REPORT

OF THE

ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH.

Read at the Annual Visitation of the Royal Observatory, 1910 *June* 18.

GREENWICH OBSERVATIONS, 1909.

THE BOARD OF VISITORS.

The President of the Royal Society	Sir A. Geikie.
The President of the Royal Astronomical Society.	Sir David Gill.
Nominated as Fellows of the Royal Society	Prof. W. G. Adams. Prof. Sir J. Larmor. Prof. Sir J. Norman Lockyer. Lord Rayleigh. Principal Sir A. W. Rücker. Prof. A. Schuster.
Nominated as Fellows of the Royal Astronomical Society.	Capt. Sir W. de W. Abney. Prof. Sir R. S. Ball. Prof. R. B. Clifton. Dr. J. W. L. Glaisher. Mr. E. B. Knobel. (Vacant).
Savilian Professor of Astronomy at Oxford	Prof. H. H. Turner.
Plumian Professor of Astronomy at Cambridge	Prof. Sir G. H. Darwin.
Hydrographer of the Navy	Rear-Admiral H. E. P. Cust.
Secretary	Mr. W. D. Barber.

REPORT OF THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH.

Read at the Annual Visitation of the Royal Observatory, 1910 *June* 18.

The Report here presented refers to the year from 1909 May 11 to 1910 May 10, and exhibits the state of the Observatory on the last-named day.

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

Additional accommodation for the storage of the Greenwich and Cape Observatory Publications having become necessary, eight double sets of shelves have been erected in the storehouse.

New spring-contacts have been fixed to all the lightning-conductors of the domes.

A new 4-inch gas-main to the Observatory was laid in October. The 3-inch main by which the gas was formerly supplied, was liable to frequent interruption through choking; this was a source of considerable inconvenience, involving the interruption of magnetic and meteorological registers, and the failure of the heating of the chronometer-ovens.

The periodical painting of the domes and external parts of the buildings is now in progress.

E (12)4720. Wt. 33155. 950 & 50. 6/10. E. & S.

The principal movable instruments are thus distributed:—

At Greenwich—

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

Altazimuth E.

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:

No. 1. Equatorial section of mounting and driving clock only.

No. 2. Complete—mounted on roof of South Wing.

No. 3. Stand and mounting only.

No. 5. Complete except the object glass. (There is no camera for an 8-inch image of the Sun.)

Detached Telescopes (on tripod stands).—Two 4-inch (Simms Nos. 1 and 2), two 4-inch (R.O. Nos. 1, mounted as finder on Thompson Equatorial, 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.

Altazimuths.—A, at the Science Schools, South Kensington; B, at the Cape Observatory; D, to the Colonial Office for the use of Major Watherston for Longitude Observations on the Gold Coast since 1903 September.

Equatorials.—Lee (6-inch), at the Hong Kong Observatory; Simms No. 2 (6-inch), lent to the Board of Education.

Photoheliographs:

No. 1. At the Cape Observatory with the exception of the parts mentioned above.

No. 3. Object glass and tube lent to Government Astronomer, Melbourne, for the Solar Eclipse of 1910.

No. 4. Complete at Kodaikanal Observatory.

No. 5. Object glass on loan to Professor Turner, Oxford 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; 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 the Victoria and Albert Museum, South Kensington.

A 6-inch photographic lens of 27 inches focus has been kindly lent to the Royal Observatory by Mr. Franklin Adams for use in the observations of Halley's Comet. The 4-inch lens, kindly lent by him last year, has been returned.

A new 4-inch portrait lens of 16 inches focus has been purchased from Messrs. Ross, Ltd., for photographing comets.

The photoheliograph No. 1 which, with the exception of the lower parts of the stand, had been returned from the Cape Observatory, has been fitted with a new enlarging lens and camera to adapt it to take photographs of the Sun on the 8-inch scale—or, more precisely, on a scale of one decimetre to the solar radius at mean distance. After the new lens had been adapted to it, the object glass and tube of No. 1 with the new camera were returned to the Cape Observatory, instead of effecting an exchange with No. 2, as had been previously proposed. The equatorial head and driving clock of Photoheliograph No. 1 are retained at Greenwich.

The Photoheliograph No. 2 has been fitted with a new enlarging lens and camera similar to those thus provided for No. 1; and a new camera has been constructed for the Thompson Photoheliograph, the old one being worn out. Advantage has been taken of the change to make the scale of the Thompson Photoheliograph correspond to that of the Dallmeyer instruments, Nos. 1, 2, and 4, viz., one decimetre to the solar radius at mean distance.

The annual examination of the Library has been made as usual, the books on the shelves being compared with the catalogue. No books have been lost during the year, and the book reported missing from the Magnetic and Meteorological Library last year has since been returned. There remain only 12 books missing; these have been reported every year for several years past, and will now be written off the Catalogue as lost.

II.—Astronomical Observations :—

Transit Circle.—The improved method of illuminating the field of view has been in regular use during the year. From comparisons between the observations of two clock stars made each night with the old annular illumination and the observations with the new central illumination, it appears that the time of transit of stars observed with the annular illumination was $0^s \cdot 024$ earlier than with the new central illumination (63 nights 1909 January 1 to 1910 May 10), which agrees very well with the value formerly found $0^s \cdot 019$ (31 nights from 1908 September 17 to December 31).

The Sun, Moon, planets, and fundamental stars have been regularly observed on the meridian as in previous years. The other stars observed are taken from a working catalogue of stars of 9·0 magnitude and brighter between the limits 24° to 32° of N. declination, serving as reference stars for the Oxford Astrographic Zones.

In order to provide material for the comparison of the observations of these reference stars with any system of fundamental stars that may be ultimately adopted by the *Comité International Permanent*, it has been decided that, starting with 1910 January 1, six stars from Newcomb's Fundamental Catalogue, comprised within the limits of the Zones 24° to 32° N., should be observed each night.

The number of observations with the Transit Circle from 1909 May 11 to 1910 May 10 is as follows :—

Transits - - - - - - -	9,431
Determinations of Collimation error - - - -	299
Determinations of Level error - - - - -	529
Circle observations - - - - - -	9,340
Determinations of nadir point (included in the number of circle observations) - - - - - -	518
Reflexion observations of stars (similarly included) - -	293

The transits are completely reduced (so as to exhibit Mean R.A. 1910·0) to 1910 April 7, and Apparent R.A. is formed to May 2.

The circle observations are completely reduced to 1910 April 7.

The investigation of personal equations is complete for 1909.

The R–D discordance has been investigated for 1909.

As during the year 1908 the observations of clock stars were made with different methods of illumination, viz., from the beginning of the year till 1908 April 29 with the old annular illumination, from April 30 to September 16 with central illumination with simple condensing lens, and from September 17 to the end of the year with central illumination with compound corrected lens, the observations of the Sun were corrected to the system of clock error given by the annular illumination as follows:—

Corrections to the right ascension of the Sun to reduce the clock error to the annular method of illumination, deduced from comparisons between observations of clock stars by the two methods of illumination:—

Date 1908.	Correction.
January 1 to April 29 - - -	$0^s \cdot 00$
April 30 to September 16 - - -	$+0^s \cdot 06$
September 17 to end of year - - -	$+0^s \cdot 02$

As the central illumination was in use during the whole of the year 1909 the observations of the Sun depend on the clock error deduced by that method of illumination.

The corrections for variation of latitude for 1909 were received earlier than usual from Professor Albrecht, so that the results of the colatitude and ecliptic investigations are now given both for 1908 and 1909.

The values of the colatitude determined from observations made in 1908 and 1909 with Pulkowa refractions were 38° 31′ 21″·66 and 38° 31′ 21″·83.

The correction to the tabular obliquity of the ecliptic from solar observations in 1908 is $-0''\cdot12$. The discordances between the results of summer and winter solstices is $-0''\cdot02$, indicating that the mean of the observed distances from the pole to the ecliptic is apparently too large by $0''\cdot01$. The apparent correction from observations of the Sun to right ascensions of clock stars is $-0^s\cdot067$.

The correction to the tabular obliquity of the ecliptic from solar observations in 1909 is 0″·00. The discordance between the results of summer and winter solstices is + 0″·04, indicating that the mean of the observed distances from the pole to the ecliptic is apparently too small by 0″·02. The apparent correction from observations of the Sun to right ascensions of clock stars is − 0ˢ·043.

The apparent correction for discordance between the nadir observations and stars observed by reflexion in 1909 is − 0″·16. The values found from 1892 to 1908 range from − 0″·20 to − 0″·41. Four-fifths of this quantity is applicable to observations of the nadir in forming the zenith point on days when no reflexion observations of stars are obtained, and since 1897 January 1 the value − 0″·25 has been adopted for this correction.

Observations of level and nadir have been made when practicable three or more times a day. The following are the mean values of the diurnal changes of level and nadir for 1909, and for the nine years 1897 to 1905, observations within three hours of noon, 6 p.m., midnight, and 6 a.m., respectively, being grouped together:—

	Diurnal Changes of Level.				Diurnal Changes of Nadir.			
	Noon.	6 p.m.	Midnight.	6 a.m.	Noon.	6 p.m.	Midnight.	6 a.m.
1909	+ 0″·15	0″·00	+ 0″·08	...	+ 0″·18	0″·00	+ 0″·12	...
1897–1905	+ 0·25	0·00	+ 0·21	+ 0·37	+ 0·14	0·00	+ 0·12	+ 0·11

The correction for R − D discordance found for 1909 is + 0″·040 + 0″·600 *sin* Z.D., the co-efficient of *sin* Z.D. agreeing exactly with the adopted value (+ 0″·600).

The mean error of the Moon's tabular place derived from the mean of the observations of the limb and the crater Mösting A made with the transit-circle and altazimuth (computed from Hansen's lunar tables with Newcomb's corrections) for 1908 is − 0ˢ·395 in R.A., and 0″·00 in N.P.D., deduced from 126 observations. The corresponding mean errors in longitude and in E.N.P.D. from these observations are − 5″·97 and + 0″·45.

The mean error of the Moon's tabular R.A. for 1909 from observations made with the transit-circle is $-0^s\cdot442$, deduced from 111 observations.

The Second Nine-Year Catalogue, Epoch 1900, the observations for which were terminated at the end of 1905, has been printed and distributed.

Altazimuth.—The comparison of the annular and central illuminations by observations of clock-stars has been continued. It is found that there is no sensible difference between the results.

The instrument has been used as a reversible transit-circle in the meridian in four positions during the year, the positions being changed regularly every two months. Observations of the Sun, Moon, planets, and the fundamental stars, contained in the National Ephemerides and in Newcomb's Fundamental Catalogue, have been made throughout the year.

A list of reference stars for the series of photographs of Mars, taken with the Thompson Equatorial, was prepared, and as many of these as possible have been observed.

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

The instrument has also been used for extra-meridian observations of Halley's Comet.

The observations of the crater Mösting A, started in 1905, are being continued, whenever the object is observable. The observations of transits serve to connect the observations of the first and second limbs made before and after full moon respectively; and the observations of zenith distance will, in combination with similar observations now being made at the Cape Observatory, serve to determine the parallax of the Moon. Mösting A has also been regularly observed with the transit-circle when practicable.

The following observations have been made with the altazimuth during the year:—

	No. of Observations.
Collimation, Level, and Azimuth	232, 451, and 126 respectively.
Nadir: Reflexion observations of stars	442 and 87 ,,
R.A. and N.P.D. of Sun, planets, and stars (in meridian)	1,554 and 1,304 ,,
R.A. and N.P.D. of Moon (in meridian)	81 and 73 ,,
R.A. and N.P.D. of Mösting A	43 and 43 ,,
Azimuth and Zenith distance of stars (extra meridian)	174
Azimuth and Zenith distance of Sun and planets (extra meridian)	8
Azimuth and Zenith distance of Moon (extra meridian)	47
Azimuth and Zenith distance of Halley's Comet (extra meridian)	4

The altazimuth observations are reduced to the end of 1909. Of the observations of 1910, the transits and meridian zenith distances are reduced to March 31.

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 in reversed positions of the instrument with the positions given in Newcomb's Fundamental Catalogue. Since 1907 it has been decided to employ the R−D correction deduced from the reflexion observations alone, instead of using the constant part of the correction as given by the comparison with Newcomb's places.

The values for the mean error in R.A. of the Moon's Tabular Place from the altazimuth observations in 1909 are—

Moon's limb in meridian	$-0^s\cdot48$
Mösting A in meridian	$-0^s\cdot46$
Moon's limb, extra-meridian	$-0^s\cdot40$

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 1910 May 10:—

Time of Moon's Meridian Passage.	Transit Circle.		Altazimuth.		
			Meridian.		Extra Meridian.
	Limb.	Mösting A.	Limb.	Mösting A.	Limb.
h. h.					
1–2 G.M.T.	0		0		3
2–3 „	0		0		3
3–4 „	1		0		3
4–5 „	5		1		9
5–6 „	5		3		1
6–9 „	18	11	18	11	3
9–12 „	24	17	18	11	0
12–15 „	27	15	14	5	0
15–18 „	19	13	23	16	3
18–19 „	5	1	2		6
19–20 „	7		2		3
20–21 „	3		0		3
21–22 „	0		0		5
22–23 „	0		0		5

The total number of observations of the Moon is 114 with the transit-circle and 128 with the altazimuth, viz.:—81 in the meridian and 47 extra-meridian.

Taking both instruments, observations of the Moon have been obtained on 146 days during the year.

The work on the Ten-Year Catalogue of stars observed with the altazimuth in the meridian in the years 1899 to 1908, has been begun. All the observations for the ten years have been entered up and the reduction to the equinox 1900·0 is now in progress.

Reflex Zenith Tube.—During the year, 1,302 double observations and 13 single observations have been obtained, the number of different stars observed being 86.

The enlarged scheme of observation introduced in 1906 November has been in operation throughout the year. The following table shows the number of observations obtained in each month in each group of stars since 1907 May. In this table the principal groups denoted by A and B are each divided into two halves (A_1, A_2, B_1, B_2); *a* and *b* are the subsidiary groups introduced to strengthen the connection between the principal groups. It will be seen that the overlap of the groups is sufficient to obtain a good connection between them.

Group.	A_1.			A_2.			*a*.			B_1.			B_2.			*b*.		
Limits of R.A.	$4^h\,59^m$–$7^h\,6^m$.			$7^h\,6^m$–$9^h\,26^m$.			$12^h\,19^m$–$14^h\,22^m$.			$17^h\,28^m$–$19^h\,31^m$.			$19^h\,31^m$–$22^h\,34^m$.			$0^h\,12^m$–$1^h\,44^m$.		
—	1907–8.	1908–9.	1909–10.	1907–8.	1908–9.	1909–10.	1907–8.	1908–9.	1909–10.	1907–8.	1908–9.	1909–10.	1907–8.	1908–9.	1909–10.	1907–8.	1908–9.	1909–10.
May -	—	—	—	—	—	—	24	29	36	67	75	194	—	—	—	—	—	—
June -	—	—	—	—	—	—	19	5	—	65	57	59	1	—	—	—	—	—
July -	—	—	—	—	—	—	—	1	—	158	88	139	10	13	5	—	—	—
August -	—	—	—	—	—	—	—	—	—	87	67	110	90	96	83	—	—	—
September	5	—	—	—	—	—	—	—	—	141	41	44	266	101	143	2	6	4
October -	33	15	29	1	—	1	—	—	—	25	22	6	92	42	46	21	12	11
November	19	18	29	2	—	—	—	—	—	7	4	18	13	7	30	5	10	15
December	10	8	19	4	4	14	—	—	5	10	1	1	9	2	—	11	—	—
January -	25	25	36	9	25	31	50	19	30	14	1	3	4	2	—	5	2	3
February -	30	18	36	69	38	79	57	19	43	6	1	2	—	—	—	—	—	—
March -	—	1	22	37	11	57	22	9	20	8	—	9	—	—	—	—	—	—
April -	—	—	—	2	12	2	42	39	16	15	48	35	—	—	—	—	—	—

Group B_1 contains the bright stars, β and γ Draconis and ι^2 Cygni, which are observed throughout the year.

Observations are completely reduced to 1909 December 31, and as far as to exhibit apparent Z.D., to 1910 April 30.

Clocks and Chronographs.—The clock Graham 2, after use in the Malta longitude determination, was sent to Messrs. E. Dent & Co. for testing and cleaning. The clock Dent 2017 is at present with the same firm for cleaning and testing.

Equatorials.—During the year ending 1910 May 10, 53 disappearances and 14 reappearances of stars occulted by the Moon have been observed by one or more observers. A great number of the stars were below the limit of magnitude adopted by the Nautical Almanac, which is 7·0.

The 28-inch Refractor.—Observations of double stars have been made from a working catalogue containing all known double stars showing appreciable relative motion, the G. W. Hough stars not previously observed at Greenwich, and a number of pairs from Hussey's and Aitken's Catalogues under 2″ separation.

The measures made during the year consist of—

150	pairs	under	0″·5	separation.	
146	„	between	0″·5	and 1″·0	separation.
131	„	„	1″·0	„ 2″·0	„
218	„	over	2″·0	separation.	

κ Pegasi was observed on 7 nights, δ Equulei on 8 nights, and 70 Ophiuchi on 13 nights.

In general the pairs under 2″ separation have been observed on two nights each.

Measures of the diameters of the planet Saturn and of the ring-system were made on seven nights with the bi-filar micrometer.

Measures of the diameters of Mars were also made on 15 nights.

Thompson Equatorial.—The 30-inch mirror was dismounted for re-silvering in August 1909 and again in February 1910. To simplify the dismounting of the mirror, an arrangement was contrived by which the hoisting pulleys were secured to the telescope itself, thereby doing away with the wooden scaffolding previously employed. A slight elongation of the images, with a long exposure, was suspected to be due to the mirror cell moving on its bed plate. The three tilting screws in the cell flange were rounded, and corresponding hollows formed in the bed plate to receive them. The images have since been perfectly round.

For photographing the extension of the tail of Halley's Comet a 6-inch lens, kindly lent by Mr. Franklin-Adams, was mounted on the 30-inch Reflector. For photographing the spectrum of the Comet, a prismatic camera was made up and mounted also on the 30-inch Reflector. The parts employed were two 60° prisms and a short focus portrait lens, kindly lent by Mr. Edney. Very fair spectra of comparison stars have been obtained, but the bright twilight and low altitude have prevented success with the Comet up to the present.

All the wiring for lighting the instrument and controlling the driving clock of the Thompson Equatorial was renewed in January, as the insulation of the wire previously used was found to be defective.

A gas stove was put in the Thompson Dark Room in December.

With the 26-inch Refractor, the following photographs have been obtained:—

73	photographs	of Neptune and Satellite	on 25 nights.
4	„	Saturn	2 „
7	„	Jupiter	4 „
62	„	Mars	29 „
2	„	Comet *a* 1910	on 2 nights.

The photographs of Saturn and Jupiter have been taken for determination of their positions with reference to the stars used in the reduction of the photographs of their faint satellites taken with the 30-inch Reflector. The series of photographs of Mars extends from 1909 July 23 to 1910 May 14 (4^h before opposition to 9^h after); it was undertaken in order to provide observations for the investigation of the orbit of the planet over a longer geocentric arc than is practicable with meridian observations. All the photographs of the planets were taken with the occulting shutter.

With the 30-inch Reflector the following photographs have been taken:—

12	photographs	of Saturn and Satellite	IX. on 9 nights.
13	„	Jupiter „	VIII. „ 8 „
56	„	24 minor planets.	
8	„	Comet *a*, 1909,	on 7 nights.
11	„	„ *b* „	„ 9 „
44	„	„ *c* „	(Halley) on 32 nights.
30	„	„ *e* „	on 15 nights.

(After February 17 Halley's Comet was too low to be observed with the 30-inch Reflector, but the observations were continued with the 13-inch Astrographic Refractor till March 7—seven photographs being obtained on 7 nights.)

In addition to the above, all of which were taken for place, four photographs of Halley's Comet were taken with long exposures for the tail.

Besides these, a number of miscellaneous photographs have been taken for instrumental adjustments.

During the year the following photographs have been measured and the results published in the *Monthly Notices R.A.S.* :—

Jupiter, Satellite VI.	1909	27 photographs.
„ „ VII.	1909	7 „
„ „ VIII.	1909	17 „
Saturn, „ IX.	1909	12 „
Comet *a*	1909	8 „
„ *b*	1909	11 „
35 minor planets,	1908	89 „

The measurement and reduction of the photographs of minor planets taken in 1909 are well advanced, as is also the work on the photographs of Halley's Comet.

Considerable progress has been made with the measurement and discussion of the photographs of Comet Morehouse for the determination of the motions of the matter forming its tail, and a preliminary paper by Mr. Eddington on the envelopes of the head has been communicated to the R.A.S.

The first photograph of Jupiter's Eighth Satellite this opposition was obtained on 1910 January 19, its position being within 7″ of that given by Messrs. Cowell, Crommelin, and Davidson's orbit. The first revolution since the date of discovery has now been completed.

Astrographic Equatorial.—From 1909 May until October work with this instrument was mainly confined to replacing Chart plates which, though satisfactory in other respects, were, owing to slight photographic defects, unsuitable for reproduction of enlarged copies. From the latter date until 1910 March 31 the instrument was used for taking photographs of comets and subsidiary photographs

of reference stars for the determination of positions of the faint satellites of Mars, Jupiter, and Saturn on photographs taken with the 30-inch Reflector.

As recommended by the Board of Visitors, provision has been made for taking the Chart plates for the Zones + 25° to + 31° declination, originally allotted to the Oxford University Observatory (so far as the Astrographic Catatogue is concerned) and for counting the number of stars on these Plates (exposure 40^m), as well as on the Catalogue plates of the same zones (exposures 6^m, 3^m, and 20^s) which are to be retaken for this purpose. This work was begun in April.

Altogether, with the 13-inch Astrographic Telescope, 144 photographs have been taken on 65 nights. Fifteen of these have been rejected; two because the exposure was unfinished owing to cloud, thirteen for photographic defects and miscellaneous causes.

The remaining 129 plates are made up as follows:—

Chart Plates (exposure 40^m)	Dec. + 83° to + 90°	19
„ „ „	Dec. + 25° to + 31°	19
Fields for Mars		18
„ Jupiter		4
„ Saturn		4
„ minor planets		9
Venus		2
Halley's Comet		28
Other comets		8
Plates for adjustment of telescope		18
		129

The portrait lens of 4 inches diameter and 16 inches focal length, supplied by Messrs. Ross, Limited, has been mounted on a camera attached to the tube of the 10-inch Guiding Telescope, for the purpose of photographing Halley's Comet.

In connection with the purchase of this lens, 32 experimental photographs with lenses lent by Messrs. Ross and Mr. Franklin-Adams were taken.

The computing work of the Astrographic branch during the year has consisted in converting the rectangular co-ordinates of selected stars between declination 73° and 81°, given in Volume II. of the Greenwich Astrographic Catalogue, into

Right Ascension and Declination in continuation of the similar work from declination 81° to the Pole mentioned in last year's Report. This has been done for the stars in Zone 80° of the Bonn Durchmusterung, those in the Kasan Catalogue of the Astronomische Gesellschaft and those between declinations 73° and 75° in the Dorpat Catalogue, a manuscript copy of which has been supplied by Professor Lewitsky. Altogether during the year, the positions of 5,820 stars have been computed, a work which involved the computation of about 13,500 separate star places. The results of these computations will form the Greenwich Photographic Catalogue 1900, the copy for Press of which has been written for the Zones from the Pole to 80° N. inclusive, and the places of the stars therein have been compared with those of Carrington's Catalogue reduced to the same epoch.

The reproduction of enlarged prints of the Chart plates of the Greenwich Zone was completed at the end of December 1909. Since the date of the last report sets of prints were made for the Zones 83° to 89°, with five of the field having the Pole as centre taken in different orientations and at different dates. The total number of prints made during the year is about 7,800, reproducing on double scale 129 plates, which makes a total of 1,153 plates reproduced since 1904 April, and completes the Greenwich Zone.

In last year's Report Mr. Cowell and Mr. Crommelin's predicted dates of perihelion passage of Halley's Comet were given, namely, 1910 April 13, by Pontécoulant's method, and April 16 by the new method of mechanical quadratures of rectangular co-ordinates, originally devised by Mr. Cowell for dealing with the Eighth Satellite of Jupiter, and subsequently adopted as suitable for this comet. The actual date is now known from preliminary discussions of the observations to be very close to April 19·68 G.M.T. which differs by 3·07 days from the calculated date, April 16·61. The hope expressed last year that neither computation was seriously in error has thus been realized, and the new method gives a result decidedly nearer to the truth than that first employed. The other elements of the orbit are also near their predicted value, the greatest discordance being 1′. Since the discovery of the comet a new investigation has been made for the period 1828–42, which includes the largest part of the Jupiter perturbations, using time-intervals half those previously employed; this investigation brought to light a few small numerical errors, whose

combined effect on the period is under one day. As differencing gives a sufficient check against appreciable errors for the remainder of the two revolutions, it does not appear that more than one day of the 3·07 days' discordance between theory and observation can be accounted for by numerical errors. The remaining two days' discordance appears to be due to causes other than the attraction of known matter in the solar system.

The details of the original investigation have been printed by the Astronomische Gesellschaft. They will also be printed together with the supplementary calculations in the *Greenwich Observations*, the copy for Press being ready with the exception of the Introduction and the planetary co-ordinates.

III.—Heliographic Observations:—

In the year ending 1910 May 10, photographs of the Sun were taken in all upon 194 days, the Thompson photoheliograph being in regular use for this work throughout the year, except when the 30-inch mirror, which is carried by the same equatorial, was being re-silvered. On these occasions the Dallmeyer photoheliograph, which has throughout remained on its own mounting on the South Terrace of the New Building, was used. The Dallmeyer has also been employed a few times for the purpose of testing a new enlarging lens. In all, the Thompson photoheliograph was used alone on 185 days, the Dallmeyer alone on two days, and both instruments were used on seven days.

Of the photographs taken, 403 have been selected for preservation, besides 24 with double images of the Sun for the determination of zero of position angles. Supplementary photographs have been received from Kodaikánal Observatory, India, up to 1909 December 24; from Dehra Dûn, India, through the Solar Physics Committee, up to 1910 February 28; and from the Royal Observatory, Cape of Good Hope, for the month of March 1910.

The Greenwich series of photographs, supplemented by the photographs from the two Indian observatories, was complete for the year 1909, with the exception of two days, 1909 August 1 and November 5, which are, at present, unrepresented. The record for 1910 is complete, with the exception of March 28, up to March 31, the date of the last photograph received from the Cape, which came to hand on May 9.

The photographic record at present in hand, for the year 1909, is made up from the following sources:—

Greenwich	171 days.
Dehra Dûn	175 „
Kodaikánal	17 „
Unrepresented	2 „
Total	365 „

The measurement of these photographs is complete to the end of 1909, and for those taken at Greenwich to 1910 April 2, whilst those taken at Dehra Dûn have been measured up to 1910 January 24.

The re-measurement of a large number of photographs taken in 1906, 1907, and 1908, which became necessary in consequence of a serious error in the orientation of the spider-lines of the Dehra Dûn photoheliograph, has been completed, and the positions and areas of the spots and faculæ have been computed. The Photoheliographic Results for 1906 have been printed and distributed; those for 1907 have been passed for Press, with the exception of the Introduction; and the copy for press of the first Section for 1908, the daily results for the entire year, is ready to go to the printer. The Results for 1909 will be ready to follow, as soon as those for 1908 have been passed through the Press.

With the end of the year 1909 the Royal Alfred Observatory, Mauritius, ceased to be a source from which the Greenwich series of solar photographs could be supplemented. On 1910 March 1 the daily photographic record of the Sun's surface was commenced at the Royal Observatory, Cape of Good Hope, under the direction of Mr. S. S. Hough, H.M. Astronomer, and the first batch of negatives, viz., those for the month of March 1910, was received at Greenwich Observatory on 1910 May 9. The combined Cape and Greenwich series represents every day in March, but one, March 28; and it is hoped that this average may be maintained throughout the year, so that it may be only occasionally necessary to have recourse to other sources in order to render the series complete.

The numeration of the spot-groups from a preliminary examination of the solar photographs, and the publication, month by month, in *The Observatory* of

the lists of the spot-groups thus numbered, with their descriptions and rough estimations of their areas and mean heliographic longitudes and latitudes, have been continued during the year, the last list published being that of the groups of 1910 January, appearing in *The Observatory* for 1910 May. This numeration of the spot-groups has been officially communicated, month by month, to the Director of the Kodaikánal Observatory.

The solar activity, as shown in the numbers and areas of sun-spots, was maintained in the year 1909 at much the same level as in the previous year; indeed, if the month of August, which was very active in 1908 and very quiet in 1909, were excluded from the record of both years, 1909 would appear as decidedly the more prolific year of the two. But there was a diminution in the number of very large groups, readily visible to the naked eye, and the faculæ, which as in previous years were less subject to sudden and violent fluctuations than the spots, have steadily declined in area throughout the year.

The present year, 1910, has opened quietly, and the month of April, 1910, has yielded the smallest mean daily spotted area, and the largest number of days on which the sun has been entirely clear of spots, since September 1903. The maximum of the present cycle would, therefore, appear to be definitely over, though the decline towards minimum has not as yet advanced very far.

IV.—Magnetic Observations :—

The variations of magnetic declination, horizontal force and vertical force, have been registered photographically, and accompanying eye observations of absolute declination, horizontal force and dip, have been made as in former years. The variations of earth currents were registered photographically until the end of 1909, but have been discontinued since that date, as an extensive renewal of the wires had become necessary, which, in view of the serious disturbances from electric tramways, did not appear to be justified. A suggestion has been made that satisfactory results less liable to disturbance from electric railways could be obtained from quite short earth-wires within the confines of the Park, if not of the Observatory Grounds, but no experiments have yet been undertaken to test the value of the suggestion.

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.

In 1909 December the suspension skein of the horizontal force magnet gave way, and it was found on replacing it with a new skein that it was no longer possible to register the photographic trace when the magnet was perpendicular to the magnetic meridian, owing to the gradual change of the direction of the meridian since the installation in the magnetic basement. Dismounting the magnet and carrier, it was found quite easy to extend the range of adjustment by slotting the screw-holes in the plate binding the mirror support to the magnet carrier. This was done at the end of January, but during January the magnet was suspended in a direction differing by several degrees from its proper position, for which a correction will be necessary.

The magnetic reductions for 1909 are completed to the following stages:—

The eye observations of the declination and horizontal and vertical force magnets are completely reduced, and the hourly ordinates of the photographic registers are read off and tabulated. 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 eye observations of declination, dip, and deflexion made in the Magnetic Pavilion are completely reduced.

The principal results for the magnetic elements for 1909 are as follows:—

Mean declination - - -	15° 47′·6 West.
Mean horizontal force - - -	4·0179 (in British units). 1·8526 (in metric units).
Mean dip (with 3-inch needles) -	66° 53′ 57″.

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

Since the adjustment of the dip needles referred to in the last report there has been a satisfactory agreement between the sets of observations with the two three-inch needles.

In 1909 there were two days of great magnetic disturbance, and there were six of lesser disturbance. Traces of the photographic curves for these eight days selected in concert with M. Angot, will be published in the annual volume. The calculation of diurnal inequalities from five typical quiet days in each month, selected in concert with Dr. Chree, has been continued. The list of "quiet" or "normal" days is also communicated to Paris, Lisbon, Bombay, and Mauritius, and

for publication by the International Committee on Terrestrial Magnetism in their "quiet day" circular. To the same International Committee quarterly reports are sent classifying the days in three divisions according to their magnetic character.

V.—Meteorological Observations:—

The meteorological instruments are all in good order. The new thermometer screen mentioned in the last report has been set up in the Magnetic Pavilion enclosure and is equipped with a set of four thermometers as in the Stevenson screen. Commencing with 1910 January 1 the readings of these are regularly entered and corrected for index error, and dew-points calculated in the same way as for those in the open stand and the two Stevenson screens.

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. Cloud observations in connection with the international balloon ascents have been made with a Fineman nephoscope.

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 1910 April, except for the electrometer, which is complete to the end of 1910 March. The table of principal changes of the wind for 1909 is not yet completed.

The mean temperature for the year 1909 was 48°·6, or 1°·0 below the average for the 65 years 1841–1905.

During the 12 months ending 1910 April 30 the highest temperature in the shade (recorded on the open stand in the Magnetic Pavilion enclosure) was 86°·2 on August 12. On the same day the highest temperature in the Stevenson screen in the Magnetic Pavilion enclosure was 85°·6, and in that in the Observatory Grounds 85°·4.

The lowest temperature of the air recorded during the same period was 20°·3 on January 27. During the winter there were 50 days on which the

temperature fell to or below 32°·0, being six less than the average number. It may be mentioned that an additional day of frost in the air has occurred since 1910 April 30.

The mean horizontal movement of the air in the year ending 1910 April 30 was 302 miles, which is 20 miles above the average of the preceding 42 years. The greatest recorded daily movement was 859 miles on December 3, and the least 62 miles on November 4. The greatest recorded pressure of the wind was 30·7 lbs. on the square foot on February 20, and the greatest velocity in an hour 56 miles on December 3. The last two dates correspond to two storms of exceptional severity, one of which exceeded in violence of gusts, and the other in duration. On both occasions the velocity was for several minutes greatly in excess of 56 miles per hour, which is, as above stated, the greatest amount recorded for an hour during the year.

During the year 1909, Osler's anemometer showed an excess of 19 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 1910 April 30, by the Campbell-Stokes instrument, was 1,567 out of 4,458 hours during which the Sun was above the horizon, so that the mean proportion of sunshine for the year was 0·351, constant sunshine being represented by 1. The distribution in the different months was very uneven, the fine April mentioned in the last Report being easily surpassed by the next month, 1909 May, 325·9 hours, or nearly 68 per cent. being registered, which exceeded by 8 per cent., and by more than 30 hours respectively, the relatively and actually sunniest months previously recorded. This remarkable May was followed by the dullest and coldest June on record. Towards the end of the year there was an improvement, the amount registered in November being the highest and that in December the second highest, on record in those months, and the total duration for the six months October to March inclusive was also the highest recorded during a winter half-year.

The rainfall for the year ending 1910 April 30 was 27·72 inches, being 3·60 inches greater than the average of the 65 years 1841–1905. The number of rainy days (0·005 inch or over) was 192, the highest number for many

years. The greatest daily amount was on April 16, when the total exceeded an inch and a half, most of which fell between 5^h and 9^h p.m., and more than half between 5^h and 6^h p.m. More than an inch of rain fell on June 24. February for the first time on record provided a "rain-spell" (more than 14 consecutive rainy days), inasmuch as every day from February 10 to 26 inclusive was rainy.

The 40 years' summary of the Robinson anemometer records is not yet completed. Owing to the imperfect way in which the early observations were entered (as mentioned last year) it was decided to read in the hourly velocities on the early sheets, thus making the investigation complete, instead of restricting part of it to 32 years.

VI.—Printing and Distribution of Greenwich Publications :—

The copies of the volume of Greenwich Observations for 1907 were distributed in December 1909, together with the Second Nine-Year Catalogue (1897–1905), Precession Tables for Third Ten-Year Catalogue, and Catalogue of Recurrent Groups of Sun-Spots 1873–1905.

The printing of the Greenwich Observations for 1908 is finished, with the exception of the Photoheliographic Results. As explained in previous reports, the preparation of the Photoheliographic Results has been unavoidably delayed, but the Results for 1907 will be included in the Volume for 1908.

As regards the 1909 Observations, the Zenith Distance Observations with the Transit Circle and the Rates of Chronometers and Watches are in the press.

VII.—Chronometers, Time Signals, and Longitude Operations :—

The number of Government marine chronometers and watches now at the Observatory is 455, viz., 232 box chronometers, 30 pocket chronometers, 108 chronometer watches, and 85 hack watches.

In addition to these there are, at the Observatory, 17 eight-day chronometers on trial for purchase for the Indian Government, and 5 box chronometers being tested after repair. Also one chronograph watch awaiting repair.

The are also 19 hack watches on trial for purchase by the Admiralty.

In the year ending 1910 May 10, the average daily number of chronometers and watches being rated was 596, the total number received was 1,746, the total number issued was 1,684, and the number sent for repair 776. This last number includes 53 box chronometers and 1 pocket chronometer belonging to the Indian Government.

For the annual trial of chronometers, which lasted 29 weeks with a range of temperature from 46° to 106°, 66 chronometers were sent in. During the trial 24 were rejected because the difference between one week's rate and the next exceeded 12 seconds. Of the remaining 42 chronometers, 8 were purchased for the Navy and 4 for the Indian Government.

The performance of the chronometers generally was very satisfactory.

For the annual trial of chronometer watches, lasting 16 weeks and including trials in the oven and in positions, 173 watches were entered, of which 74 were classified, and of these 35 were purchased for the Navy. Among the watches classified were 22 with centre-seconds' dials; of these 9 were purchased. There were 16 "Karrusel" or "Tourbillon" watches classified, of which 8 were purchased. The performance of the watches, on the whole, is as good as that of last year.

A trial of pocket chronometers took place concurrently with the trial of chronometer watches, and under the same conditions as regards duration of trial, temperatures, and positions. Of the 17 pocket chronometers sent in, 2 were purchased for the Navy.

The next trial of box chronometers will commence on June 18, and of pocket chronometers and chronometer watches on July 30.

Provision has been made to receive a number of non-magnetic watches on trial. These will be tested concurrently and under the same conditions as the chronometer watches.

The Greenwich time-ball was not raised on one day (February 17), owing to the violence of the wind. On May 8 (Sunday), in consequence of the clips not being set, the ball was not held in position for dropping at 13^h.

During the cloudy weather at the end of October, an incorrect clock rate was carried on, which caused an error in the signals on November 1 and November 2, the signals being $1^s \cdot 0$ early on the first date and $1^s \cdot 4$ early on the latter date.

The automatic drop of the Deal time-ball failed on 3 days owing to interruptions of the telegraphic communications. On April 6, the current was too weak to drop the ball. On February 24 a false signal dropped the ball 8 seconds too soon. Return signals have been received daily except on 37 days.

The return signal from Devonport failed on 65 days (of which 10 were Sundays), and could not be observed on 38 days (of which 21 were Sundays) 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 $0^s \cdot 2$ on 90 per cent. of the 260 days of observation, and did not exceed $0^s \cdot 5$ on 97 per cent. On 7 occasions it exceeded $0^s \cdot 5$, but never exceeded $1^s \cdot 0$. The average error for the year was $\pm 0^s \cdot 11$.

The return signal from Portsmouth failed on 41 days (of which 21 were Sundays), and could not be observed on 31 days (of which 24 were Sundays) owing to interruptions by telegraph signals. The apparent error of the clock (corrected in the same manner as the Devonport clock) did not exceed $0^s \cdot 2$ on 67 per cent. of the 291 days of observation, and did not exceed $0^s \cdot 5$ on 97 per cent. On 10 occasions it exceeded $0^s \cdot 5$, but never exceeded $1^s \cdot 0$. The average error for the year was $\pm 0^s \cdot 19$.

The return signal from Portland failed on 63 days (of which 25 were Sundays), and could not be observed on 32 days (of which 24 were Sundays), owing to interruptions by telegraph signals. The apparent error of the clock (corrected in the same manner as the Devonport clock) did not exceed $0^s \cdot 2$ on 91 per cent. of the 268 days of observation, did not exceed $0^s \cdot 5$ on 98 per cent., exceeded $0^s \cdot 5$ on 6 occasions, on two of which it was over $1^s \cdot 0$. The average error for the year was $\pm 0^s \cdot 12$.

The automatic signals from the Westminster clock have been received regularly since the last report. On 11 days the signal failed, and on 2 days it was interrupted by telegraph signals. Its apparent error was not greater than $0^s \cdot 5$ on 41 per

cent. of the days of observation, not greater than $1^s \cdot 0$ on 77 per cent., not greater than $2^s \cdot 0$ on 98 per cent., and was between 2^s and 3^s on six occasions, but never exceeded 3^s.

The reduction of the observations for the determination of the longitude of Malta has been completed, but the final result cannot be given until the observing station at Malta has been accurately connected by triangulation with Spencer's monument, which is the fundamental point adopted. Using, however, the difference of longitude between these points, measured as accurately as possible, on the War Office charts, the longitude of Spencer's monument (old site) is $0^h\ 58^m\ 2^s \cdot 595 \pm 0^s \cdot 010$ E. This is in close agreement with the determination by Auwers and Gill "German Transit of Venus Expedition, 1875," viz., $0^h\ 58^m\ 2^s \cdot 65$ E.

At the request of the Secretary of the Admiralty, Lieutenant Harold F. J. Young, R.N., was attached to the Observatory from October 4 to November 16 for practice in the use of a small transit instrument preparatory to taking up his appointment as Superintendent of the Chart and Chronometer Depôt at Malta.

VIII.—Personal Establishment:—

Mr. Cowell resigned on May 2 his position as Chief Assistant in order to take up the appointment of Superintendent of the Nautical Almanac on the retirement of Dr. Downing. The vacancy has not yet been filled up.

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

Chief Assistants—Mr. Eddington, and a vacancy.

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

Clerical Assistant—Mr. Outhwaite.

Established Computer (Higher Grade)—Mr. Davidson.

Established Computers—Mr. Bowyer, Mr. Burkett, Mr. Cullen, Mr. Edney, Mr. B. Evans, Mr. J. Evans, Mr. Furner, Mr. Melotte, Mr. Stevens, Mr. Witchell.

The following table shows the arrangement of the Staff (permanent and temporary) under the general superintendence of the Chief Assistants:—

Branch.	Established Staff.		Temporary Staff.
	Assistants.	Established Computers.	Supernumerary Computers.
Transit Circle:—			
1. Meridian Computations	Thackeray	Cullen	Kemp, *Rotherham, (Percival).
2. Transits		Witchell	*Daniels, *Acton.
3. Zenith Distances		B. Evans	Davies, (Bartle).
Reflex Zenith Tube	*nil*	Witchell	*Daniels.
Altazimuth	Crommelin	Furner	*Jeffries.
Time Signals, Chronometers, and 28-inch Refractor.	Lewis	Bowyer	*Shepperd, *Green, Newton.
Astrographic Equatorial	Hollis	Stevens J. Evans	*Peirce. *Passfield, Wheate (Leary).
Thompson Photographic Equatorial.	*nil*	Davidson (Higher Grade). Melotte.	Richards, (Lord).
Photoheliograph	Maunder	*nil*	*Smith, *Lait, *Saville.
Magnetic and Meteorological	Bryant	Edney	*Kirby, *Timbury, *Loomes, *Richardson.
Clerical	Outhwaite	Burkett	*Lyne.
Summary—Nine Branches	Seven	One (Higher Grade) Ten (Lower Grade).	† Twenty-five.

The names in brackets are those of Computers who have joined since 1910 May 10.

* Qualified as Observers with one or more of the instruments.

† 16 of the 25 are qualified as Observers.

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 regularly employed at the Observatory is 61.

IX.—General Remarks:—

I desire to take this opportunity of tendering to the whole of the Established Staff my hearty thanks for their loyal co-operation in carrying on and extending the work of the Royal Observatory during my tenure of office as Astronomer Royal.

The extent to which the activity of the Observatory has been increased by the zeal and devotion of the Staff may be judged from a comparison of the output of work 30 years ago with that recorded in the present Report.

In the older meridian work the annual number of observations with the Transit Circle has increased from about 4,000 to 10,000, and the number of stars for which accurate positions are given in the Star Catalogues periodically issued, from 2,263 in the Nine-Year Catalogue (1872) to 11,550 in the Second Nine-Year Catalogue (1900). With the new Altazimuth, as compared with the old, the number of observations for position has quadrupled. The development of work with the Reflex Zenith Tube is shown by the increase in the number of observations from 38 in 1880–81 to 1,302 in 1909–10.

To meet the recent development of Astronomy in various directions, new branches of work have been added, and these have been energetically carried on by the Staff.

With the 28-inch Refractor the observation of difficult double stars has been actively taken up, and in the past year 645 pairs have been measured, for all of which observations were needed.

The Thompson Equatorial with its twin refractor and reflector has been devoted assiduously to photography of faint satellites, comets, and planets, involving great strain on the observers through long night watches kept up unremittingly whenever photographs could be taken.

With the Astrographic Telescope the section of the International Chart and Catalogue allotted to Greenwich has been completed. The positions of nearly 180,000 stars have been measured in duplicate for the Catalogue, and about 65,000 enlarged prints of the Chart plates have been made at the rate of 12,000 to 13,000 a year. Nearly 720,000 stars have been counted on these plates.

In the heliographic work the average number of days on which photographs of the Sun are secured at Greenwich has been increased from about 150 to 210 a year, mainly by the introduction of Sunday duties, and the measurement of photographs from other sources supplementing the Greenwich series has been undertaken so as to secure a record of the Sun's surface practically complete for every day of the year.

There has also been development in the Magnetic and Meteorological branch which has involved additional work for the Staff, mainly in the direction of facilitating comparison with observations made elsewhere under different instrumental conditions. Discussions of the long series of Greenwich records have also been undertaken.

The large increase of work in the Chronometer and Time Signal branch may be inferred from the number of Navy chronometers rated daily at the Observatory, which increased from 194 in 1880–81 to 596 in 1909–10.

In contrast to this summary of the growth of work, it may be mentioned that the vote for the Royal Observatory has increased from 7,783*l.* in 1881–82 to 9,998*l.* in 1909–10 (exclusive of the special vote of 500*l.* for the Photo-mapping of the Heavens), so that the largely increased output of work, indicated above, is represented by an increase, in the course of 30 years, of about 2,200*l.* in the provision made for the Royal Observatory.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich,
1910 June 9.