

R E P O R T
OF
THE ASTRONOMER ROYAL
TO THE
BOARD OF VISITORS
OF THE
ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1904 June 4.

GREENWICH OBSERVATIONS, 1903.

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REPORT OF THE ASTRONOMER ROYAL
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The Report here presented refers to the year from 1903 May 11 to 1904 May 10, and exhibits the state of the Observatory on the last-named day.

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

The Lower Computing Room has been partitioned off from the staircase leading to the Upper Room and Dome, as much inconvenience was felt from draughts by the staff employed there, especially during the winter.

The whole of the New Observatory Building was painted internally last autumn with the exception of the East and West Library Rooms, which remain at present as originally distempered. The Magnet House and the old Record Rooms were also painted internally during the summer.

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The principal movable instruments are thus distributed :—

At Greenwich—

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

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

Photoheliographs.—Nos. 2, 3, and 5.

Detached Telescopes (on tripod stands).—Two 4-inch (Simms Nos. 1 and 2), two 4-inch (R.O. Nos. 1 and 2), one $3\frac{1}{2}$ -inch (R.O. No. 3).

Two Hilger Chronographs.

A single prism Spectroscope.

On loan—

Transit.—A, at the Cape Observatory. D and E, lent to the Paris Observatory for use in the longitude determination.

Altazimuths.—A, at the Science Schools, South Kensington; B, at the Cape Observatory; D, on loan to the Colonial Office for use of Major Watherston for Longitude Observations on the Gold Coast; 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. 4, complete, at the Kodaikanal 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 mounted above the roof of the Octagon Room of the Royal Observatory, lent for exhibition at South Kensington Museum.

Lent to the Royal Observatory by the Royal Astronomical Society :—

4-inch Rapid Rectilinear Lens, for use in the photographic determination of places of stars in the immediate neighbourhood of the Pole.

As reported last year, the re-arranging and cataloguing of the Astronomical Library has been completed, and the new system is now in working order. The North Library (containing the Transactions of Societies and Periodical Literature) is in good order, and has been worked so far with the old Catalogues, but an effort will be made this year to make a new Card Catalogue on the same lines as for the Astronomical Library. As the books are for the most part in long series, the work of making this catalogue will not be so heavy as in the case of the Astronomical Library.

The Alphabetical Card Catalogue of the Magnetical and Meteorological (East) Library has been completed so far as bound volumes are concerned, and the Library is in good order. The binding is much in arrear owing to the large number of unbound contributions which are received, but arrangements are being made to bring the binding up to date this year.

The annual examination of the library has been made, the books on the shelves being compared with the catalogues. Twenty books are missing from the shelves and are not entered in the lending book and cannot be traced at present. Of these 20 books, 7 were missing last year. Last year 25 books were missing, but 18 out of these 25 have since been found.

In connection with the examination of the library, it may be remarked that during the painting of the Observatory last year, it was necessary to use the library rooms as computing rooms for a time, and also that, to admit of painting the walls of the North Library, the books had to be removed from the shelves.

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 1903 May 11 to 1904 May 10, is as follows :—

Transits, the separate limbs being counted as one observation	-	13,270
Determinations of collimation error	-	307
Determinations of level error	-	628
Circle observations	-	11,470
Determinations of nadir point (included in the number of circle observations)	-	600
Reflexion observations of stars (similarly included)	-	379

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The transits are completely reduced (so as to exhibit Mean R.A. 1904.0) to 1904 April 12, and as far as Apparent R.A. to 1904 May 6.

The circle observations are completely reduced to 1904 April 12, and as far as Apparent N.P.D. to 1904 May 1.

The progress made in the observation of the reference stars for the astrographic plates (for which more than 10,000 stars are to be observed, three times above and twice below pole) has been so satisfactory that it is expected that sufficient observations of all the stars will have been secured by the end of 1905, at which date it is proposed to terminate the observations. The catalogue of the astrographic reference stars will thus be completed in nine years, a year earlier than was originally proposed. The present state of the work is shown in the following table:—

Limits of N.P.D.	Area in square degrees.	No. of Stars.	Average No. per square degree.	Number of Stars observed.						Total No. of Observations.	Per cent.
				5 times or more.	4 times.	3 times.	Twice.	Once.	Not observed.		
0°-5°	78.5	359	4.6	359	—	—	—	—	—	1,795	100
5°-10°	234.8	1,062	4.5	1,062	—	—	—	—	—	5,310	100
10°-15°	389.4	1,695	4.4	1,679	10	5	1	—	—	8,452	100
15°-20°	541.1	2,379	4.4	761	477	759	299	82	1	8,670	73
20°-26°	856.0	4,557	5.3	799	838	1,788	870	260	2	14,711	64
0°-26°	2099.8	10,052	4.8	4,660	1,325	2,552	1,170	342	3	38,938	77½
Corresponding totals reported last year.				3,022	1,073	1,787	3,059	1,057	49	31,938	63½

The investigation of personal equations is complete for 1903.

The correction for R-D discordance, and the position of the ecliptic have been investigated for 1903, Bessel's refractions being used.

After consultation with Prof. Albrecht it has been arranged to apply the correction for latitude deduced by him from the provisional discussion of the international series of observations to all observations of north polar distance year by

year, commencing with 1902, Prof. Albrecht having kindly arranged to communicate his results as soon as practicable after the end of the year. This correction has been applied to all the north polar distances for 1902 and to the planetary observations for 1903, and is now being applied in the star ledgers. Owing to a slight delay in the discussion of the last year's observations, caused by the necessity for waiting for Prof. Albrecht's results, the error of the assumed colatitude was not determined before the date of this Report.

The apparent correction for discordance between the nadir observations and stars observed by reflexion for 1903 has been found to be $-0''.23$. The values found since 1892 range from $-0''.20$ to $-0''.41$. Since 1897, January 1, a correction of $-0''.25$ has been applied to observations of the nadir in forming the zenith point on days when no reflexion observations of stars were obtained.

Observations of level and nadir have been made, when practicable, three or more times on the same day. The following table shows the mean values of the diurnal changes of the level and nadir, observations within three hours of noon, 6 p.m., and midnight, respectively, being grouped together:—

—	Diurnal Change of Level.			Diurnal Change of Nadir.		
	Noon.	6 p.m.	Midnight.	Noon.	6 p.m.	Midnight.
1898 -	+ 0".25	0".90	+ 0".18	+ 0".17	0".00	+ 0".17
1899 -	+ 0".30	0".00	+ 0".18	+ 0".17	0".00	+ 0".17
1900 -	+ 0".39	0".00	+ 0".23	+ 0".14	0".00	+ 0".04
1901 -	+ 0".28	0".00	+ 0".26	+ 0".17	0".00	+ 0".09
1902 -	+ 0".22	0".00	+ 0".20	+ 0".20	0".00	+ 0".17
1903 -	+ 0".14	0".00	+ 0".22	+ 0".04	0".00	+ 0".09

The correction for R-D discordance found for 1903 is $+0''.045 + 0''.261 \sin Z.D.$, a value agreeing well with the results of recent years.

The correction to the tabular obliquity of the ecliptic from solar observations in 1903 is $+0''.24$. The discordance between the results from summer and winter solstices is $-0''.42$, indicating that the mean of the observed distances

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from the pole to the ecliptic is too large by $+0''.21$. The apparent correction from observations of the Sun to right ascensions of clock stars is $-0''.024$.

As stated in last year's Report, the equinox of Prof. Newcomb's "Catalogue of Fundamental Stars for 1900," which is sensibly the same as that resulting from observations of the Sun since 1886, has been adopted.

In determining these quantities the correction for variation of latitude has been applied. The following table shows the corrections found since 1897 to the adopted equinox of Newcomb's catalogue, both without and with the correction for latitude variation :—

—	Correction to Equinox.	Correction for Latitude Variation.	Final Correction to Equinox.
1897 " -	^s $+ .011$	^s $- .030$	^s $- .019$
1898 " -	$+ .031$	$- .026$	$+ .005$
1899 " -	$- .009$	$- .003$	$- .012$
1900 " -	$- .032$	$+ .008$	$- .024$
1901 " -	$- .031$	$+ .004$	$- .027$
1902 " -	$- .031$	$- .010$	$- .042$

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is $-0''.190$ in R.A. and $-0''.15$ in N.P.D., deduced from 112 observations. These are equivalent to a mean error of $-3''.08$ in longitude and $+0''.03$ in ecliptic north polar distance.

Provision having been made for the comparison between theory and the Greenwich meridian observations of the Moon from 1750 to the present time, as suggested in the last Report to the Board of Visitors, the discussion of the longitude of the Moon 1750–1901, compared with revised tabular places, has been undertaken by Mr. Cowell on a plan devised by him, which enables the complex calculations to be done in a very economical manner, the lunar day being adopted as the unit of time. The work naturally divides itself into two periods: (a) 1847–1901, for which Hansen's tabular places are available, (b) 1750–1851, for which the comparison is made with Airy's tabular places. For both periods the tabular places have to be revised, but the work is much heavier for (b), corrections for a much larger number of terms being required in the case of Airy's tabular places.

For the Hansen period, 1847-1901, corrections for 13 terms have been applied throughout to Hansen's tabular longitudes, which have then been compared with the observations, and the results analysed by Mr. Cowell in periods of 400 lunar days, which is a convenient interval for analysis, as being approximately equal to 15 anomalistic months and also to 14 lunations.

For the Airy period, 1750-1851, corrections for 36 short-period terms and 6 of long period have been entered opposite to the corresponding observations, but have not yet been applied.

Mr. Cowell has published explanations of his methods of analysis of the Moon's errors, together with some of the results obtained, in the *Monthly Notices* of the Royal Astronomical Society, November 1903 to May 1904.

The re-reduction of Groombridge's observations is now completed. It is proposed to publish the ledgers of the separate observations reduced to 1810.0, the catalogue of mean right ascensions and north polar distances for 1810.0, and a determination of the proper motions by comparison with the modern Greenwich observations, mainly those of the Second Ten Year Catalogue. Copy for press has been completed for the ledgers and catalogue, and that for the proper motions is well advanced.

Altazimuth.—In consequence of systematic discordances in the north polar distances from observations made in the four positions of the instrument in the year 1902, the mounting of the object glass was examined in 1903 July. It was quite tight in its cell, but when examined by Mr. Simms it was found that the lenses were not resting fairly and were slightly tilted. They were readjusted, and small brass screws inserted to secure them. The star-images were not satisfactory, and the object glass was again removed. Mr. Simms found a strain in the cell, which he corrected, and the object glass was replaced on August 12. These changes slightly altered the focus, and a ring of phosphor-bronze $\frac{1}{40}$ th of an inch thick was inserted between the cell and telescope tube.

New wires were inserted in 1903 July. The telescope-micrometer, which received a severe knock early in August and had its shaft slightly bent, was repaired and replaced by Messrs. Troughton and Simms on August 5. In 1904 March the spring of the telescope-micrometer was removed and cleaned.

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The instrument has been used in the meridian in four positions during the year, the positions being changed regularly after two months, so that they will recur at different seasons of the year in a cycle of two years. Observations of the Sun, Moon, planets, and fundamental stars from a working catalogue which includes all those in the lists of the *Nautical Almanac*, *American Ephemeris*, *Connaissance des Temps*, and *Berliner Jahrbuch*, have been made throughout the year.

The instrument has been used regularly for extra-meridian observations of the Moon during the first and last quarters of the lunation.

The following observations have been made during the year:—

	No. of Observations.
Collimation error - - - - -	335
Level error - - - - -	572
Azimuth error - - - - -	177
Nadir - - - - -	693
Flexure - - - - -	13
Reflexion observations of stars - - - - -	168
R.A. of Sun, planets, and stars (in meridian) - - - - -	1,349
N.P.D. of Sun, planets, and stars (in meridian) - - - - -	1,056
R.A. of Moon (in meridian) - - - - -	35
N.P.D. of Moon (in meridian) - - - - -	31
Azimuth and Zenith distance of stars (extra meridian) - - - - -	319
Azimuth and Zenith distance of Sun and planets (extra meridian) - - - - -	29
Azimuth and Zenith distance of Moon (extra meridian) - - - - -	53

The altazimuth observations are completely reduced to the end of 1903, including the application of the correction for latitude variation. The star-ledgers for 1903 have also been formed. Of the observations for 1904, the meridian zenith distances are reduced to 1904 April 15, the transits to 1904 May 3, and the extra-meridian observations to 1904 February 23.

The R-D discordance has been investigated separately for each two months of the year during which the instrument remained in one position. The direct observations have also been compared with the positions given in Newcomb's Fundamental Catalogue. In this way it was shown that from 1902 January to 1903 July the four positions agreed in pairs, and a constant correction was determined which, when

applied with one sign to two positions of the instrument and the opposite sign to the other two, reduced them to the mean which would have been obtained had the stars been equally observed in all four positions of the instrument. Since the object glass was readjusted in its cell in August, the discordance between the different positions has almost entirely disappeared, indicating that it was largely due to faulty mounting of the object glass in its cell.

The extra-meridian observations are very satisfactory, both in quality and numbers. The following table shows the number of days on which observations of the Moon were obtained with the transit-circle and altazimuth, respectively, in the year ending 1904 May 10:—

Time of Moon's Meridian Passage. h. h.	Transit Circle.	Altazimuth.	
		Meridian.	Extra Meridian.
1-2 G.M.T. - -	0	0	1
2-3 - -	0	0	2
3-4 - - -	4	0	6
4-5 - - -	4	0	8
5-6 - - -	5	0	3
6-9 - - -	20	13	6
9-12 - - -	23	16	0
12-15 - - -	18	6	0
15-18 - - -	16	0	8
18-19 - - -	6	0	4
19-20 - - -	3	0	4
20-21 - - -	7	0	5
21-22 - - -	0	0	6
22-23 - - -	0	0	0

The total number of observations is 106 with the transit-circle and 88 with the altazimuth, viz. :—35 in the meridian, and 53 out of the meridian.

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Reflex Zenith Tube.—Observations with this instrument (by reflexion from a surface of mercury) have been made continuously during the year. A working list has been in use of all stars brighter than $7^m.0$ magnitude, which transit within $50'$ of the zenith at Greenwich. During the year 829 double observations and 54 single observations have been obtained, the number of different stars observed being 96. The brighter stars have been observed for as long periods of the year as possible. Thus 77 observations of γ Draconis and 49 of β Draconis, distributed throughout the whole year, have been obtained: 33 observations of β Draconis extend from May 11 to September 6 and March 21 to May 10, and 33 of α^2 Cygni from May 11 to December 13 and March 21 to May 10; while the group of five stars, 27 Lyncis, f Ursæ Majoris, Bradley 1306, Groombridge 1542, and θ Ursæ Majoris were observed continuously from the middle of November to the middle of April, and the two stars β and 9 Lacertae from August 31 to December 29. In this way a sufficient overlap is provided for the co-ordination of all the observations. In order to carry out this programme it has been necessary to introduce morning watches at certain periods of the year. The observations for 1902 have been printed, and the hitherto unpublished observations from 1886 to 1899 prepared for press.

Clocks and Chronographs.—The transit-circle chronograph is now being repaired by Messrs. E. Dent & Co., some improvements being made in the train of wheels. Since May 10, when the instrument was taken away, the registration of the transit-circle observations has been made on the chronograph of the Altazimuth.

The Mean Solar Clock (Dent 2012), injured during the thunderstorm of 1903 May 17, has been repaired. The electric clock Shepherd in the Ball Lobby has been thoroughly overhauled and new contact springs applied. The clock Mudge and Dutton, used in the chronometer room, has also been cleaned and repaired.

The sympathetic dials in the New Observatory gave considerable trouble in the latter part of 1903. They were sent to Messrs. E. Dent & Co. for alteration in January and have since their return performed satisfactorily.

Equatorials.—During the year ending 1904 May 10, 22 disappearances and 6 reappearances of stars occulted by the Moon have been observed by one or more observers.

The 28-inch Refractor.—This instrument has been used throughout the year for micrometric measurements of double stars. The total number of double stars

measured during the year is 512; of these, 178 have their components less than $1''.0$ apart, and 85 less than $0''.5$. The close pairs whose distance apart is less than $1''.0$ have been measured on the average on $2\frac{1}{2}$ nights each, and the wider pairs on 2 nights. The wider pairs consist of bright stars with faint companions, stars of special interest, and stars from Struve's catalogue which have not been measured within the last 30 years.

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

	Distance.	Magnitudes.		Distance.	Magnitudes.
κ Pegasi -	$0''.1$	3.9 and 5.0	68 Comæ -	$0''.3$	6.5 and 8.0
ϵ Hydrae AB -	0.1	3.5 „ 6.0	ζ Boötis -	0.3	3.5 „ 3.9
δ Equulei -	0.2	4.1 „ 4.1	γ^2 Andromedæ -	0.3	5.0 „ 6.2
β 1099 -	0.2	6.0 „ 6.5	$\text{O}\Sigma$ 269 -	0.3	6.5 „ 7.0
β 1266 -	0.2	7.2 „ 7.5	De. 15 -	0.5	8.2 „ 8.6
β 524 -	0.2	6.0 „ 7.0	Σ 2525 -	0.5	7.4 „ 7.6
Σ 2367 -	0.2	7.2 „ 7.6	ζ Herculis -	0.9	3.0 „ 6.5
β 883 -	0.3	7.0 „ 7.0	β 1251 -	1.4	6.0 „ 11.5
Σ 2107 -	0.3	6.5 „ 8.0	70 Ophiuchi -	1.5	4.1 „ 6.1
β 612 -	0.3	6.3 „ 6.5	Procyon -	5.5	1.0 „ 13.0

Series of measures have been obtained of κ Pegasi (14 nights), δ Equulei (18 nights), 70 Ophiuchi (14 nights), and ϵ Hydrae AB (4 nights). The definition has been generally very poor during the year, and on many other nights the only stars which could be measured were the Struve stars which had been put on the working list as not having been observed recently, these being generally fairly wide pairs. The results of the observations for 1903 will be communicated to the Royal Astronomical Society at the next Meeting.

Thompson Equatorial.—The renewal of the papier-mâché covering of the 30-foot dome referred to in the last Report was carried out by Messrs. Cooke and Sons between September 17 and October 29. The painting of the dome was commenced on the completion of these repairs, and completed by November 7.

The batteries and wiring for the clock-control, hand-control, and lighting of the instrument were overhauled and the instrument and clock were thoroughly cleaned after the completion of the work on the dome.

The resilvering of the 30-inch mirror was successfully carried out on November 27, the mirror being held inverted in the silver solution. The method used was that employed by the late Dr. Common, details and formulæ for the solutions being kindly communicated by Mr. Andrew Common.

The instrument was thus necessarily out of use from September 17 to November 27.

The occulting shutter has been used in the photography of Neptune and its satellite with the 26-inch refractor, and a good series of photographs have been obtained during the opposition of 1903-4. During the year the following photographs have been taken :—

With the 26-inch Refractor :—

- 58 photographs of Neptune and Satellite.
- 22 photographs of 10 double stars.
- 13 photographs for adjustments.

With the 30-inch Reflector :—

- 117 photographs of 40 minor planets.
- 27 photographs on 27 nights of Comet *c* 1903.
- 17 photographs on 12 nights of Comet *a* 1904.

The above photographs of comets have all been taken with short exposures, usually four on each plate, and are for the purpose of determining positions. Four exposures have also been given on each photograph of a minor planet, the object being to obtain accurate determinations of position on three or four nights for each planet, during the opposition.

In addition the following photographs with long exposures have been obtained :—

- 8 of Comet *c* 1903.
- 2 of Comet *a* 1904.
- 3 of the Great Nebula in Andromeda, and 3 of the Pleiades.

The most interesting of the photographs of long exposure is one of Comet *c* 1903 (Borrelly) taken on August 1, with an exposure of 40^m. This photograph, which shows nine distinct tails, was reproduced in the *Monthly Notices R.A.S.* for 1903 December.

Owing to the necessity of proceeding with the measurement of the photographs of Eros, the measurement of the photographs of comets and minor planets is somewhat in arrears. The measurement of the 97 photographs of Comet *d* 1902, Comet *a* 1903, Comet *c* 1903, Comet *a* 1904, and of the 117 photographs of 40 minor planets, will be begun as soon as the measurement of the Eros photographs is completed.

Considerable progress has been made with the measurement of the long series of photographs of Eros taken during the opposition of 1900-1. After some experimental measures had been made it was arranged that besides Eros, 10 or 12 Reference Stars from M. Loewy's list, chosen as symmetrically as possible with reference to Eros and within 50' of the centre of the plate, and 6 comparison stars of about the same magnitude as Eros and within 25' of the centre of the plate, should be measured on each of the photographs taken with the Astrographic Equatorial. These comparison stars are within the field of the Thompson plates and are measured on them with Eros. There are four images on each plate, and each image is measured in direct and reversed positions of the plate, one measurer taking two images and a second one the other two. All four images of Eros are measured twice by both measurers, at the beginning and end of the set of measures. The progress made in the measurement by May 10 is as follows:—

Astrographic Photographs.—119 plates—1900 October 1-7, and October 26-December 26, by two measurers. 17 plates—in addition, completing the series from 1900 October 1 to December 26, by one measurer.

Thompson Photographs.—55 plates—1900 October 26-December 17, by two measurers.

The measures of the photographs of Eros have been made with the new micrometer referred to in last year's Report. A brief description of this micrometer was communicated to the Royal Astronomical Society on 1904 May 13. The micrometer is thoroughly satisfactory, and with it astronomical photographs are measurable with all the accuracy of which they admit. With the magnification in use the probable error of the bisection of a perfectly defined speck is $\pm''\cdot020$; the probable accidental error of a single measure of an image of Eros is found to be $\pm''\cdot067$ on an Astrographic plate and $\pm''\cdot049$ on a Thompson plate.

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Owing to the error inherent in the star-images, the probable error of a position of Eros derived from a number of measures of four images on one plate is not nearly so small as the above measures suggest. Comparison of the positions of Eros for October 26 and 27 with the tabular places of M. Loewy's Ephemeris gives a probable error of $\pm''\cdot082$ and $\pm''\cdot045$ for photographs taken with the two instruments respectively. With the parallax factor of October 26 and October 27, it results that two of the Thompson plates at the beginning of the evening compared with two at the end are sufficient to give the Solar parallax with a probable accidental error of $\pm''\cdot016$. We may therefore expect an adequate result for the somewhat arduous measurements and reductions involved.

Astrographic Equatorial.—The photography for the Greenwich Section (Dec. $+64^\circ$ to the Pole) of the Astrographic Chart and Catalogue being completed, only a few photographs have been taken to replace some which appeared to be inferior to the general standard. This applies especially to chart plates which, though satisfactory in other respects, are, owing to photographic defects, unsuitable for production of enlarged prints.

Altogether 104 photographs were taken on 61 nights during the year; of these 42 were rejected, 22 of them because the plates showed specks or spots, and 16 because they did not reach the standard in showing faint stars. The 62 successful plates include 35 for the Chart, 9 for the Catalogue, 5 of Nova Persei, 1 of Comet *c* 1903, 2 of Comet *a* 1904, and 10 for adjustments of the instrument.

Since the last report 67,500 measures of pairs of images (6^m and 3^m) have been made as well as measures of the diameters of the 6^m images. The number of plates measured in the twelve months is 122, covering 195 square degrees. This completes the measurement from Dec. 64° to Dec. 84° , with the exception of one-third of Zone 83° . In all 1,051 plates out of 1,149, and 1,959 square degrees out of 2,087, have been measured, leaving only 98 photographs to be measured, covering 128 square degrees, and it is hoped that the measurement will be completed about the end of the year.

In addition, re-measures of discordant observations have been made for Zones 73° , 74° , 75° , and 76° , and measures of the Reference Stars outside the limits common to the overlapping plates, but within the réseau lines, have been made for Zones 73° and 74° .

The total number of stars measured (including an estimate for plates not yet measured in Zone 83°) with the corresponding numbers in the *Bonn Durchmusterung*, and in the catalogues of the *Astronomische Gesellschaft*, are :—

Limits of Declination.	Number of Stars measured.	Number in B.D.	Number in A.G.C.	A.G.C.
64°–65°	8,954	1,932	1,200	Helsingfors.
65°–70°	49,014	8,159	3,700	Christiania.
70°–75°	49,900	5,872	—	Dorpat.
75°–80°	42,300	4,451	3,777	Kazan.
80°–84°	19,000	3,063	—	
Totals 64°–84°	169,168	23,477		

It is to be noted that in the above table the numbers refer to separate stars, measured in duplicate in the great majority of cases.

Means of measures have been taken and examined for Zones 76°, 77°, 78°, and part of Zone 79°.

Copy for press has been written for Zones 73° and 74°, and for Zone 75°, with the exception of the identification of the B.D. stars and the addition of the measures of the Reference Stars outside the limits of the overlapping plates.

The printing of the measures for Zone 72° in Vol. II. of the Greenwich Section is in hand.

The Introduction to Vol. I. of the Measures, extending from Dec. 64° to Dec. 72°, has been completed, and this volume, which contains half of the Greenwich Section, is printed, and a few advance copies have been distributed.

Zones 70° and 71° of the chart plates have been counted during the year. In conjunction with the Volume of Measures just published, these counts furnish full material as to the distribution of stars brighter than about 14.5 magnitude, between the limits 64° and 72° of N. declination. In the following table the total number of stars shown with exposures 20^s, 3^m, 6^m, 40^m, as well as the number shown in

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duplicate, are given for each Zone of 1° , the first column in each case giving the number of stars shown in duplicate—*i.e.*, on *both* the overlapping plates. (Zone 64° , being at the limit of the Greenwich Section, was not measured in duplicate.)

Zone.	No. of Square Degrees.	Number in B.D.		Number shown on Photographs.							
		$9^m.0$ and brighter.	Total Number.	Exposure 20^s		Exposure 3^m		Exposure 6^m		Exposure 40^m	
64°	155	743	1,932	1,890		8,727		8,954		45,281	
65°	149	762	2,005	1,473	2,476	6,355	9,220	7,109	9,239	39,401	47,080
66°	144	632	1,744	1,294	2,155	6,486	9,491	7,213	9,505	38,631	45,333
67°	138	624	1,577	1,201	1,849	6,149	9,516	7,236	9,586	39,188	44,489
68°	132	529	1,470	1,277	2,103	5,915	9,611	8,106	9,939	41,036	45,627
69°	126	547	1,363	1,418	2,435	6,497	10,447	8,598	10,745	41,520	46,897
70°	120	536	1,375	1,400	2,448	6,491	10,601	8,735	10,954	37,780	41,888
71°	114	446	1,267	1,313	2,385	6,257	10,738	8,288	10,939	34,245	39,168
Totals -	923	4,076	10,801	9,376	15,851	44,150	69,624	55,285	70,907	271,801	310,482
Number per square degree (Dec. 65° - 72°).		4.4	11.7	10.2	17.2	47.8	75.9	59.9	76.8	294.5	336.4
Ratios -	-	1.0	2.6	2.3	3.9	10.8	17.1	13.6	17.4	66.7	76.2

A satisfactory start has been made in the reproduction of enlarged prints of the chart plates, as proposed in the last Report. The commencement of the work has been delayed through various causes—the repair of the Lassell Dome which interfered with the use of the adjoining lobbies as photographic rooms, the preparation of photographic exhibits for the St. Louis Exhibition of 1904, and the perfecting of arrangements for the photographic reproductions—but good progress is now being made, and it is found that a set of 50 enlarged prints of a plate can be taken, developed, and washed in a day. Zones 65° , 66° , and 67° are now being reproduced on the enlarged scale, and it is expected that the work for these zones will be completed in 12 months. The prints will be distributed monthly, and it is hoped that the first batch, covering about 2 hours in R.A. and 4° in declination, will be sent off early in June.

III. Spectroscopic and Heliographic Observations :—

No observations have been made with the spectroscope during the year.

In the year ending 1904 May 10, photographs of the Sun have been taken on 227 days. The Thompson photoheliograph was used on 170 days, and the Dallmeyer on 63 days (during the repairs to the Thompson Dome), both instruments being used concurrently on six days. Of the photographs taken, 523 have been selected for preservation, besides 21 with double images of the Sun for the determination of zero of position angles. Supplementary photographs have been received from India to 1904 February 24, and from Mauritius to 1903 May 17.

For the year 1903, Greenwich photographs have been selected for measurement on 220 days, and photographs from India and Mauritius (filling up gaps in the series) on 122 days, making a total of 342 days out of 365 on which photographs are at present available.

The measurement and reduction of the photographs is completed for 1903, with the exception of 23 days, for which photographs from Mauritius are required. The Greenwich photographs for 1904 are measured to April 9 and the Indian ones to February 21 (the last date received).

The solar activity has increased considerably during the year ending May 10, the Sun being free from spots on only 25 days, as against 190 in the previous year. The mean daily spotted area for 1903 is nearly six times as great as for 1902; still, as yet, the rate of increase is not so great as in the corresponding periods of the two preceding cycles. The greatest outburst of the year commenced on 1903 October 5, with the appearance at the east limb of the Sun of a group of spots much larger than any seen since 1898 September. Several fine groups have appeared since, particularly those first seen on 1903 October 26, October 30, November 5, November 30, and 1904 April 21.

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.

The regular determinations of magnetic declination, horizontal force and dip have been made with the new declinometer, the Gibson deflexion instrument, and the Airy dip circle mounted in the Magnetic Pavilion.

The magnetic reductions for 1903 are completed to the following stages :—

The eye observations of the declination and 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 are completely read 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 declination, dip and deflexion observations made in the Magnetic Pavilion are completely reduced.

The principal results for the magnetic elements for 1903 are as follows :—

Mean declination	-	-	-	16° 19' 1 West.
Mean horizontal force	-	-	-	{ 4·0132 (in British units).
				{ 1·8504 (in Metric units).
Mean dip (with 3-inch needles)	-	-	-	67° 0' 51".

These results depend on observations in the Magnetic Pavilion and are free from any disturbing effect of iron.

The magnetic disturbances in 1903 have shown a marked increase in number and extent. There were 5 days of great magnetic disturbance and 7 of lesser disturbance. Traces of the photographic curves for these days will be published in the annual volume. The calculation of diurnal inequalities from five typical quiet days in each month, selected in concert with M. Moureaux and Dr. Chree, has been continued.

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. A Fineman nephoscope has been provided for cloud observations in connection with the international balloon ascents.

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 to the end of 1903 for the dry and wet bulb thermometers and the barometer. The table of principal changes of the wind is complete for 1903.

The mean temperature for the year 1903 was $50^{\circ}\cdot 2$, or $0^{\circ}\cdot 7$ above the average for the 50 years 1841–90.

During the twelve months ending 1904 April 30, the highest temperature in the shade (recorded on the open stand in the Magnetic Pavilion enclosure) was $87^{\circ}\cdot 5$, on July 14. The highest temperature in the Stevenson screen in the Magnetic Pavilion enclosure was $84^{\circ}\cdot 2$, and in the Observatory Grounds $85^{\circ}\cdot 0$, on the same day.

The lowest temperature of the air recorded in the year was $23^{\circ}\cdot 8$, on January 1. During the winter there were 43 days on which the temperature fell below $32^{\circ}\cdot 0$, being 13 days below the average number.

The mean daily horizontal movement of the air in the year ending 1904 April 30, was 300 miles, which is 18 miles below the average of the preceding 36 years. The greatest recorded movement was 796 miles, on February 13, and the least 69 miles, on January 23. The greatest recorded pressure of the wind was 36 lbs. on the square foot, on September 10, and the greatest hourly velocity 43 miles, on September 10 and 11.

During the year 1903 Osler's anemometer showed an excess of 16 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 1904 April 30, by the Campbell-Stokes instrument, was 1,361 out of 4,472 hours during which the Sun was above the horizon, so that the mean proportion of sunshine for the year was $0\cdot 304$, constant sunshine being represented by 1.

The rainfall for the year ending 1904 April 30 was $35\cdot 42$ inches, being $10\cdot 88$ inches greater than the average of the 50 years 1841–90. The number of

rainy days was 182. The rainfall during 1903 was 35·54 inches, the heaviest ever recorded at Greenwich during the calendar year. The summer months in particular were very wet, more than 16 inches being recorded in June, July, and August, viz. :— 6·07 inches registered in June, 5·27 inches in July, and 4·82 inches in August. The greatest fall registered at Greenwich in a single day for many years past, viz., 2·46 inches, occurred on July 23. In 1904, January and February were wet months, so that the total fall from 1903 March 1 to 1904 February 29 was over 37 inches.

VI.—Printing and Distribution of Greenwich Publications :—

The copies of the volume for 1900 were received and distributed near the end of 1903, and the copies of the volume for 1901 have just been received, and will be distributed shortly.

The printing of the volume for 1902 is in a forward state, being completed with the exception of the Thompson Equatorial Observations, which have been sent to the printer, and of the Introduction.

The printing of the volume for 1903 has commenced.

The printing of Volume I. of the Astrographic Catalogue, Greenwich Section, is completed. The copies are now being bound and will be distributed shortly with the Greenwich Observations for 1901. A few advance copies have been received. The printing of Volume II. has commenced.

The printing of the results of the Montreal longitude determination, 1892, is now complete. There remain the Killorglin and recent Paris determinations still to be printed.

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

The number of Government marine chronometers and deck-watches now being tested at the Observatory is 513, viz., 299 box chronometers, 42 pocket chronometers, and 172 deck-watches. In addition to these, 13 chronometers are being tested after repair for the Indian Government.

In the year ending 1904 May 10, the average daily number of chronometers and deck-watches being rated was 609; the total number received was 1,377, the total number issued was 1,382, and the number sent for repair 584. These include 19

box chronometers, and 2 deck-watches for the Indian Government. At the present time there are 4 eight-day box chronometers on trial for purchase for the Indian Government.

For the annual trial of chronometers, which lasted 29 weeks, with a range of temperature from 43° to 105° , 68 chronometers were sent in. During the trial 26 were rejected because the difference between one week's rate and the next exceeded 12 seconds. Of the remaining 42 chronometers, 27 were purchased for the Navy, 3 for the Transvaal Government, and 8 for the Indian Government. There was a slight improvement in performance, 19 chronometers this year having trial numbers less than 30, as against 13 last year.

For the annual trial of deck-watches, lasting 16 weeks and including trials in the oven and in positions, 192 watches were entered, of which 114 were classified, and of these 42 were purchased for the Navy. Among the watches classified were 44 with centre seconds dials, of which 18 were purchased. There were 74 "Karrusel" watches classified, of which 29 were purchased. The performance of the deck-watches is very satisfactory, being above the average of the last nine years. There were 74 watches with trial numbers less than 80, as compared with 41 last year.

A competitive trial of pocket chronometers took place concurrently with the trial of box chronometers, and under the same conditions as regards length of trial and temperature, trials in positions as for deck-watches being included. Only 2 of the 9 pocket chronometers sent in came up to the standard for purchase.

The Greenwich time-ball was not raised on three days during the year, owing to the violence of the wind. On January 24 the ball failed to drop although the clips were released. The ball was dropped 24^s too soon on June 26, and on October 18, through a false signal, and about 30^s too soon on September 13 (Sunday) through a mistake with the commutator.

The Greenwich time signal at 13^h failed on May 18 through the effect of the thunderstorm on May 17. On May 31 (Sunday) it was $1^s.0$ late; on September 13 (Sunday) it was 30^s early; on February 2 it was $0^s.8$ late, through delay in the clock contact, and on May 8 (Sunday) it was $1^s.0$ early.

The automatic drop of the Deal time-ball failed on 18 days owing to interruptions of the telegraphic connections, and on May 18, when no signal left the Observatory. On 5 days the ball was not raised owing to the violence of the wind. On February 3 the ball was dropped $0^s.8$ late owing to the error of the Greenwich signal. On the other days when the Greenwich signal was in error it apparently failed to reach Deal, and these days are included in the number 18. On July 11 the ball was dropped 6^s late; it was raised again at 14^h and dropped by hand.

The return signal from Devonport failed on 41 days (of which 8 were Sundays) and could not be observed on 9 days owing to interruptions by telegraph signals. The apparent error of the clock signal (after daily correction of the clock by aid of a time signal from Greenwich, on the plan described in the Report for 1885) did not exceed $0^s.2$ on 90 per cent. of the 313 days of observation, did not exceed $0^s.5$ on 97 per cent., and never exceeded $1^s.0$.

The return signal from Portsmouth failed on 99 days (of which 43 were Sundays) and could not be observed on 6 days owing to interruption by telegraph signals. The apparent error of the clock (corrected in the same manner as the Devonport clock) did not exceed $0^s.2$ on 83 per cent. of the 258 days of observation, did not exceed $0^s.5$ or 97 per cent., and never exceeded $1^s.0$.

The automatic signals from the Westminster clock have been received throughout the year except on 26 days, when the signal failed, and on 21 days it could not be observed owing to interruptions from telegraphic signals. The apparent error of the clock was not greater than $0^s.5$ on 19 per cent. of the days of observation, not greater than $1^s.0$ on 43 per cent., not greater than $2^s.0$ on 71 per cent., not greater than $3^s.0$ on 93 per cent., not greater than $4^s.0$ on 99 per cent., and exceeded $4^s.0$ on two occasions.

Longitude Operations, &c.—The determination of the longitude of Potsdam by Prof. Albrecht and Dr. Wanach was completed in July. The result, which has been recently published by Prof. Albrecht, leads to an indirect determination of the longitude of Paris which is in close accordance with the results obtained by the Greenwich observers in 1902.

Major Burrard and Major Lenox-Conyngham, of the Indian Survey, swung their "Von Sterneek" pendulums in the Record room in July, and again in October, in order to standardise them before using them in India.

Staff-Commander Roberts, R.N., in charge of the chronometer depôt at Malta, attended at the Observatory during November and December to acquire practice in time-determination with a small transit instrument.

It may here be mentioned that an exhibit of photographs illustrating the work of the Royal Observatory has been prepared for the St. Louis Exhibition, and was sent off early in January.

VIII.—Personal Establishment :—

Mr. W. Carpenter Nash retired on December 31, after a long and honourable connection with the Observatory of nearly 48 years, having been for the last 10 years Superintendent of the Magnetic and Meteorological Branch. He was succeeded by Mr. Bryant.

Mr. Crommelin was also appointed in January an Assistant on the New Establishment, in place of a Second-Class Assistant of the Old Establishment.

Mr. Davidson was promoted to the Higher Grade of Established Computers on January 1, to fill the vacancy in this class. Mr. Burkett and Mr. Evans were appointed Established Computers in October, filling the vacancies caused by the death of Mr. Bischlager and the retirement of Mr. Rendell on his appointment as First Assistant at the Natal Observatory.

The permanent staff at the present time is constituted as follows, the names in each class being arranged in alphabetical order :—

Chief Assistants—Mr. Cowell, Mr. Dyson.

Assistants—Mr. Bryant, Mr. Crommelin, Mr. Hollis, Mr. Lewis, Mr. Maunder, Mr. Thackeray.

Established Computer (Higher Grade)—Mr. Davidson.

Established Computers—Mr. Bowyer, Mr. Burkett, Mr. Edney, Mr. Evans, Mr. Furner, Mr. Melotte, Mr. Stevens, Mr. Storey, Mr. Witchell, and one vacancy.

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

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and reductions. Mr. Lewis has charge of the clocks, time-signals, and chronometers, and of the 28-inch equatorial. Mr. Thackeray superintends the meridian work and miscellaneous astronomical computations, and this year has been specially engaged in the re-reduction of Groombridge's observations. Mr. Hollis superintends the photographic mapping of the heavens, the measurement of the plates, and computations for the Astrographic Catalogue. He also has charge of the reductions of the longitude determinations. Mr. Crommelin has charge of the altazimuth and of the observations of occultations. Mr. Bryant superintends the magnetic and meteorological observations and reductions. Mr. Outhwaite acts as responsible accountant officer, has charge of the library, manuscripts, and stores, and conducts the official and general correspondence. Mr. Davidson has charge of the Thompson equatorial and the measurement of the photographs taken with it. In particular, he has this year been employed on the measurement of the photographs of Eros taken in the opposition of 1900-1 for the determination of the Solar parallax. Mr. Bowyer, Mr. Edney, and Mr. Furner assist Mr. Lewis, Mr. Bryant, and Mr. Crommelin respectively. Mr. Witchell and Mr. Storey, under Mr. Thackeray's direction, undertake the reduction of the meridian zenith distances observed with the transit circle and with the reflex zenith tube, and of the transit observations with the transit circle, respectively. Mr. Melotte and Mr. Stevens are engaged alternate weeks, under Mr. Hollis' direction, in the reproduction of the enlarged prints of the astrographic chart. At other times Mr. Melotte assists in the measurement and reduction of the Thompson photographs, and Mr. Stevens in the astrographic work. Mr. Evans also assists Mr. Hollis in the measurement and reduction of the astrographic plates. Mr. Burkett assists Mr. Outhwaite.

The number of Supernumerary Computers at present employed in the Observatory is 29; of these, 12 are attached to the Astronomical Branch, 3 to the Chronometer work, 6 to the Astrographic and Thompson equatorial measures and reductions, 3 to the Heliographic, 4 to the Magnetic and Meteorological, and 1 to the Clerical Branch.

A foreman of works, with 2 carpenters and 2 labourers; a foreman mechanic, with 2 assistants; a gate-porter, 2 messengers, a watchman, a gardener, a labourer, and a charwoman, are also attached to the Observatory.

The whole number of persons employed at the Observatory is 63.

IX.—General Remarks :—

The record of the work of the Observatory for the past year is the best testimony to the spirit and zeal of the staff, to whom great credit is due for the very satisfactory output of work with the large number of instruments now kept in regular use. With the transit circle, altazimuth, reflex zenith tube, 28-inch refractor, and Thompson equatorial, exceptionally large numbers of observations have been obtained notwithstanding the unfavourable weather of the past year. In particular, the observations with the altazimuth and reflex zenith tube have been very successful. The work of the chronometer branch continues to develop with the growth of the Navy, and strenuous efforts on the part of the staff concerned are required to deal with the continuous increase of work in this branch.

The revision of Groombridge's Catalogue for 1810, in connection with the Greenwich Second Ten Year Catalogue (1890), and the determination of the proper motions of about 4,000 stars from Groombridge's observations, compared with recent Greenwich observations at an interval of about 80 years, have now been completed under Mr. Thackeray's supervision, and the results will be published without delay.

The heavy work of measurement of the photographs of Eros taken in 1900–1 and the deduction of the Solar parallax from them is now approaching completion, after which the staff in this branch will be more free to deal with the photographs of comets and minor planets which are awaiting measurement.

In the Astrographic branch the publication of Volume I. of the measures for the Catalogue, dealing with half of the circumpolar area assigned to Greenwich, marks a distinct step towards the completion of the work, which is now clearly in sight. For the Chart the reproduction of enlarged photographic prints for distribution to a limited number of observatories and institutions has been taken in hand and is in good train.

The discussion of the Greenwich lunar observations 1750–1901 suggested in the last Report has been taken up energetically by Mr. Cowell, who has devoted a large portion of his time to the work. He has already made considerable progress in the comparison with revised places of the Moon, and has deduced important results for the correction of Hansen's tables.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich,
1904, May 28.
