REPORT

OF

THE ASTRONOMER ROYAL

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1892 *June* 4.

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I cannot present my usual Report without a reference to the loss we have sustained by the death of Sir G. B. Airy, who for 60 years has been connected with the Royal Observatory as Astronomer Royal, or as Member of the Board of Visitors. The annual Reports to the Board of Visitors which he originated and which, as Astronomer Royal, he presented during 46 years remain as a lasting record of his able and devoted conduct of the work of the Observatory. The personal attachment to the Royal Observatory which characterized his life has been fittingly shown on his death by a bequest of his books and manuscripts which, valuable as it is, will be valued all the more for the spirit which prompted it.

The Report here presented refers to the year from 1891 May 11 to 1892 May 10, and exhibits the state of the Observatory on the last-named day.

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

The Admiralty have authorized the building of the South wing of the proposed Physical Observatory during the present financial year, in order to provide additional accommodation for chronometers and deck watches, the room under the Chronometer Room and the Lower Record Room to be appropriated to chronometers as soon as the South wing is ready to receive the contents of these two rooms. The completion of

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the proposed Physical Observatory by the building of the three other wings and of the two upper storeys of the central tower (to carry the Lassell Equatorial and Dome) has been postponed for the present, the Admiralty, while recognizing the desirability of carrying out the work, being unable to make provision for it in the present financial year. The objects for which the new building is required were set forth in my last Report, and the experience of the past year has shown the urgent need for the accommodation which would be provided by the proposed Physical Observatory.

The new 36-foot dome to be erected on the South-East tower for the accommodation of the new 28-inch refractor is not yet completed, great delay having occurred in its construction by Messrs. T. Cooke & Sons, partly occasioned by the necessity for the erection of a larger workshop before it could be commenced, and partly by the nature of the work.

The pair of semi-domes for the new Transit Pavilion in the Front Court was completed last October, and the building is now quite satisfactory. Before the completion of the roof, the portable transit, used in this building while the transit-circle object glass was being repolished, was protected by a canvas tent.

The principal moveable instruments are thus distributed :—

At Greenwich—

Transit D, and the transit with axis view.

Altazimuth D.

Equatorials (6-inch).—Cooke, No. 2 ; Simms, No. 1 ; Hodgson, and Corbett.

Photoheliographs.—One complete (No. 4, mounted in the South Ground), two tubes (E 2, A 5, with object glasses), a driving clock (used for the Personal Equation Instrument), and a complete mounting (No. 3) mounted on the first floor of the New Museum for use, during the winter months, when the new building obstructs the view of the Sun from the Photoheliograph Dome.

Detached Telescopes (on tripod stands).—Two 4-inch (Simms, Nos. 1 and 2), two 4-inch (R.O., Nos. 1 and 2), two $3\frac{1}{2}$-inch (R.O., Nos. 3 and 4), and one $2\frac{3}{4}$-inch (R.O., No. 5).

At Waterville (temporarily for Montreal longitude)—

Transit E, clock Dent 2016, a portable chronograph, a relay, a galvanometer, and a rheostat.

On loan—

Transits.—A, at the Cape Observatory; B and C with two stands at Montreal and Canso for longitude operations.

Altazimuths.—A, at Bethnal Green Museum; B, at the Cape Observatory; E, at the Royal Naval College, Greenwich.

Equatorials (6-inch).—Lee at the Hong Kong Observatory, and Simms, No. 2, at Bethnal Green Museum.

Photoheliographs.—One complete at the Cape Observatory, one complete and the mounting of another (without driving clock) lent to the Science and Art Department.

Clocks.—Dent, No. 1916, and Dent, No. 2013, at the Cape Observatory, and Dent, No. 2011, at Kew Observatory.

For use in longitude operations, two portable chronographs by Hilger, and two relays, two galvanometers, and two rheostats by Siemens, have been obtained.

A photographic camera and stand have been purchased to take photographs of instruments and buildings which are required for various purposes.

An electric light installation for the principal instruments (as proposed in the last Report) has been sanctioned by the Admiralty, and will be provided during the present financial year.

The old gas main within the Park being defective, as mentioned in the last Report, a new main was laid last September, and since then the gas supply has been quite satisfactory.

The Royal Observatory copies of the Standard Yard and Pound were removed to the Standard's Office for the decennial comparison last autumn, and were returned in February.

Owing to the pressure of the Montreal longitude work, the annual comparison of the books and manuscripts with the Catalogue has not yet been completed.

Sir G. B. Airy left by his will to the Observatory such books, manuscripts, &c., as his executors might consider likely to be useful, and in accordance with this bequest, Mr. Wilfrid Airy has transferred to the Observatory 94 volumes and 134 unbound tracts, which form an important and valuable addition to the Library, as well as the voluminous manuscript calculations of Sir G. B. Airy's Numerical Lunar Theory.

Sir G. B. Airy has also bequeathed to the Observatory the marble bust of himself, by Foley, placed in the Octagon Room.

II.—Astronomical Observations :—

Transit-Circle.—The object glass was removed for repolishing on August 10, and returned on October 5, Mr. Simms having taken great pains in improving the definition and colour-correction of this old object glass, as well as in polishing the tarnished surfaces. Since its return the performance of the object glass has been eminently satisfactory. This opportunity was taken for applying new steel screws to the R.A. and Z.D. micrometers, and altering the wire system. The screws were made precisely equal, with 40 threads to the inch, and the value of a revolution of each is slightly more than 37″. There are now 10 wires, distant from each other by exact multiples of a screw-revolution, and so arranged that the mean of the 10 nearly coincides with one of them. A little computation is thus saved in taking the mean of a transit, and the only thing lost is symmetry in the arrangement.

In the absence of the transit-circle object glass, time observations were made with one or other of the portable transits, mounted in the Transit Pavilion in the Front Court: but the early observations were almost worthless owing to faulty mounting of the object glasses, which allowed them to slip, and it was some considerable time before a satisfactory mounting was applied to these instruments.

During the rest of the year, the Sun, Moon, and planets have been regularly observed on the meridian as before, though the number of observations, as shewn in the following statement, is naturally smaller than usual :—

Transits, the separate limbs being counted as separate observations	4801
Determinations of collimation error	249
Determinations of level error	335
Circle observations	4463
Determinations of nadir point (included in the number of circle observations)	319
Reflexion observations of stars (similarly included) . .	436

The annual catalogue of stars observed in 1891 contains 1813 stars.

A preliminary discussion of the observations for determination of variation of personal equation with stellar magnitude was published in a paper read to the Royal Astronomical Society (*Monthly Notices*, vol. li., p. 455). As far as they go the results indicate that there is a general tendency with all the observers to observe stars later when the light is diminished by placing a gauze screen before the object glass: but it is not clear that we are here measuring a real change of personal equation in observations of fainter stars, as the introduction of the screen modifies the image of the star, and this modification of the image may give rise to a change of personal equation unconnected with the diminution of brightness.

As regards the computations :—

The transits are completely reduced (so as to exhibit Mean R.A. 1892·0) to April 18, and observed R.A. corrected for instrumental errors and clock errors to April 30, collimation and level errors being applied to May 6, and means of transits being taken to May 9. The copy for press for 1891 is prepared.

The investigation of personal equations is completed for 1891, and the values accord with those of previous years. From 1892 January 1, Mr. Lewis has been selected as the Standard Observer, Mr. Downing having left the Observatory on 1891 December 31, on his appointment as Superintendent of the Nautical Almanac.

The circle observations are completely reduced to April 17, circle readings, &c., being complete to May 4. The copy for press for 1891 is prepared.

The apparent correction for discordance between the nadir observation and stars observed by reflexion is $+0''\cdot07$.

The correction for R—D, the error of assumed colatitude, and the position of the ecliptic have been investigated for 1891 ; and the ledgers of mean R.A. and N.P.D. of stars are complete. Some of the other ordinary computations have been delayed by the preparation of a catalogue of fundamental stars (epoch 1890) from observations in the five years 1887–1891. The advisability of publishing places of fundamental stars, revised by recent observations, at more frequent intervals, has been lately recognized, and a special effort has been made to furnish the Superintendent of the Nautical Almanac with the new places at an early date, so as to enable him to include them in the Nautical Almanac for 1896.

The R — D correction, from the observations in 1891, is found to be $-0''\cdot013+0''\cdot536$ sin Z.D., the second term agreeing with that of last year in being a little smaller than in previous years since 1883. A discussion of the accordant results for the years 1883–1890, shews that there is a well marked annual inequality in this discordance, which Mr. Turner proposes to investigate (Vide *Monthly Notices*, vol. lii., p. 374).

The Colatitude of the transit-circle as found by the observations of 1891 is $38°\ 31'\ 21''\cdot84$, differing by $-0''\cdot06$ from the adopted value. The correction to tabular obliquity of the ecliptic from solar observations in 1891 is $+0''\cdot05$, which accords with observations in the last three years. The discordance between the results from the summer and winter solstices is $-0''\cdot14$, indicating that the mean of the observed distances from the pole to the ecliptic is too small by $-0''\cdot07$. The reading of the Front Court thermometer was used in computing refraction for these

observations up to 1891 March 2, when the post carrying it was dug up in consequence of building operations. From that date the readings of the Standard Meteorological thermometer, which observation had shewn to agree sensibly with those of the Front Court thermometer, have been used for reducing observations of the Sun. The mean monthly excess of the adopted readings over those of the ordinary exterior thermometer (corrected for index error) was least in January (+ 0°·2) and November (+ 0°·3); and greatest in February and May (+ 2°·6). The mean for the year is + 1°·6.

The mean error of the Moon's tabular place (computed from Hansen's lunar tables with Newcomb's corrections) is + 0ˢ·077 in R.A. and + 1″·22 in longitude as deduced from 80 observations in 1891. These values are not strictly comparable with those of former years owing to the omission of observations in the autumn when the transit-circle was under repair; but, judging by recent years, the inclusion of autumnal observations would increase this mean error. and confirm the tendency to increase shown in 1887 and 1888, but intermitted in 1889 and 1890. The means for years since 1883 are as follows :—

Year.	R.A.	Long.	Year.	R.A.	Long.
	s	″		s	″
1883	+ 0·031	+ 0·42	1888	+ 0·090	+ 1·21
1884	+ 0·018	+ 0·29	1889	+ 0·010	+ 0·12
1885	+ 0·024	+ 0·36	1890	+ 0·020	+ 0·23
1886	+ 0·029	+ 0·34	1891	+ 0·077	+ 1·22
1887	+ 0·059	+ 0·66			

The mean error in N.P.D. for 1891 is − 0″·41.

The readings of the thermometers placed at various points in the Transit-Circle Room have been collected and discussed for the period 1888 January—1891 March.

It is found that as the external temperature rises there is a nearly uniform decrease in the excess of the readings of such thermometers over that of a standard exterior thermometer, the excess vanishing at something over 70°. Approximate formulæ for the readings of such thermometers are,—

$$\text{I—F} = (87° - \text{F}) \times 0{\cdot}055$$
$$\text{M—F} = (77° - \text{F}) \times 0{\cdot}050$$
$$\text{N—F} = (79° - \text{F}) \times 0{\cdot}033$$
$$\text{S—F} = (68° - \text{F}) \times 0{\cdot}031$$
$$\text{E—F} = (50° - \text{F}) \times 0{\cdot}024$$

where F is the Front Court thermometer, exposed under standard conditions ; I is the ordinary interior thermometer near the instrument, E the ordinary exterior thermometer near the north wall of the room, and M, N, S, are three thermometers placed in the middle, and at the north and south corners respectively of the horizontal shutter opening in the roof. But the season of the year has also an effect on the readings, which are higher in summer than we should expect according to the above formulæ, and lower in winter. This is possibly due to the influence of the walls of the room, whose sub-permanent temperature slowly changes throughout the year. It is found also that the readings are generally higher for north and east winds than for south and west. The complete discussion will shortly be printed in the " Monthly Notices."

Altazimuth.—The total number of observations made in the year ending 1892 May 10 is as follows :—

Azimuths of the Moon and Stars	345
Azimuths of Mark I.	162
Azimuths of Mark II.	182
Zenith distances of the Moon	166
Zenith distances of Mark I.	164
Zenith distances of Mark II.	176

These numbers are slightly greater than in recent years owing to the fact that during August and September, when the transit-circle was under repair, the observations of the Moon with the altazimuth were made throughout the lunation instead of being confined to the first and last quarters.

The observations are completely reduced to March 4.

The following table shows the number of days on which complete observations of the Moon were obtained with the transit-circle and altazimuth respectively :—

Moon's Time of Meridian Passage.	Transit-circle.	Altazimuth.
13^h to 14^h civil time	0	2
14^h to 15^h ,,	0	8
15^h to 16^h ,,	2	9
16^h to 17^h ,,	6	13
17^h to 18^h ,,	4	8
18^h to 21^h ,,	20	16
21^h to 0^h ,,	19	3
0^h to 3^h ,,	10	3
3^h to 6^h ,,	18	2
6^h to 7^h ,,	1	3
7^h to 8^h ,,	2	7
8^h to 9^h ,,	1	5
9^h to 10^h ,,	0	5
10^h to 11^h ,,	0	1

The whole number of places of the Moon observed with the transit-circle is 83 or 8·0 per lunation (excluding the two lunations during which the transit-circle was under repair), and with the altazimuth 85 or 7·0 per lunation.

The Moon's diameter has been measured with the transit-circle once in R.A. and 9 times in N.P.D., and with the altazimuth the vertical diameter has been measured once.

Clocks and Chronographs.—The daily rate of the Sidereal Standard clock changed rather suddenly from $1^s{\cdot}0$ to $2^s{\cdot}0$ gaining in October last. On enquiry it was found that workmen had been fixing a new shelf in the magnet-basement near the clock, and the necessary hammering in the neighbourhood had doubtless caused this change. Since then the rate has been steady, although it was deemed expedient to reduce this large rate by mechanical adjustment.

The clock "Dent 2016" was fitted with contact springs and sent to Waterville in April, in connexion with longitude operations. It was placed in the Artificial Cable Room at the Telegraph Station, where the temperature is kept approximately uniform, and under these conditions its rate was found to be remarkably steady. The clock "Graham 2" was mounted in the Transit Pavilion in August last, but has been dismounted for transport to Paris, in connexion with the redetermination of the longitude, Paris—Greenwich. These and other clocks are at present all in good order.

The two portable chronographs made by Mr. Hilger have performed satisfactorily, after some trouble spent in adjustment.

Reflex Zenith Tube.—Since the date of the last Report, 18 double observations of γ Draconis have been made. The reductions are not yet complete, owing to great pressure of other work and recent changes in the staff.

Equatorials.—The telescope tube and cradle of the South-East equatorial were dismounted on 1891 November 23, in preparation for the mounting of the 28-inch refractor in its place. The declination-axis cones, declination circle, and clamping circle were sent to Sir H. Grubb for the requisite adaptation of the new tube. The new 28-inch object-glass was brought here by Sir H. Grubb in March, and has been placed in the new Museum. The erection of the new 28-inch refractor is necessarily delayed pending the completion of the new 36-foot dome, which, as previously mentioned, is not yet ready.

A Maclean star-spectroscope has been procured, and a Rowland diffraction grating, with 14,438 lines to the inch, has been ordered from Mr. Brashear for use with the new refractor.

The 13-inch Merz refractor of the South-East equatorial is now being mounted in place of the Lassell 2-foot reflector, which for this purpose was dismounted on April 20.

The Thompson photographic-telescope will be carried on the tube of the 13-inch refractor instead of on the tube of the Lassell reflector.

The 13-inch photographic equatorial has been in constant working order since the date of the last Report, except that on 1891 June 4, the clock weight fell from a considerable height, damaging the floor beneath, owing to the giving way of a splice in the sustaining wire. Some improvements were made in the arrangements for orientation of the plate in 1891 July and September.

Since the date of the last Report, 10 occultations of stars by the uneclipsed Moon (8 disappearances and 2 reappearances) and 48 phenomena of Jupiter's satellites have been observed with the equatorials, or with the altazimuth. These observations are completely reduced to 1891 December 31. On the occasion of the partial eclipse of the Moon on 1892 May 11, 7 disappearances and 3 reappearances were observed of the faint stars in a list prepared by Mr. Crommelin : and the times of transit of the shadow over some principal craters were also noted. But it is to be regretted that, although favoured by fine weather on this occasion, we were seriously crippled in our instrumental equipment, the 13-inch refractor of the South-East equatorial and the Lassell 2-feet reflector being both dismounted.

Comet *b* 1891 has been observed with the Sheepshanks equatorial on 7 nights, and Comet *a* 1892 on 6 nights.

During the partial Solar Eclipse of 1891 June 6, two measures of the difference of N.P.D., and 8 of the difference of R.A. of the *p* and *f* Cusps were made, and 7 of the difference of N.P.D. of the south limbs of the Sun and Moon. The observations have been completely reduced, and the results are published in the *Monthly Notices*, vol. li., p. 559.

With the photographic equatorial 301 plates, with a total of 1190 exposures, have been taken on 112 nights in the year ending May 10, the majority of these being taken for special investigations, which have consumed a large amount of time. Of these 46 were taken to test the efficiency of various screens for diminishing the light of a star in a constant ratio, an investigation rendered necessary by a resolution of the Permanent Committee for the Astrophotographic Chart at their last meeting. The results arrived at were generally unfavourable to the use of such screens.

Sixty-two plates (including 18 of the Pleiades, mostly with long exposures) have been taken to determine the relation between diameter of image, duration of exposure, and brightness of star, and the results of this investigation are published in the *Monthly Notices* for January 1892. The eighteen plates of the Pleiades have, however, not yet been discussed. As far as they have been examined, they show that an exposure

of $40^{m.}$ under good conditions is sufficient to give images of stars of magnitude 14 and fainter. For testing the adjustment of the equatorial 8 plates of the Pole have been taken with trails and with clock driving, and for testing the orientation of the plate in different positions of the telescope 25 plates have been taken, from which it appears that the line of collimation of the telescope is sensibly inclined to the polar axis at an angle of about 30′, the orientation for 65° N. Dec. differing by about 20′ from that for the equator. Twenty-one plates have been taken to test the zero, and 8 sets of transits of λ Draconis for the scale value of the scales at the eye piece of the guiding telescope. Forty-eight plates have been taken of Nova Aurigæ for determination of its photographic magnitude, with an average of 2 or 3 exposures each, and besides all this experimental and special work, which has required careful and continuous discussion, 15 plates of the regular chart series (40 min. exposure) and 59 of the catalogue series (exposures $6^{min.}$, $3^{min.}$ and $20^{sec.}$) have been obtained. The supplementary exposure of $20^{s.}$ has been given since 1891 Dec. 2 to afford a ready means of detecting, by comparison with the Bonn Durchmusterung, whether through haze in the sky or dew on the object glass there has been failure in obtaining images of 11th magnitude stars with the $3^{m.}$ and $6^{m.}$ exposures. Thus if Argelander's stars of $8\frac{1}{2}$ to 9 magnitude are shown with the $20^{s.}$ exposure we may safely presume that the $3^{m.}$ exposure will show stars of magnitude 11. As a matter of fact out of 34 catalogue plates examined, only one failed to show Argelander's stars of 9·0 to 9·5 magnitude with the $20^{s.}$ exposure, this plate having been taken on a hazy night.

The *réseaux* hitherto supplied have proved unsatisfactory, the silver film rapidly developing pin holes, the images of which on the photographic plate closely imitate star images. Three *réseaux* have thus become so seriously defective that they can no longer be used. M. Gautier is now supplying two more in which the silver film is coated with collodion to preserve it, and it is hoped that these may prove more durable. In the Greenwich photograph micrometer, however, the measures can be made quite independently of the *réseau*, which will only be useful in the rare event of displacement of the film, and in that case the measures of the duplicate plates would suffice, even if the distortion were not shown at once by the triple images on the catalogue plates.

The measurement of diameters of star-discs on photographs for determination of the relation between diameter, exposure, and brightness of star, as well as of the photographic magnitude of Nova Aurigæ, and the discussions of the measures have taken up much time, but I hope that the results obtained may prove commensurate with the labour expended in obtaining them and in any case experience in measuring star images has been gained which will be useful in the systematic measurement of the catalogue plates.

The first discussion, which is given in the Monthly Notices for January, leads to the conclusion that, through a range of exposures corresponding to 8 magnitudes, or 1 to 1600 in the light intensities, the square root of the diameter increases as the logarithm of the exposure, and further that for equal photographic effects duration of exposure should vary inversely as the brightness of the star. These results are derived from 2200 measures of 150 star images.

In the other discussion the photographic magnitude of Nova Aurigæ from the announcement of its discovery on February 1 to April 1 when it had fallen to the 14th magnitude is deduced, but owing to great pressure of work recently the complete results have not yet been published. Preliminary results giving the magnitude from February 1 to March 9, were given in the Monthly Notices for last March. They incidentally confirm the empirical law deduced from the first discussion.

These measures of diameter were made with the photograph-micrometer used for measuring the 1874 Transit of Venus photographs, a single wire being used in the micrometer-microscope. Since then this measuring apparatus has been adapted by Mr. Simms to the more convenient measurement of positions and diameters of star images on the stellar photographs. A double-wire micrometer, on the same plan as that of the Reflex-Zenith Tube, has been applied, as well as an improved microscope, so that the diameter of a star image will be measured at once by means of the two wires, and read off on the second micrometer head, which gives the separation of the wires, while the position is given by reference to a millimetre scale on glass read by another microscope, as arranged for the measurement of the Transit of Venus photographs. It has also been arranged that the plate should be held in the slide of the measuring apparatus under the same conditions as in the frame of the photographic telescope during exposure, and that it should be capable of rotation readily through a right angle to admit of the measure of two rectangular co-ordinates.

The formation of catalogues of guiding stars for the zones + 60° to the Pole, + 25° to + 29°, and − 3° to − 5° which has been undertaken at Greenwich is almost finished. The catalogues of places (epoch 1900) are complete for the Greenwich zones + 65° to + 80° (the reductions for the circumpolar region being deferred) also for the zones + 60° to + 64° to be photographed at Rome, and for the Oxford zones + 25° to + 29°. For the San Fernando zone − 3° to − 5° the stars have all been selected and the places have been computed for those between R. A. 12^h and 18^h.

III.—Spectroscopic and Photographic Observations :—

The regular series of observations of the displacement of lines in Stellar Spectra for the determination of their motion in the line of sight has not been continued during the past year, but as a preliminary discussion of the results obtained in former years

appeared to show that they were affected to some extent by the position of the spectroscope, Vega and Altair were observed during the summer and autumn at as wide a range of hour-angle as possible, and with the spectroscope set to each of the four positions 0°, 90°, 180°, and 270° ; the slit being parallel to the declination circle at 0°. The numbers of observations obtained of the F line in the spectrum of Vega are :—at 0°, 39 ; at 90°, 42 ; at 180°, 36 ; and at 270°, 39 ; and of the F line in the spectrum of Altair :—at 0°, 30 ; at 90°, 32 ; at 180°, 26, and at 270°, 29. The measures are now under discussion, and give clear indications of the existence of the systematic error referred to. The observations were interrupted by the dismounting of the $12\frac{3}{4}$-inch telescope on 1891 November 19.

When the new star in Auriga was discovered in February, the South-east equatorial, and consequently the spectroscope were dismounted. The object-glass prism presented to the Observatory by Sir Henry Thompson, was mounted as quickly as possible on the Thompson telescope, but alterations of the telescope tube were found necessary to bring the spectrum to focus on the photographic plate, and before these could be completed, the Nova had become nearly too faint for observation. One photograph of the spectrum of the Nova was however secured, and plates exposed upon Sirius, Procyon, and Capella promise good results in the future.

The telescope and camera of the Dallmeyer photoheliograph were removed on 1891 September 9 from the wooden dome, where the new buildings obscured the horizon, to the first floor of the new museum, where they were mounted on stand No. 3 (last used in the Cape Ledo Eclipse expedition) which was simply placed on the floor and found sufficiently steady. From this position it was possible to photograph the Sun during about 2 hours each day. The tube was taken back to the old mounting on 1892 April 6, the Sun being then visible over the roof of the intervening building.

In the year ending 1892 May 10, photographs of the Sun have been taken with this instrument on 219 days, and of these 547 have been selected for preservation, besides 28 photographs with double images of the Sun for determination of zero of position.

The photographic telescope presented by Sir Henry Thompson was mounted on the Lassell equatorial for use as a photoheliograph and was fitted with an enlarging camera to give 8-inch pictures of the sun, with an exposing slit specially constructed for very short exposures. Photographs of the sun were taken with this instrument on 11 days from 1891 November 10 to 1892 February 3, when the enlarging camera was removed for observation of Nova Aurigæ.

Grooved shelves for storing the solar photographs (six-inch and ten-inch plates) have been fitted up in the New Library, as a temporary arrangement.

For the year 1891 Greenwich photographs have been selected for measurement on 224 days, and photographs from India and Mauritius (filling up the gaps in the series) on 136 days, making a total of 360 out of 365 on which photographs are available.

The solar activity has increased in a remarkable manner during the past year. While there were 175 days without spots in the year 1890, there were only 21 such days in 1891, and since 1891 March 28, the Sun has not been free from spots on a single day on which it has been observed. The number of groups visible on the disk at the same time and their average size and complexity have all greatly increased during the past 12 months, the group of February 5–18 being the largest ever photographed at Greenwich. This group has had an unusually long life, appearing first on 1891 November 15, and persisting till 1892 March 17.

The measures of the photographs are complete to 1891 August 7, and the reductions of areas and positions of spots and faculæ to 1891 July 10. The photographs showing the great group of February 1892 in its successive appearances from November 1891 to March 1892 have also all been measured and reduced.

Photographs from India and Mauritius up to 1891 December 31 have been received from the Solar Physics Committee.

IV.—Magnetic observations :—

The continuous register by photography of the changes in magnetic declination, horizontal force and vertical force has been satisfactorily maintained, absolute values of the declination, horizontal force and dip being obtained by eye observations from time to time to give the values for the reference lines from which the ordinates are measured on the photographic registers. Since the new gas main was laid in the Park up to the Observatory, no difficulty has been experienced in maintaining the temperature of the magnet basement at about 67° throughout the year.

It was discovered last year just after the Report had been written, that the serious disturbances of the earth current registers, mentioned in that Report, were due to the passage of trains on the City and South London Electric Railway, distant about $2\frac{1}{2}$ miles from the nearest earth-plate (at the North Kent East Junction of the South Eastern Railway) and about $4\frac{1}{2}$ miles from the Observatory. The abnormal excursions of the needles, which still continue, indicate a change of potential, every 2 or 3 minutes, varying from a small fraction of a volt to one-third of a volt or more. The amount of this change is approximately the same in both circuits, one of which is perpendicular to the line of the electric railway, and the other parallel to it, with one earth-plate very near the river.

The galvanometers in connection with the earth current apparatus having varied considerably from time to time in their scale value, a non-magnetic pointer of hard drawn silver was substituted in March for the upper magnetic needle, which from its position tended to neutralize the action on the needle inside the coil. The sensitiveness of the galvanometer has thus been largely increased, the scale value on the earth current registers being adjusted to a suitable value by shortening the shunt.

The magnetic reductions are completed to the following stages :—

The eye-observations of the upper declination magnet, and of the horizontal and vertical force magnets, are completely reduced to the end of 1891. The time-scales for declination, horizontal force, and vertical force are complete to the end of 1891, and the base line values, deduced from eye-observations, are entered on the photographic sheets for declination, and for horizontal and vertical force.

The hourly ordinates of the photographic curves are read out to the end of 1891 for all three elements, and the daily and hourly means taken for a few months of vertical force ; the time scales for earth currents are laid down. The dip observations are completely reduced to the present time, and the deflexion observations for absolute measure of horizontal force to the end of 1891. The temperature of the magnet basement at every hour has been read off from the sheets of the Richard thermograph to the end of 1891, and the daily and hourly means have been taken.

The following are the principal results for the magnetic elements for 1891 :—

Mean declination (approximate) . .	17° 23′ West.
Mean horizontal force . .	3·9587 (in British units). 1·8253 (in Metric units).
Mean dip	67° 19′ 49″ (by 9-inch needles). 67° 21′ 0″ (by 6-inch needles). 67° 23′ 22″ (by 3-inch needles).

In the year 1891 there were five days of great magnetic disturbance, but there were also about 20 other days of lesser disturbance, for which tracings of the photographic curves will be published, these days having been selected in concert with M. Mascart according to the arrangement mentioned in the last Report. The calculation of diurnal inequalities from 5 typical quiet days in each month, commenced in 1889 at Professor Rücker's suggestion, has been continued.

The new Kew unifilar instrument has, up to the present, only been used in the ordinary way for determination of absolute horizontal force near to the times at which

observations were made with the regular instrument. The means of the monthly values for horizontal force from June to December 1891 are :—

With the old instrument	...	...	1·8258 metric.
With the new instrument	...	...	1·8288 metric.

The reduction of the magnetic results for the years 1865–1867, and the correction of those for 1868–1882 is nearly complete.

A very large magnetic disturbance occurred on February 13–14, commencing about a day after the large Sun-spot was on the central meridian. Considerable magnetic disturbances, presumably associated with the presence of this large Sun-spot, also occurred on March 6, 11, and 12. Other important disturbances on 1891 September 9, 1892 April 25–26, and May 1, may perhaps be connected with spots then on the Sun's disc. The question of the association of magnetic disturbances with Sun-spots is of great interest, and in connection with this, a list of the important magnetic disturbances recorded since the commencement of the Greenwich series of solar photographs in 1873 has been communicated to the Royal Astronomical Society (Monthly Notices for March 1892). It appears from this list that most of these magnetic storms occurred when an exceptionally large spot was visible on the Sun near the centre of the disc, or about the time of some great change in a Sun-spot. It would appear also from a paper read by Mr. Ellis before the Royal Society recently that magnetic storms are generally characterized by a sudden initial movement of the magnets, which, within the limits of error of the time-scales at present in use, is simultaneous in all parts of the earth.

Copies of the photographic registers of the magnetic disturbance of February 13–14 have been sent to Prof. Neumayer, and the Washington Weather Bureau, and of the earth-currents on February 12–15 and five other disturbed days to Mr. Preece.

V. Meteorological Observations :—

All the meteorological instruments are in good order, and the continuous registration of atmospheric pressure, temperature of the air, and of evaporation, pressure and velocity of the wind, rainfall, sunshine, and atmospheric electricity has been maintained with them as usual. A new pendulum, made by the Observatory mechanic (Mr. Niblett), was applied to the thermograph clock in March, the old one being inconvenient for adjustment of rate. The old Robinson anemometer, which was mounted in 1889 for comparison of its readings with those of the older instrument, was taken down in January, when it was found that the pivots were much worn.

The vane of the Osler anemometer, which had been in use since the year 1841, began last autumn to show signs of weakness, and in the gale of November 11, it was found that the tail piece had broken adrift from the pointer. A scaffold was erected, and the vane, which is more than 9 feet long, was removed on December 8, and, after being thoroughly repaired, was reinstated on December 19. It was satisfactory to find that the anti-friction bearings of the vane, on which its sensitiveness depends, were in excellent condition, after having been in action continuously for 25 years.

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 the time-scales are laid down, and the hourly ordinates are read out for the dry and wet bulb thermometers and electrometer to the end of 1891. The table of principal changes in the direction of the wind for 1891 is complete to October.

The mean temperature of the year 1891 was 48°·4, being 1°·1 below the average of the 50 years, 1841-1890. The highest air temperature in the shade was 85°·1 on July 17, and the lowest 12°·0 on January 10. The mean monthly temperature in 1891 was below the average in all months excepting June, September, October, December. In January it was below the average by 4°·4, in April and August by 3°·0, and in May by 2°·8.

The mean daily motion of the air in 1891 was 278 miles, being 4 miles below the average of the preceding 24 years. The greatest daily motion was 960 miles on December 10, and the least 34 miles on February 23 and 24. The greatest pressure registered was 31·5 lbs. on the square foot on November 11. On December 10 the pressure plate was not in action.

During the year 1891 Osler's anemometer showed an excess of about 11 revolutions of the vane in the positive direction N., E., S., W., N., excluding the turnings which are evidently accidental.

The number of hours of bright sunshine recorded during 1891 by the Campbell-Stokes sunshine instrument was 1222, which is about 66 hours below the average of the preceding 14 years, after making allowance for difference of the indications with the Campbell and Campbell-Stokes instruments respectively. The aggregate number of hours during which the Sun was above the horizon was 4454, so that the mean proportion of sunshine for the year was 0·274, constant sunshine being represented by 1.

The rainfall in 1891 was 25·0 inches, being 0·5 inches above the average of the preceding 50 years.

The daily means of mean temperature of the air from the 50 years' results 1841–90 are completed, corresponding values of daily maximum and minimum temperature have been formed, and a considerable portion of the calculation (formation of daily means) is done.

The Port of London Sanitary Authority having decided last June to discontinue the observations of the temperature of the Thames made at Deptford since 1883, the series, which was first commenced in 1844, has now come to an end.

VI.—Printing and Distribution of Greenwich Publications :—

The distribution of the volume of Greenwich Observations for 1889, and the Spectroscopic and Photographic Results for 1890, with which the late Second Division Clerk was charged, has been delayed under unusual circumstances, but will be now proceeded with as rapidly as possible.

The volume for 1890 is all in type except the Introductions, which are in the printer's hands.

The Altazimuth Results for 1891 are in the printer's hands, and the Transits and Meridian Zenith Distances are ready for printing ; but the great pressure of work has somewhat delayed their preparation. The large increase in spotted area of the Sun during 1891 has made it impossible to keep the Photographic Reductions up to date with the present staff

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

The number of chronometers and deck watches now being tested at the Observatory is 157 (91 box chronometers, 19 pocket chronometers, and 47 deck watches). The annual competitive trial of chronometers commences on July 2, and the trial of deck watches on October 22.

In the year ending 1891 May 10 the average daily number of chronometers and deck watches being regularly rated was 243, the total number received was 765, the total number issued was 750, and the number sent for repair was 442.

For the annual trial of chronometers (which lasted for 29 weeks) with a range of temperature from 41° to 100°, 51 chronometers were sent in, and of these 22 have been purchased for the Navy. The performance of the chronometers generally was good, and the average trial number of the first six was 21·4, which compares well with those for previous years.

For the annual trial of deck watches, the watches were separated into two classes, A and B, 72 being entered (by their makers) as A and 21 as B, the trial in positions for the latter (which are intended for ordinary use on board ship) being limited to "dial up" and "pendant up." Of these, 65 have been purchased for the Navy, 22 being classed as A, and 43 as B, on the results of the trial, 22 of the latter having been entered for Class A by their makers. The first two watches in Class A were exceptionally good.

Harrison's machines for measuring time and the chronometers lent to the Royal Naval Exhibition have been returned.

New shelves have been fitted up in the Chronometer Room round the central pillar for deck watches, but notwithstanding this there was not sufficient shelf-room during the trials of chronometer and deck-watches, with the result that they could not be kept in orderly arrangement—a serious difficulty in providing for their safe custody.

On 1891 October 14, December 10 and 13, the Greenwich time-ball was not raised on account of the violence of the wind ; and on 1892 April 1 the springs of the Mean Solar clock failed to act, so that the ball did not drop, nor was any signal transmitted to the Post Office. On October 19, through sudden failure in the electric train of the Mean Solar clock, the signal at 13^h was 8^s late. On November 22 (Sunday) the Greenwich signal did not reach the General Post Office through failure in the connections outside the Observatory. On all other days the time-ball was dropped correctly.

The automatic drop of the Deal time-ball failed on 12 days owing to interruption of the telegraph connexions, on one day (November 11) high wind prevented the raising of the ball, and on February 18, the ball was not raised as some alterations were being made in the cylinder. On October 19, the ball was dropped 8^s late through the error in the Greenwich signal previously mentioned. On this occasion it was raised again and dropped by hand at 14^h.

There were repeated failures in the automatic return signal from Deal last November, and it was ultimately found by Captain Wrottesley, R.E., of the Post Office Telegraphs (who gave much personal attention to the matter), that these were due to the accumulation of grease which for many years had been applied to the piston on account of the excessive windage in the cylinder, intended to act as an air cushion. Under the supervision of Captain Wrottesley, to whom my thanks are due for his valuable assistance, the cylinder was taken to pieces and cleaned out on February 17, (after the ball drop at 13^h) and the windage having been corrected by an asbestos pad,

it was remounted on February 18, the ball being dropped by hand at 14^h on that day. The signal has since been received regularly, though the times of beginning and end vary from time to time by one or two seconds.

Signals from the Devonport clock have been received regularly since the date of the last Report, except on 51 days when the signal totally failed, or was interrupted by telegraph signals. The apparent error of the clock signal (after daily correction of the clock by the help of a time-signal from Greenwich) was under $0^s{\cdot}2$ on 61 per cent. of the 312 days of observation, under $0^s{\cdot}5$ on 91 per cent., between $0^s{\cdot}5$ and $1^s{\cdot}0$ on 11 per cent., and exceeded 1^s on two occasions only.

The automatic signals from the Westminster clock have been received regularly throughout the year ending 1892 May 10, except on 14 days when the signal failed. The error of the clock was insensible on 58 per cent. of the days of observation; it amounted to 1^s on 30 per cent., to 2^s on 7 per cent., to 3^s on 4 per cent., and to 4^s on 1 per cent.

The publication of the observations for the Paris-Greenwich longitude in 1888, and of those for the Dunkerque-Greenwich longitude in 1889, has been delayed pending a redetermination of the former longitude which will be commenced on June 6 of the present year; and it is hoped to settle several questions of importance raised by the discussion of the results obtained in 1888.

The first stage of the operations for the longitudes Montreal-Canso-Waterville-Greenwich was completed on Sunday night, May 23. In May of last year Mr. Turner paid a preliminary visit to Waterville, the terminus of the cable kindly placed at our disposal by the Commercial Cable Company. He selected a site for the transit after consultation with Major Johnston, of the Ordnance Survey; and discussed the general arrangements with the Telegraph Superintendent, Mr. T. J. Wilmot, and several experiments were made on the best method of transmission of signals. It was found that these could be sent and received either directly with the siphon-recorder, the clock taps and sent signals being recorded by slightly upsetting the balance of the bridge used in the duplex method, and the signals from Canso being received in the ordinary way; or that a chronograph might be used, the siphon-recorder being converted into a very delicate relay by attaching to the suspension-thread, a very light aluminium rocker, which would dip into mercury on being disturbed and so complete a circuit. This last device was suggested by the Superintendents at Waterville and Canso, and found to work satisfactorily. It was especially useful in transmitting signals direct from Montreal to Greenwich and back, which was done on Sunday 1892 May 23. In May 1891 however the exchanges were only experimental, though it was found in the course of

them that the time of transmission along the Cable Waterville-Canso was about a quarter of a second,—a result confirmed by a rough comparison of signals on 1892 May 11. Professor McLeod of Montreal paid a similar preliminary visit to Canso in 1891 June, and found an accordant value for the time of transmission.

Portable Transits B, C, D, and E were to be used for the time-determinations at the four stations, one instrument to be appropriated to each observer and considered as forming part of him. Several improvements in details were found necessary, especially in the mounting of the object glasses, which experience in 1888 had shewn to be unsatisfactory. New striding levels were also made, mounted on aluminium forks, and a micrometer screw attached to each (according to a suggestion made by Mr. Turner), so as to avoid the use of the defective bubble scales. The transits B and C were sent to Montreal in August, after testing them as well as was practicable under the tent-covering of the Transit Pavilion, whose semi-domes had not yet arrived. Two chronographs with stylographic pens had been made by Mr. Hilger, and four tables of electrical apparatus were constructed on the general principle of the French chronographs used in 1888 and 1889, but in a more compact form. The relays, rheostats and galvanometers were supplied by Messrs. Siemens Brothers, who kindly gave us considerable assistance in this matter. Two of these tables were sent to Montreal and used in the operations at Montreal and Canso, but a different plan of operations was ultimately adopted at Greenwich and Waterville. A transit hut was sent to Waterville in August, and erected under Mr. Wilmot's supervision. These preparations and unexpected small delays had taken so much time that it was found impossible to complete the work in 1891 before the winter, and the date of commencement was altered by agreement to 1892 April 19. Mr. Turner went to Waterville on April 11, taking with him his instruments and the clock Dent 2016. This clock was mounted in the Artificial Cable Room at the station, where the temperature is kept nearly uniform, and has under these conditions performed extremely well. Signals were exchanged between Greenwich and Waterville twice each night from April 18–26, and again from May 5–12, when Mr. Hollis was at Waterville and Mr. Turner at Greenwich, and between Canso and Waterville once or twice each night during the same periods, and also on May 13, 14, 15 (after the date of this Report), when there was interruption between Greenwich and Waterville, the siphon-recorder being used according to the first method above described. Through signals between Greenwich and Montreal were exchanged on Sunday May 23, using the siphon-recorders as relays for connexion at Waterville and Canso. It was found by experiments in 1891 that the virtual time of action of these relays was about $0^{s}\cdot2$, the rocker not responding until the received current reached a certain strength.

Time determinations were made in all on 14 nights at Greenwich, 12 at Waterville, and about the same number at Canso and Montreal, our information not being quite complete on this head. A preliminary reduction gives every promise of satisfactory accuracy at Greenwich and Waterville.

Professor McLeod will reach here in July, bringing with him some account of his observations ; and after discussion with him, Mr. Turner will leave for Montreal early in August.

In February and again in March, Captain Grant, R.E., of the Ordnance Survey Office, came to the Observatory to consult me as to the determination of the boundary of Mashonaland, in conjunction with the Portuguese Government, and to practise the requisite transit observations. The most difficult part of this operation was the fixing of a meridian of longitude on the spot, and without, of course, any possibility of telegraphic communication. I recommended the method of Moon culminations, observed with a small transit, which was specially made by Messrs. Troughton and Simms ; and to minimize the errors of this method, a rough prediction of the Moon's errors was made. For this purpose all the observations of R.A. of the Moon made in the years 1883–1891 were collected, and arranged as though the lunations corresponded to calendar months ; that is the errors on the day of full Moon in the first lunation of each year were considered together and plotted in a curve, which was then produced conjecturally to get the error on the day of full Moon in the first lunation of 1892 ; and similarly for other lunations, and other epochs in the lunation, before or after full Moon. About one broad general feature of the curves there was no doubt, viz :—the error is larger algebraically after full Moon than before, and this excess is large in summer, and small in winter. A possible explanation would be, that the adopted diameter is too large, being deduced from observations made at the full when the sky is darkest, and irradiation increases the apparent diameter to the maximum extent. In summer there is diffused light from the sky even near midnight, and irradiation is not so large ; consequently transits of the second limb give apparently a larger tabular error than those of the first.

During the past year the apparatus for the Singapore time-ball, about which the Crown Agents for the Colonies had consulted me, was tested and ultimately made satisfactory, after some alterations suggested by me had been made. A chronograph for Hong Kong Observatory, made by Sir H. Grubb has also been tested, and after some adjustment found to be very satisfactory.

VIII. Personal Establishment :—

There have been an unusual number of changes in the staff since the date of the last Report. The Treasury having sanctioned the addition of one First-class

Assistant and one Second-class Assistant to the staff, the former (by the decision of the Admiralty) to be appointed from among the existing Second-class Assistants, Mr. Andrew C. D. Crommelin, B.A., was appointed on May 11 the additional Second-class Assistant, and on November 3, Mr. Lewis was promoted to be the additional First-class Assistant. On January 1 Mr. Downing was appointed Superntendent of the Nautical Almanac, thus creating a vacancy among the First-class Assistants, which was filled up by the promotion of Mr. Thackeray. The two vacancies in the Second-class resulting from the promotions of Mr. Lewis and Mr. Thackeray were filled up by the appointment of Mr. W. W. Bryant, B.A., and Mr. T. C. Hudson, B.A., as Second-class Assistants, who entered on their duties on February 8 and 12 respectively. The 2nd Division Clerk was relieved of his duties on May 6. The staff at the present time is thus constituted, the names being arranged in alphabetical order in each class :—

Chief Assistant—Mr. Turner.

First-class Assistants—Mr. Criswick, Mr. Ellis (Superintendent of the Magnetic and Meteorological Branch), Mr. Lewis, Mr. Maunder, Mr. Thackeray.

Second-class Assistants—Mr. Bryant, Mr. Crommelin, Mr. Hollis, Mr. Hudson, Mr. Nash.

2nd Division Clerk—Vacant.

Mr. Turner supervises the work of the Observatory generally, and has full power to act in all matters in my absence. Mr. Criswick has charge of the photographic mapping of the heavens, and since May 6 has also taken charge temporarily of the cash accounts pending definitive arrangements to be made by the Admiralty. Mr. Maunder is charged with spectroscopic and photographic observations and reductions. Mr. Lewis has the charge of time-signals and chronometers, and Mr. Thackeray superintends the miscellaneous astronomical calculations. Mr. Hollis has the care of the library and manuscripts and assists Mr. Turner in the Montreal and Paris longitude operations. Mr. Crommelin is responsible for the altazimuth and equatorial computations, Mr. Bryant for the transit reductions, and Mr. Hudson for the meridian zenith-distance reductions. In the magnetical and meteorological branch, Mr. Ellis superintends the whole of the work, assisted by Mr. Nash, who is specially charged with the meteorological reductions and instrumental adjustments.

There are at the present time ten computers attached to the astronomical branch, one to the astrophotographic, two to the spectroscopic and photographic, and five to the magnetic and meteorological.

A gate-porter, a watchman and a gardener, as well as a foreman of works, with two carpenters and one or two labourers, and a skilled mechanic, with a boy as assistant, are also attached to the Observatory.

IX. General Remarks :—

In considering how the fundamental determinations of places of Sun, Moon, planets, and stars could be advantageously supplemented and checked by observations, under different conditions, which should be comparable with meridian observations in precision, I have been led to work out a plan for making observations out of the meridian with a transit circle, so constructed that, by means of a turntable, it can be placed and firmly fixed in certain definite azimuths, the instrument being used essentially as a transit-circle for a complete series of observations in the selected azimuthal plane. The general principles of the instrument, and of the method of observation, are given in a paper recently communicated to the Royal Astronomical Society. Such an instrument would advantageously replace the existing altazimuth, designed nearly 50 years ago for extra-meridian observations of the Moon, and it could be utilized not only for this important object, but also for observations of the Sun, planets, and stars (in the meridian as well as out of the meridian), for the elimination, as far as practicable, of systematic errors, and for the more accurate determination of astronomical constants. I would propose that this instrument should be a reversible transit-circle, having an object glass of eight inches aperture, and circles of three feet diameter (each read by four microscopes), with special arrangements to adapt it for use in the prime vertical, or any other selected azimuth. A suitable location for the instrument could be found in the magnetic meridian of the declination magnet, about 90 feet north of it, where a considerable mass of iron might be placed without appreciable effect on the magnet, and a practically unobstructed view could be secured by mounting the instrument with its axis at a height of about 20 feet above the ground.

The longitude operations, which are occupying so much of our attention during the present year, are directed not only to the fixing of the longitudes of Montreal and Paris with all possible accuracy, but also to the determination of the longitude of Waterville (the terminus in Ireland of the Commercial Company's cable) as a geodetic station at the western extremity of the great European arc of longitude. The longitude of this station, however, as well as that of Valentia (determined many years ago), may, not improbably, be affected by considerable local attraction, situated, as they both are, between the Atlantic on the west, and a mountain mass on the east. It would, therefore, be very desirable in the interests of geodesy, that the longitude of a station on the other side of this mountain mass should also be determined, and I would suggest Killorglin, at the head of Dingle Bay, as probably the most suitable for the purpose.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich.
1892 May 26.