituted for screws in the attachment of the telescope to the axis, and the attachment of the eye-end to the tube was strengthened. As the images of stars were found to be slightly coloured, the object-glass was re-centered, and springs were substituted on one side for the dead fitting, so as to prevent any shake in the lenses. These various changes were not completed till February 23, and since then the observations, both of transits and zenith distances in reversed positions, show a satisfactory accordance.

In March, brackets were fixed to the reversing gear to carry the boxes which hold the counterpoise springs, so that the telescope can be reversed on its Y's without the necessity for removal and re-adjustment of these springs.

A chronograph for use with the altazimuth is being made by Sir Howard Grubb.

The instrument has been used mainly in the meridian throughout the year, and a large number of observations of collimation, level, and nadir have been made to test the stability of the instrument. Observations at other azimuths than the meridian have been recently made. The following observations, including those made on six nights when the instrument was in the prime vertical, and one night at an azimuth 100° W., have been made during the year :—

	No. of Observations.
Collimation error	519
Level error	794
Azimuth error	170
Nadir	1,037
R.A. of Sun, Planets, and Stars	1,017
N.P.D. of Sun, Planets, and Stars	961
R.A. of Moon	20
N.P.D. of Moon	20

Clocks and Chronographs.—New contact wheels were fitted to the Mean Solar Clock Dent 2012 in December, the time signals being sent during the alterations by the Clock Shepherd.

Electric dials, sympathetic with the Mean Solar Clock, have been placed in the East and West rooms of the new building, similar to those in the North and South rooms.

Electric bells have also been fitted up to give an hourly time signal from the Mean Solar Clock. The Clock Graham I. was removed from the old Altazimuth dome and fixed in the new Altazimuth dome on March 17. The Clock Dent 2016 has been

placed in the dome of the Thompson Equatorial and is used to control the driving clock of the Equatorial. The alternate seconds contact wheel was replaced by one giving contacts each second in March.

Reflex Zenith Tube.—Since the date of the last Report, 38 double observations of γ Draconis have been made.

Equatorials.—During the year ending 1899 May 10, 6 disappearances and 4 reappearances of stars occulted by the Moon have been observed by one or more observers. Both phases of the occultation of Venus on 1893 May 22 were observed by four observers. The disappearance of Mars on 1898 September 9 was observed by one observer.

Comet *b* 1898 (Perrine) was observed with the Sheepshanks Equatorial on one night, Comet *h* 1898 (Perrine-Chofardet) on one night, Comet *i* 1898 (Brooks) on nine nights and Comet *a* 1899 (Swift) on two nights.

Thompson Equatorial.—The return of the object-glass of the 26-inch refractor on 1898 May 16 is referred to in the last Report. Slight figuring of the outer surface under Sir Howard Grubb's direction was continued till June 8. The object-glass was further tested by photographs taken inside and outside of focus and with diaphragms and was finally approved in September. The new 30-inch mirror, of slightly shorter focal length (corresponding to the length of the tube), was received from Dr. Common on September 1. Photographs to test the mirror were taken in the principal focus and also in the secondary focus, and it was found to be quite satisfactory.

A number of minor alterations and additions have been made to the instrument during the year. The scales for the sliding eye-piece of the Merz 13-inch guiding telescope were divided by Messrs. Troughton and Simms on June 21. An alteration of the breech-piece of the 26-inch, rendered necessary by a slight lengthening of focus found after the refiguring of the object-glass, was completed on July 20. Cords and pulleys were applied on November 25 to adapt the slow motion in declination for use at the eye-end of the reflector. On January 10 a weight of 15 lbs., passing over a pulley, was attached to the sector of the equatorial to keep it up to its bearing and correct the end shake which interfered with accurate driving. On January 17 an

occulting shutter was arranged for use with the refractor. A zinc exposing shutter at the eye-end was fitted on February 15. On April 17 the Hodgson 6-inch refractor, the guiding telescope of the reflector, was fitted with rectangular slides and scales for the eye-piece, similar to those of the astrographic guiding telescope and the Merz refractor.

With the 26-inch refractor 12 successful photographs of Neptune and its satellite have been obtained, using the occulting shutter to screen the planet during the greater part of the long exposure necessary to show the satellite, a series of short intermittent exposures for the planet being given by lifting the arm of the shutter. The results of these observations are given in the *Monthly Notices of the Royal Astronomical Society*, Vol. LIX., May. 42 successful photographs of 16 double stars have also been obtained, including 6 of Aldebaran, for which the occulting shutter was used in order to obtain measurable images of Aldebaran and the faint companion, for which a 20^m exposure was required. A few photographs of fields of stars have also been obtained.

The large light-gathering power of the reflector made it a suitable instrument for obtaining photographs of planet Eros. Altogether, 32 photographs were obtained, extending from September 20 to March 31. The results of these observations have been communicated to the Royal Astronomical Society, and are published in the *Monthly Notices*, Vol. LIX., April. Nine photographs of Neptune and its satellite were obtained with the reflector, five of comet Brooks, and one of comet Tuttle. These photographs have been measured and reduced, but the measures of Neptune's satellite on the photographs with the reflector are found to be much less accurate than those obtained with the refractor. Five photographs of the Pleiades have been taken with the reflector to investigate the distortion of the field. A fine photograph of the nebula in Andromeda has been obtained with an exposure of one hour, and two photographs of the Moon have been obtained at the secondary focus.

The 28-inch Refractor.—This instrument has been used throughout the year for micrometric measurements of double stars. 410 stars have been measured; 206 of these have their components less than $1''{\cdot}0$ apart, and 87 less than $0''{\cdot}5$. The stars whose distance apart is less than $1''{\cdot}0$ have been measured on the average on three nights each, and the wider pairs on two and a half nights. The wider pairs measured consist of stars in which there is a considerable difference of magnitude between the components, of third companions to close pairs, and of stars which are of special interest.

The following list includes some of the most interesting and difficult stars measured during the year :—

	Distance.	Magnitudes.		Distance.	Magnitudes.
	"			"	
Aldebaran	31·1	1 and 14	ζ Herculis	0·5	3 and 6
ω Andromedae	1·6	5 ,, 11½	γ^2 Andromedae	0·4	3 ,, 5
O Σ 225 A.B.	0·6	8 ,, 11	ε Hydrae AB	0·2	3½ ,, 6
β 883	0·3	7½ ,, 7½	β 552	0·4	7 ,, 10
Σ 1639	0·2	6½ ,, 8	Σ 1728	0·2	6 ,, 6
κ Pegasi	0·3	4 ,, 5	O Σ 269	0·3	6½ ,, 7

A long series of measures of 70 Ophiuchi have been obtained.

Lists of unpublished measures, containing altogether 128 stars, have been sent to Professor Burnham for incorporation in his catalogue of double stars. Recently the measures made in 1896-7-8 have been collected and communicated to the *Royal Astronomical Society*, and are published in the *Monthly Notices*, Vol. LIX. April.

Astrographic Equatorial.—During the year ending 1899 May 10, 465 plates have been taken on 120 nights. Of these 78 have been rejected, viz., 34 because the exposure was interfered with by cloud, or because the images were too faint to show 9th magnitude stars with a 20ˢ exposure; 17 owing to faults in guiding or exposure; 8 on account of wrong setting; and 19 from miscellaneous defects.

The following statement shows the progress made with the photo-mapping of the heavens :—

	For the Chart (Exposure 40ᵐ).	For the Catalogue (Exposures 6ᵐ, 3ᵐ, and 20ˢ).
Number of photographs taken	256	200
,, successful plates	211	167
,, fields photographed successfully	206	160
Total number of successful fields reported 1898 May 10	828	909
Number of photographs, previously considered successful, rejected during the year	7	39
Total number of successful fields obtained to 1899 May 10	1,027	1,030
Number still to be taken	122	119

Six photographs for adjustments of the equatorial, and three experimental photographs are included in the total number of 465 photographs taken during the year.

Each plate has undergone a preliminary examination to see whether it is generally satisfactory, and whether the adopted limits of magnitude were approximately reached, as inferred from the 20^s exposure, which should give 9th magnitude stars of Argelander's scale.

During the year positives on glass have been made of 288 chart plates, which, with the 663 mentioned in last year's Report, gives 951 as the total number of chart plates which have been copied.

Of the 122 fields still to be photographed, 101 are within 7° of the Pole. The photography of this part of the sky was purposely deferred till near the epoch 1900, and has just been begun.

The deterioration of some of the plates, owing presumably to the effect of damp in the building in which they were stored, which was referred to in last year's Report, has continued, as it was not found practicable to move the photographs into the new Observatory Building till March. Besides the plates which have been rejected during the year, as mentioned in the tabular statement above, there are about 40 Catalogue plates in the zones yet to be measured which should be taken again. The damaged chart-plates have all been copied, and the positives on glass will in any case be available. But it seems advisable that all the damaged plates, whether measured or copied, should be replaced by others, and, as the photo-mapping for the zone allotted to Greenwich is now nearly completed, this work can shortly be taken in hand.

Réseau Gautier No. 80 which has been in use from 1898 January 24, was replaced on 1899 March 13 by No. 81, as it showed more pin-holes and scratches than could be conveniently stopped out.

During the year more than 80,000 measures of pairs of images (6^m and 3^m) as well as of the diameters of the 6^m images have been made. The number of quarter plates measured in the twelve months in two positions of the plates is 576.

At the date of the last report the measurement of the plates was completed from Dec. 64° to 68°; and in Zone 68° (Dec. 68° to 69°) from R.A. 0^h to 12^h. During this year Zone 68° has been measured from R.A. 12^h to 0^h, the whole of Zone 69° and

Zone 70° as far as $13^h\ 48^m$. The measurement is thus complete from Dec. 64° N. to 70° N. and for R.A. 0^h to $13^h\ 48^m$ as far as Dec. 71° N.

The total number of separate stars measured, with the corresponding numbers in the *Bonn Durchmusterung*, and in the catalogues of the *Astronomische Gesellschaft* are approximately :—

Limits of Declination.	Number of Stars Measured.	Number in B.D.	Number in A.G.C.	——
64°–65°	9,080	1,900	1,200	Helsingfors.
65°–70°	49,100	7,782	3,700	Christiania.
70°–71° (0^h to $13^h\ 48^m$)	6,100	760	—	Dorpat.

Copy for press of the measures is completed for Zones 64° to 68° inclusive (Dec. 64° to 69°). Specimen pages have been put in type, and the printing of the measures will be begun immediately.

During the year the plate constants already found for the Zones 65°, 66°, 67°, have been corrected or re-computed, where necessary, for the differences introduced by using the mean of the direct and reversed measures. Plate constants have been determined for Zone 68°. The residuals have been computed, and those in Zones 65°, 66°, 67°, collected for each star.

The division errors of *Réseau* Gautier 72 have been determined and found to be so small that it is not considered necessary to apply them to the measures.

III.—Spectroscopic and Heliographic Observations :—

The adjustment of the new photographic spectroscope on the 30-inch reflector of the Thompson Equatorial has been delayed, first by the necessity for the mounting of a new 30-inch mirror of shorter focal length, and afterwards by the pressure of work with the telescope in connexion with the photographs of the planet Eros and the satellite of Neptune mentioned in the preceding section. The adjustment of the spectroscope has now been taken in hand.

In the year ending 1899 May 10, photographs of the Sun have been taken on 195 days, either with the Dallmeyer or Thompson photo-heliographs. The former, mounted on the terrace roof of the South wing of the Physical Observatory, was used as the regular instrument for solar photography up to and including 1898 July 27,

when the Thompson 9-inch photo-heliograph was substituted for it. The Dallmeyer photo-heliograph was dismounted and placed in the upper floor of the Museum on 1898 October 13. Of the photographs taken with either instrument, 394 have been selected for preservation, besides 16 photographs with double images of the Sun, for determination of zero of position-angle. Photographs to supplement the Greenwich series have been received from India or Mauritius up to 1899 January 13.

For the year 1898, Greenwich photographs have been selected for measurement on 165 days, and photographs from India and Mauritius (filling up the gaps in the series) on 192 days, making a total of 357 days out of 365 on which photographs are at present available. No photographs have been received from Mauritius of later date than 1898 August 7, and as the eight days which are at present unrepresented are all since that date, it is possible that the record for the year may yet be rendered complete.

The chief incident in the history of the Sun's surface, during the period covered by this Report, was the very remarkable temporary revival of activity which set in at the end of July and lasted almost to the middle of November, culminating in the appearance of the great group of September 3–15. Apart from this, the Sun's surface has been very quiet during the year, the spots being few, isolated, and small. There have, however, been no such long-continued instances of the entire absence of spots as to suggest that the minimum had been actually reached or is immediately at hand; the number of days without spots for which a record is at present available being 49, as compared with 42 in the previous Report.

As regards the measurement of the photographs, the Greenwich photographs have been measured in duplicate up to 1899 May 8, and the Indian and Mauritius photographs so far as received. The reductions are complete to 1898 October 24; the copy for press of the Daily Results has been sent to the printer up to that date, and the Spot Ledger has been completed to the same date. The conversion of the measures into heliographic longitude and latitude has been effected for the Greenwich photographs as far as 1898 December 31, and for the Indian and Mauritius photographs for all that have yet been received.

IV.—Magnetic Observations:—

The variations of magnetic declination, horizontal force, and vertical force, and of earth currents have been registered photographically, and accompanying eye

observations of absolute declination, horizontal force, and dip have been made as in former years.

On the completion of the new Magnetic Pavilion, last September, the Gibson deflexion instrument and the Airy dip circle were mounted there, and regular determinations of magnetic horizontal force and dip have been made there from that time. Previous to that the observations made at the old site in the Observatory, which are to a certain extent affected by iron in the neighbouring buildings, were supplemented by determinations of horizontal force and dip made near the site of the Magnetic Pavilion, Prof. Rücker having kindly lent his dip circle (Dover 74) for the purpose until June 20, when it was required for other work.

For determination of magnetic declination in the Magnetic Pavilion, the hollow cylindrical magnet of the Elliott declinometer has been mounted in conjunction with the theodolite used for the large declination magnet in the Observatory, the aperture of the viewing telescope being reduced to that of the magnet collimator (0·3 inch) and a low-power eye-piece being provided. Some trouble was experienced through a defect in one of the piers, and the new declinometer was not finally mounted and adjusted till the end of December. From 1899 January 1 regular observations of declination have been made in the Magnetic Pavilion, alternating with determinations in the Magnet House, to give the correction required to the results found at the latter site, representing the effect of the iron in the Observatory Buildings. Determinations of declination with the Elliott declinometer were also made in September and October, near the site of the Magnetic Pavilion, for comparison with the observations in the Magnet House.

The magnetic reductions for 1898 are completed to the following stages:—

The eye observations of the upper declination magnet, and of the horizontal and vertical force magnets, are completely reduced. The time-scales for the magnetic registers are complete; the base line values, deduced from eye observations, are entered on the sheets, and the hourly ordinates of the photographic curves for declination are read out and reduced. The temperature of the magnet basement at every hour has been read from the Richard thermograph sheets, and the daily and hourly means have been taken. The time-scales for earth currents are laid down. The dip and deflexion observations are completely reduced.

The principal results for the magnetic elements for 1898 are as follows:—

Mean declination		16° 39′·2 West.
Mean horizontal force		3·9878 (in British units). 1·8387 (in Metric units).
Mean dip	January to June — 67° 12′·4 October to December — 67° 11′·3	(with 3-inch needles.

These results depend on observations on the site of the Magnetic Pavilion, and are free from any disturbing effect of iron. The correction to the declination, as found in the Magnet House, is $-10'\cdot7$, deduced from the observations with the Elliott declinometer, in September and October, and with the new declinometer in the Magnetic Pavilion, the values found with the two instruments being precisely the same.

Careful examination has shown that the movement of the new altazimuth in azimuth produces no sensible effect on the magnetic registers.

The magnetic disturbances in 1898 have been few in number. There were two days of great magnetic disturbance and 14 of lesser disturbance. Tracings of the photographic curves for these days, selected in concert with M. Mascart, will be published in the annual volume as usual. The calculation of diurnal inequalities from five typical quiet days in each month has been continued.

The question of the protection of the Observatory from disturbance of the magnetic registers by electric railways or tramways in the neighbourhood has caused much anxiety during the past year. A number of such railways are now projected, and the value of the magnetic registers, which have now been carried on continuously for nearly 60 years, will depend entirely on the conditions under which electric traction is used. Steps have been taken, in concert with Professor Rücker, acting on behalf of Kew Observatory, to have a special clause inserted for the protection of Greenwich and Kew Observatories. This has already been accepted in several cases and it is hoped that it will be agreed to in others where necessary.

V.—Meteorological Observations:—

The meteorological instruments are all in good order. The registration of atmospheric pressure, temperature of the air, and of evaporation, pressure and velocity of the wind, rainfall, sunshine, and atmospheric electricity has been continuously maintained.

The standard thermometers and rain-gauge (No. 6) were removed at the beginning of January to the enclosure of the Magnetic Pavilion, where there is a freer circulation of air than in the Observatory grounds since the erection of the new buildings. To preserve as far as possible the continuity of the temperature record, the thermometers in the Stevenson screen and on the roof of the Magnet House are available for comparison with the standard thermometers in the Magnetic Pavilion enclosure. The former have not been moved and have been read regularly as for the last twelve years.

Consequent on the changes in connexion with the new Observatory Building now completed, the shed containing the photographic registering thermometers will be shifted 15 feet westwards of its present position. [This was carried out on May 16 and 17.]

The meteorological reductions are in the following state :—The observations of barometer, thermometers, anemometers, rain-gauges, and sunshine recorder (corrected, where necessary, for instrumental error) are reduced up to the present time. On the photographic sheets all time-scales are laid down, and the hourly ordinates are read out and completely reduced for the barometer, and for the dry and wet bulb thermometers to the end of 1898. The table of principal changes of the wind for 1898 is complete.

The mean temperature of the year 1898 was 51°·3, being 1°·8 above the average for the 50 years 1841–90.

During the twelve months ending 1899 April 30, the highest daily temperature in the shade recorded on the open stand was 92°·1 on September 8. The highest reading recorded in the Stevenson screen was 90°·0 on the same day.

It is exceptional for the highest annual temperature to occur in September, only one other case having been recorded in the preceding 57 years, viz., in 1895.

Temperatures exceeding 90° are also rare in September, one other instance only having been previously recorded, viz., in 1868, when there was a similar temperature of 92°·1 on September 7. The lowest temperature in the year occurred in March, and was 20°·3; and, with the exception of a brief wintry period in that month, the winter, like that of the preceding year, was exceptionally mild. This was especially marked

during the greater part of the month of February, the mean temperature from February 7 to 23 being 7°·1 in excess of the 50 years' average, and the mean daily temperature for February 10 being 18°·8 in excess of its average. The maximum temperature for that day (63°·9) is the highest temperature recorded in the month of February during the whole period of 59 years, 1841–99, and exceeded the previously recorded maximum by 1°·6.

The monthly mean temperatures were in excess of their corresponding averages from August to February (inclusive) to the mean amount of 3°·9. In December the excess amounted to 6°·1, and in September to 4°·9. In the five remaining months of the year the mean temperatures were below the average values.

The mean daily horizontal movement of the air in the 12 months ending 1899 April 30 was 291 miles, which is 10 miles above the average for the preceding 31 years. The greatest recorded movement was 950 miles on January 21, and the least, 67 miles, on March 14. The greatest recorded pressure of the wind was 33 lbs. on the square foot on February 13, and the greatest hourly velocity 53 miles on January 12.

During the year 1898 Osler's anemometer showed an excess of 11 revolutions of the vane in the positive direction N., E., S., W., N., excluding the turnings which are evidently accidental.

The number of hours of bright sunshine recorded during the 12 months ending 1899 April 30, by the Campbell-Stokes instrument was 1,500 out of the 4,454 hours during which the sun was above the horizon, so that the mean proportion of sunshine for the year was 0·337, constant sunshine being represented by 1.

The rainfall for the year ending 1899 April 30 was 22·74 inches, being 1·80 inches less than the average of 50 years. The number of rainy days was 158. The rainfall in the month of September amounted to 0·305 inch, being the smallest September rainfall on record in the period 1841–98, with the exception of September 1865, when the rainfall was only 0·16 inch.

VI.—Printing and Distribution of Greenwich Publications :—

The printing is now in a satisfactory and forward state. The copies of the Greenwich Observations for 1896 were distributed in April, together with the Heliographic Results for 1897.

As regards the Volume for 1897, the whole of the Transits, Zenith Distances, Ledgers, and Catalogue have been printed, and the remainder of the Astronomical Results are in the press. The Altazimuth Section and the Heliographic Results are printed. The whole of the Magnetic Results (with the exception of the plates), and half of the Meteorological Results are printed, and the remainder of the Meteorological Results is in the press. The 1897 Volume may, therefore, be considered as nearly complete, only the Introduction remaining to be prepared.

As regards the volume for 1898, the manuscript of the Transits and Zenith Distances has been sent to the printers, and the Heliographic Results as far as October 24. The Heliographic Results have been printed as far as September 18, and the Transits to February 8. The copy for press of the Rates of Chronometers and Deck Watches in the Annual Trial 1898–99 has been sent to the printer.

VII.—Chronometers, Time Signals, Longitude Operations, &c. :—

The number of Government marine chronometers and deck-watches now being tested at the Observatory is 374, viz., 246 box chronometers, 30 pocket chronometers, and 98 deck-watches. In addition to these there are 5 box chronometers on trial for purchase by the Indian Government, and 10 box chronometers and 1 pocket chronometer are being tested after repair. In the year ending 1899 May 10, the average daily number of chronometers and deck-watches being rated was 499; the total number received was 1,090, the total number issued 1,087, and the number sent for repair 466. These include 32 box chronometers and 1 pocket chronometer for the Indian Government. One eight-day box chronometer and one pocket chronometer have been purchased, after trial, for the Indian Government.

For the annual trial of chronometers, which lasted 29 weeks, with a range of temperature from 46° to 108°, 103 chronometers were sent in, and of these 50 were purchased for the Navy and 4 for the Indian Government. The performance of these chronometers was fully up to the high standard obtained in recent years.

The deck-watches in the annual trial were tried in the positions "dial up," "pendant up," "pendant right," and "pendant left"; 145 were entered, and of these 43 were purchased for the Navy. The performance of the watches was very satisfactory. Among the watches sent for trial were 5 with centre seconds dials of which 4 were purchased. There were 42 "tourbillon" watches in the annual trial. The next competitive trial of chronometers commences on July 1, and of deck-watches on October 21.

As in all probability the chronometers and deck-watches required for the Navy will, in the course of the next two or three years, reach a number which is sufficient for all practical purposes, it is unlikely that any large annual number will be required after 1902. The purchases will then be merely to replace unserviceable instruments. Chronometer and watch makers have been notified accordingly.

The Greenwich time-ball was not raised on five days during the year, owing to the violence of the wind. On May 19, June 30, and December 7, the ball did not drop at 13^h owing to the failure of the time signal. It was raised and dropped at 14^h on these days.

There were 3 failures in the Greenwich time signal at 13^h due to failure in the electric contacts, and on October 10 it was $0^s{\cdot}5$ late.

The automatic drop of the Deal time-ball failed on 8 days owing to interruptions of the telegraph connexions, and on one day owing to a defect in the relay at Deal. On 8 days the ball was not raised owing to high wind.

The return signal from the Devonport clock failed on 36 days (of which 9 were Sundays), and could not be observed on 14 days owing to interruption by telegraph signals. The apparent error of the clock signal (after daily correction of the clock by aid of a time signal from Greenwich) did not exceed $0^s{\cdot}2$ on 74 per cent. of the 308 days of observation, did not exceed $0^s{\cdot}5$ on 95 per cent., and never exceeded $1^s{\cdot}0$.

The return signal from the Portsmouth clock (similarly corrected by the help of a time signal from Greenwich) failed on 53 days (28 of these being Sundays), and could not be observed on 4 days owing to interruption by telegraph signals. The apparent error of the clock signal did not exceed $0^s{\cdot}2$ on 82 per cent. of the 301 days of observation, did not exceed $0^s{\cdot}5$ on 98 per cent., and exceeded $1^s{\cdot}0$ on two occasions.

The automatic signals from the Westminster clock have been received throughout the year except on 48 days, when the signal failed. On 10 days the signal could not be observed owing to interruption by telegraph signals. The apparent error of the clock was not greater than $0^s{\cdot}5$ on 25 per cent. of the days of observation, not greater than $1^s{\cdot}0$ on 44 per cent., not greater than $2^s{\cdot}0$ on 74 per cent., not greater than $3^s{\cdot}0$ on 95 per cent., and exceeded $4^s{\cdot}0$ on one occasion.

The longitude of Killorglin, at the head of Dingle Bay, Ireland, was determined in October and November. The station was selected in order to eliminate, as far as possible, the effect of local attraction at Valentia and Waterville, both of which longitude stations are situated between the Atlantic on the West and a mountain mass on the East. The observations at Killorglin and Greenwich were made by Mr. Dyson and Mr. Hollis with the portable transits D. and E., and were divided into three groups of three, six and three full nights (or their equivalents in half nights), the observers with their instruments being interchanged between the first and second, and again between the second and third groups. Altogether signals for comparison of clocks were interchanged on 44 nights, clock errors were determined at Greenwich on 26 nights and at Killorglin on 22 nights, observations at both stations being obtained on 15 of these nights. The reduction of the observations is practically complete.

A desire has been expressed by the International Geodetic Association for a re-determination of the longitude of Paris—Greenwich in view of the discordance in the results found by the French and English observers respectively in the two determinations in 1888 and 1893, and the Council of the Paris Observatory have recommended that this work should be undertaken in concert with Greenwich Observatory. As a preliminary to the actual longitude operations it seems essential that the instruments to be used by both parties of observers should be thoroughly tested at contiguous stations.

VIII.—Personal Establishment :—

The Staff at the present time is thus constituted, the names in each class being arranged in alphabetical order :—

Chief Assistants—Mr. Cowell, Mr. Dyson.

Assistants—Mr. Hollis, Mr. Lewis, Mr. Maunder, Mr. Nash, Mr. Thackeray.

Second-Class Assistants—Mr. Bryant, Mr. Crommelin.

Clerical Assistant—Mr. Outhwaite.

Established Computers—Mr. Bowyer, Mr. Davidson, Mr. Edney, Mr. Furner, Mr. Rendell, and one vacancy.

The two Second-Class Assistants will be replaced by Higher Grade Established Computers as vacancies occur.

Mr. Dyson and Mr. Cowell have the general superintendence of all the work of the Observatory. Mr. Maunder is charged with the heliographic photography and

reductions. Mr. Lewis has charge of the time-signals and chronometers, and of the 28-inch equatorial. Mr. Thackeray superintends the miscellaneous astronomical computations, including the preparation of the new Ten-Year Catalogue. Mr. Hollis has charge of the photographic mapping of the heavens, the measurement of the plates, and the computations for the Astrographic Catalogue. Mr. Crommelin undertakes the altazimuth and Sheepshanks equatorial reductions, and Mr. Bryant the transit and meridian zenith distance reductions and time-determinations. In the magnetic and meteorological branch, Mr. Nash has charge of the whole of the work. Mr. Outhwaite acts as responsible accountant officer, has charge of the library, records, manuscripts, and stores, and conducts the official correspondence. As regards the Established Computers, Mr. Bowyer, Mr. Furner, Mr. Davidson, and Mr. Rendell assist Mr. Lewis, Mr. Thackeray, Mr. Hollis, and Mr. Bryant respectively, and Mr. Edney assists Mr. Nash.

There are at the present time twenty-three Supernumerary Computers employed at the Observatory, ten being attached to the astronomical branch, two to the chronometer branch, five to the astrographic, one to the heliographic, four to the magnetic and meteorological, and one to the clerical.

A foreman of works, with two carpenters, and two labourers; a skilled mechanic with an assistant; a gate-porter, two messengers, a watchman, a gardener, and a charwoman, are also attached to the Observatory.

The whole number of persons regularly employed at the Observatory is 52.

IX.—General Remarks:—

The completion of the new Observatory Building, which has been under construction for eight years, allows of the concentration of the greater portion of the staff, together with the photographic records and books of calculations with which they have to deal, all being now placed in one building, with ready means of intercommunication. The Library will also shortly be moved to the same building, where it will be much more readily accessible for reference. When the new arrangements are complete the work will be carried on under much more favourable conditions, but it is only quite recently that any benefit has been felt.

The work of the Observatory, in its various branches, as summarized in this Report, compares well with that of any previous year, a result which is due to the

spirit with which the staff of Assistants and Computers have worked to maintain the credit of the Royal Observatory. In the older branch of meridian observation, a new and more complete determination of the division errors of the transit circle, which entailed much labour, has resulted in a marked improvement in the accuracy of the results for zenith distance, as will be seen by comparing the results of circum-polar observations given in this Report with those in last year's Report. The measures of difficult double stars with the 28-inch refractor have furnished a large number of valuable results. The measures and reductions for the Astrographic Catalogue have made good progress, notwithstanding interruptions due to the new work with the Thompson Photographic Equatorial, and the publication of the results is now commencing. The continuity of the record of magnetic elements and of meteorological data has been secured by the building of the new Magnetic Pavilion and the installation there of magnetical and meteorological instruments on a site where they will not be affected by the disturbing influences due to the new buildings at the Observatory. The danger of disturbance of the magnetic registers from electric railways in the neighbourhood, which at one time seriously threatened the Observatory, has now, it is to be hoped, been warded off, without interference with the public convenience. The determination of the longitude of Killorglin has been carried out successfully, and will, it is hoped, serve as a valuable preparation for a new determination of the longitude of Paris with increased knowledge of the instruments to be used.

During the past year two new instruments—the Thompson Photographic Equatorial and the Altazimuth—have been got into working order. With the former valuable series of photographs of the planet Eros, and of Neptune's Satellite have been obtained, and these have been measured with very satisfactory results. The new Altazimuth has given much trouble in regard to the arrangements for relieving the weight of the telescope on its Y's. The difficulty has been successfully overcome, and the instrument is now in good working order. In the last few months a series of satisfactory observations of Sun, Moon, Planets, and Stars has been obtained with this instrument.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich,
1899 May 11.