

REPORT
OF THE
ASTRONOMER ROYAL
TO THE
BOARD OF VISITORS
OF THE
ROYAL OBSERVATORY, GREENWICH.

Read at the Annual Visitation of the Royal Observatory, 1916 June 3.

GREENWICH OBSERVATIONS, 1915.

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The Report here presented refers to the year from 1915 May 11 to 1916 May 10; and exhibits the state of the Observatory on the last-named day.

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

No alterations or additions to buildings have been carried out since 1915 May 10. The smaller domes were painted externally in April. The painting of the domes of the 28-inch and Thompson Equatorials has been deferred.

The principal movable instruments are thus distributed :—

At Greenwich—

Transits B, C, D, and E. (Object glasses of D and E on loan—*see* below.)

Altazimuths D and E.

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

Photoheliographs Nos. 2 and 3 complete and the mechanical parts of Nos. 1 and 5.

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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.

Transit, with axis view, at the Science Museum, South Kensington.

Object glasses of Transits D and E on loan to the Inspection Department, Woolwich Arsenal.

Altazimuths.—A, at the Imperial College of Science and Technology, South Kensington; B, at the Cape Observatory.

Equatorials.—Simms No. 2 (6-inch), at the Imperial College of Science and Technology.

Two Heliotropes at the Science Museum, South Kensington.

Photoheliographs :

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

No. 4. Complete at Kodaikanal Observatory.

No. 5. Object glass on loan to Professor Newall, Cambridge.

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

On loan to the Royal Observatory—

The Cookson Floating Zenith Telescope from the Cambridge Observatory for a period of seven years from July 1911.

Two 16-inch cœlostats and a 12-inch cœlostet from the Royal Astronomical Society for use at the total eclipse of the Sun, 1914 August. (At present in Russia, at Pulkovo Observatory.)

A Quartz spectroscope from Prof. H. F. Newall, Cambridge, for the same eclipse. (At present in Russia, at Pulkovo Observatory.)

The annual examination of the Library has been made as usual, the books on the shelves being compared with the catalogue. Ten books are reported missing from the shelves and cannot be accounted for at present, including two books reported missing last year. Six of the books reported missing last year have been returned.

II.—Astronomical Observations:—

Transit Circle.—The Sun, Moon, planets, and fundamental stars have been regularly observed on the meridian as in previous years. Other stars observed are taken from the list prepared by Dr. Backlund and Mr. Hough of fundamental stars equally spaced over the celestial sphere. The working catalogue containing all the stars in this list which transit at altitudes greater than 10° , including sub-polar stars, has approximately 3,000 entries. It is proposed to observe each star about 10 times.

The total number of observations made during the year is as follows:—

Transits	-	-	-	-	-	-	-	6,879
Collimation	-	-	-	-	-	-	-	298
Level	-	-	-	-	-	-	-	717
Circle observations	-	-	-	-	-	-	-	6,249
Nadir point	-	-	-	-	-	-	-	658
Reflection observations	-	-	-	-	-	-	-	272

The Sun was observed on 155 days and the Moon on 108 days.

Observations of level and nadir have been made when practicable three or more times a day. The diurnal changes of level and nadir, found by grouping together observations taken within three hours of noon, 6 p.m., midnight, and 6 a.m., are as follows:—

	Diurnal Changes of Level.				Diurnal Changes of Nadir.			
	Noon.	6 p.m.	Midnight.	6 a.m.	Noon.	6 p.m.	Midnight.	6 a.m.
1915	+ 0"28	0"00	+ 0"20	...	+ 0"06	0"00	+ 0"04	...
1906-14	+ 0"20	0"00	+ 0"20	...	+ 0"16	0"00	+ 0"06	...
1897-1905	+ 0"25	0"00	+ 0"21	+ 0"37	+ 0"14	0"00	+ 0"12	+ 0"11

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Mr. Vernon Boys kindly presented to the Observatory a new mercury trough of his own design. Beautiful images of the wires are obtained with it for the nadir observations, but the thin film of mercury is apt to burst rather easily.

No observations of stars by reflection and directly on the same night have been made, but reflection observations have been made independently. In this way more accurate observations are obtained, and they are equally available for the determination of fundamental zenith distances. An account of the results obtained from the observations of 1915 is given in the *Monthly Notices* for 1916 January. It appears that the difference R—D cannot be considered as wholly due to flexure, and it is desirable, if possible, to obtain determinations of flexure in different positions of the instrument in some other way. An attempt has been made to determine the flexure by the method used by Mr. Bonsdorff at Pulkovo, but up to the present this has not been completely successful. The observatory is indebted to Professor Dalby for making an apparatus for experimental determinations by Bonsdorff's method.

For the year ended 1914 Dec. 31, the value of the colatitude, using Pulkovo refractions, is $38^{\circ} 31' 21''.83$. From observations of the Sun the correction of the tabular value of the obliquity of the Ecliptic is $-0''.17$. The mean of the observed distances from the pole to the Ecliptic is too small by $0''.18$. The apparent correction to the right ascension of the clock stars, for which Newcomb's Equinox is adopted, is $-0^s.027$. It should be noted that the observations on which these results depend were made with the Travelling Wire Micrometer.

The mean error of the Moon's tabular right ascension (computed from Hansen's tables with Newcomb's empirical corrections) for 1915 is $-0^s.87$ from 87 observations of the limb, and $-0^s.84$ from 42 observations of Mösting A.

The reduction of Clock Stars and polars is completed to May 10 and that of other Stars to April 8. The travelling wire micrometer has very largely freed the clock errors from personal equation.

Copy for press was completed in November of a Catalogue of Fundamental Stars from observations 1905–1914, but the printing has been postponed. The catalogue of stars down to $9^m.0$ on the B.D. scale between the limits of 24° and 32° of North declination has been prepared for press with the exception of the proper motions which are being completed as rapidly as circumstances will permit.

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Altazimuth.—Work with this instrument has been largely discontinued since September, except for observations of the Moon. The number of observations made during the year are:—

Meridian transits and zenith distances - - - 517 and 493
 Extra-meridian observations - - - 174
 Determinations of collimation, level, and nadir - - 89, 95 and 98.

The observations, with the exception of the application of latitude variation, are completely reduced to 1916 April 12.

The following table shows what observations of the Moon were obtained with the transit-circle and altazimuth, respectively, during the year 1915:—

Time of Moon's Meridian Passage.	Transit Circle.		Altazimuth.		
	Limb.	Mösting A.	Limb.	Mösting A.	Extra Meridian.
h. h. 0-3 G.M.T. - - - -	0	0	0	0	3
3-6 „ - - - -	11	0	3	0	9
6-9 „ - - - -	19	13	7	5	4
9-12 „ - - - -	15	12	12	6	0
12-15 „ - - - -	16	10	8	3	0
15-18 „ - - - -	17	11	4	3	6
18-21 „ - - - -	13	0	5	0	9
21-0 „ - - - -	0	0	0	0	2

The total number of observations of the Moon is 91 with the transit-circle and 72 with the altazimuth. Taking both instruments, observations have been obtained on 128 days.

The mean error of the Moon's tabular place is $-0^s.84$ from meridian observations of the limb, $-0^s.90$ from meridian observations of the crater Mösting A., and $-0^s.93$ from extra-meridian observations of the limb.

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The table giving the mean tabular error of the Moon's longitude since 1883, when Newcomb's Empirical Correction to Hansen's tables was introduced into the Nautical Almanac, is repeated from last year's report:—

1883	-	- 0 ^{''} 03	1892	-	+ 0 ^{''} 79	1901	-	- 2 ^{''} 77	1910	-	- 7 ^{''} 85
84	-	- 0 ^{''} 16	93	-	- 0 ^{''} 06	2	-	- 3 ^{''} 15	11	-	- 8 ^{''} 34
85	-	- 0 ^{''} 09	94	-	- 1 ^{''} 20	3	-	- 3 ^{''} 08	12	-	- 9 ^{''} 79
86	-	- 0 ^{''} 11	95	-	- 1 ^{''} 47	4	-	- 3 ^{''} 16	13	-	- 11 ^{''} 93
87	-	+ 0 ^{''} 21	96	-	- 1 ^{''} 68	5	-	- 5 ^{''} 29	14	-	- 12 ^{''} 86
88	-	+ 0 ^{''} 76	97	-	- 2 ^{''} 77	6	-	- 5 ^{''} 91	15	-	- 12 ^{''} 4
89	-	- 0 ^{''} 38	98	-	- 3 ^{''} 03	7	-	- 5 ^{''} 96			
90	-	- 0 ^{''} 27	99	-	- 2 ^{''} 18	8	-	- 5 ^{''} 97			
91	-	+ 0 ^{''} 72	1900	-	- 2 ^{''} 69	9	-	- 6 ^{''} 41			

Cookson Floating Zenith-Telescope.—During the year 166 photographs have been taken, 160 for latitude groups and 6 for scale determination. The small numbers are accounted for mainly by the weather from December to February, as every effort was made to obtain the necessary plates. The measurement of the photographs to the end of 1915 is nearly completed.

Equatorial Observations.—During the year ended 1916 May 10, 17 disappearances and 2 reappearances of stars occulted by the Moon have been observed by one or more observers. The 2 reappearances and 7 of the disappearances were observed on December 18, when the Pleiades were occulted. These occultations confirm the large errors in the Moon's tabular place shown by the Transit Circle and Altazimuth. The reappearance of the star Lalande 45880 after occultation by Jupiter was observed on October 28. Taylor's Periodic Comet was observed on three nights with the Sheepshanks equatorial. Two photographs of Neujmin's Comet were taken for place with the 30-inch reflector.

The 28-inch Refractor.—The suspension springs of the pendulum of the water clock broke on January 20. New springs were applied and the clock was overhauled. The instrument has been throughout the year at the disposition of M. Jonckheere. Observations by the regular observers were discontinued at the end of October. M. Jonckheere's observations have been mainly of stars which have been discovered to be double since 1905. He has spent a good deal of

time in the identifications and verifications necessary to the completion of the catalogue of double stars referred to in last year's report. During the year, 140 new double stars with separation less than $4''$ have been discovered.

Altogether 1,027 double stars have been measured during the year. Of these stars—

232 are less than $1''$ apart.

384 „ between $1''$ and $3''$ apart.

318 „ „ $3''$ „ $5''$ „ .

And 93 are more than $5''$ apart.

Stars of particular interest were observed on several nights, *e.g.*, κ Pegasi, δ Equulei, β Delphini, ζ Bootis, ξ Ursæ Majoris, γ Andromedæ, η Cassiopeïæ, Σ 2281, 70 Ophiuchi, β 612, ζ Cancri, ϵ Hydræ and Sirius.

Thompson Equatorial.—Photographs have been continued for the determination of Stellar parallax in accordance with the programme outlined in last year's report. During the year ended 1916 May 10, a first exposure has been given to 209 plates, and a second exposure, approximately six months after the first, on 226 plates. In the same period 164 plates have been measured, but the measurement has had to be discontinued.

During the year 37 photographs have been taken for the determination of the magnitudes of the stars in Kapteyn's selected areas. Of these 34 have been passed as satisfactory for measurement. Altogether of the 90 fields from declination $+15^\circ$ to $+75^\circ$, 149 photographs of 59 fields have been taken. The measurement is well advanced for the plates in zone 15° , but has made very little progress during the year.

Astrographic Equatorial.—The taking of chart plates in the Oxford Zone was continued till November 8, 72 plates being taken on 45 nights. Of these plates 13 were rejected on account of atmospheric conditions and 5 owing to faulty guiding, &c. This series of photographs, in which 207 satisfactory plates have been secured, has been suspended owing to lack of Observers.

The comparison of the positions of stars given in Vol. III. of the Greenwich Section of the Astrographic Catalogue with those given in earlier catalogues for

the determination of proper motions has been continued. With the exception of from 12^h to 0^h in the Zone 65° to 70° , this is practically completed. A search for all stars in the *Bonn Durchmusterung* between the pole and Declination 64° with large proper motions is in progress by comparison of photographs from 16 to 20 years apart. Already 200 plates with centres at declinations 66° , 68° , 70° have been compared in this way.

III.—Heliographic Observations :—

In the year ended 1916 May 10, photographs of the Sun were obtained on 244 days. Of these 502 have been selected for preservation, including 36 with double images of the Sun for the determination of Zero of position angle. Photographs have been received from the Royal Observatory, Cape of Good Hope, to 1916 January 31; and supplementary photographs have been received through the Solar Physics Committee, from Dehra Dûn, India, to 1915 December 12, and from the Director of the Kodaikanal Observatory to 1915 June 14. A complete series of photographs for the year 1915 will be made up from the four contributing Observatories.

The measurement of the photographs for 1915 is completed as far as November 12, except for two photographs from India not yet received.

The mean daily spotted area of the Sun, which was 152 millionths of the Sun's visible hemisphere in 1914 as against 7 in 1913, rose in 1915 to considerably over 700 millionths.

IV.—Magnetic Observations :—

The variations of magnetic declination, north force and vertical force have been registered photographically. Absolute observations of declination are made five or six times a week, of horizontal force with the Gibson deflection instrument twice a week, and of dip with the dip-inductor three times a week. The inductor has been in regular use since the beginning of 1914, and gives very satisfactory results. Observations with the dip-needles were discontinued at the end of 1914.

The magnetic reductions are completed to the following stages :—

The hourly ordinates of the declination registers are read off and tabulated for 1915, and those of the other registers for the year 1914. The temperature

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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 absolute observations are all reduced. The mean values of the magnetic elements for 1915 and four previous years are as follows:—

Year.	Declination W.	Horizontal Force in C.G.S. Units.	Dip.
1911 - - - -	15° 33' 0	0.18549	66° 52' 6" (3-inch needles)
1912 - - - -	15 24.3	0.18548	66 51 46 " "
1913 - - - -	15 15.2	0.18534	66 50 27 " "
1914 - - - -	15 6.3	0.18518	{ 66 49 27 66 51 13 (dip inductor)
1915 - - - -	14 56.5	0.18494	66 51 58 " "

There were no days of great magnetic disturbance in 1915, but three were classified as of lesser disturbance. Traces of the photographic curves for these days will be published in the annual volume.

The new Magnetograph House is satisfactory. The arrangements for maintaining a constant temperature have developed a defect. Air appears to gradually leak into the controlling apparatus and consequently the temperature at which the room is being kept has slowly fallen from 66° to 61°. This is too low for summer temperatures, but it has not been possible to get the apparatus set right. It was not found possible to instal the new vertical force instrument during the year.

A mirror of platinized quartz has been obtained and has kindly been mounted by Mr. Colebrook of the Imperial College of Science, as the manipulation of quartz fibres could not be done at the Observatory. The adjustment of the instrument is proceeding.

V.—Meteorological Observations:—

The registration of atmospheric pressure, temperature of the air and of evaporation, pressure and velocity of the wind, rainfall, sunshine, and atmospheric electricity has been continuously maintained.

The observations of barometer, thermometers, anemometers, rain-gauges, and sunshine recorder are entered and reduced to date. On the photographic sheets time-scales are laid down, and the hourly ordinates read off and reduced to the end of April 1916.

The principal features of interest in the meteorological conditions at Greenwich during the year ending 1916 April 30 are—(i) the warm January with a mean temperature 2° higher than any January from 1841 to 1915; (2) the great pressures of wind in the gales in the winter; and (3) the heavy rainfall in March, the wettest March since the commencement of the Greenwich records in 1841.

The following details of the chronicle of the weather refer to the year ended 1916 April 30. The mean temperature was $49^{\circ}\cdot6$ or $0^{\circ}\cdot1$ above the average of the 70 years 1841–1910. The highest temperature in the shade was $87^{\circ}\cdot2$ on June 8, and the temperature exceeded 80° on only 6 days as against 21 in the previous year. The lowest temperature was $23^{\circ}\cdot0$ on November 27, and on 40 days fell as low as $32^{\circ}\cdot0$.

The mean daily horizontal movement of the air was 287 miles, which is 3 miles above the average of the previous 48 years. The greatest daily movement, 955 miles, was recorded on February 16, and the least, 63 miles on October 15. The greatest recorded pressure on the square foot was 35·0 lbs. on January 1; the greatest velocity in one hour 51 miles on December 27. Osler's anemometer showed an excess of 16 revolutions of the vane in the positive direction N., E., S., W., accidental turnings being excluded.

The duration of bright sunshine registered by the Campbell-Stokes instrument was 1,476 hours out of a possible 4,473 hours, or 33 per cent. This is below the average principally owing to a deficiency in August and March.

The rainfall was 32·17 inches or 8·05 inches above the average for the period 1841–1905. The number of rainy days (0·005 inch or over) was 168. June with 0·56 inch was the driest and December with 5·20 inches the wettest month. The rainfall in March was 4·13 inches.

VI.—Printing and Distribution of Greenwich Publications:—

The Greenwich observations for 1913, and the Photographic Magnitudes of Stars brighter than $9^m\cdot0$, between Declination $+65^{\circ}$ and $+75^{\circ}$, were distributed in August to places in the British Empire and the United States of

America. Distribution of publications on the continent of Europe is postponed during the war.

The printing of the 1914 observations was completed in October as far as the sections of the Transit Circle, Altazimuth and Planetary Results are concerned. Copy for press of the Fundamental Catalogue for 1910, of the Heliographic Observations for 1914, the Magnetic Observations for 1914, and a part of the Meteorological Reductions has been prepared but the printing has been postponed in accordance with Government instructions.

VII.—Chronometers :—

The number of chronometers and watches belonging to the Admiralty now at the Observatory is 229, viz., 49 box chronometers, 4 pocket chronometers, 71 chronometer watches, and 100 hack watches. Three box chronometers are also being tested for the Indian Government.

There are 93 box chronometers, 50 chronometer watches and 64 hack watches belonging to various makers, now at the Observatory on trial for purchase by the Admiralty. In addition, five 8-day chronometers are on trial for purchase by the Indian Government.

During the year ended 1916 May 10, 5,085 chronometers and watches have been received and 5,090 issued. The number sent for repair was 1,546, including 30 box chronometers, and 6 watches belonging to the Indian Government.

Purchases of chronometers and watches have been made after severe trial in temperature and position. Three trials of box chronometers have been held. Altogether 143 chronometers were entered, and of these 81 were purchased. A fourth trial, for which 77 chronometers have been deposited at the Observatory, is now proceeding.

Five trials of chronometer watches have been held. The total number of watches deposited was 516. Of these 250 have been purchased.

Provision has been made for two further trials of chronometer watches in summer and autumn.

Trials of hack watches have proceeded continuously throughout the year. In all 812 watches have been under trial, and 536 have been purchased.

A cheaper form of watch, which has been given the name of Pocket Watch, was called for by the Admiralty during the year. Of these 600 have been purchased after being tested.

VIII.—Clocks and Time Service :—

The renewal of the Time-Ball mentioned in last year's report is again necessarily deferred.

The daily time signals from the Eiffel tower have been observed regularly by Mr. Lewis and Mr. Bowyer. The mean of the times as observed by Mr. Lewis is $+ 0^s\cdot011$ late on Greenwich Time from 221 observations, and by Mr. Bowyer $+ 0^s\cdot003$ from 291 observations. The accordance between the telegraphic signals from Greenwich and the wireless signals from the Eiffel Tower has been quite satisfactory.

On four occasions, December 10, December 17, January 1 and February 16, the Greenwich Time-Ball was not raised on account of the violence of the wind. On November 26, owing to failure in the action of the clips, the ball did not drop at 13^h. It was dropped correctly at 14^h.

The Time-ball at Deal, which is released by the 13^h signal from Greenwich, failed to drop accurately on six occasions, and could not be raised on three days owing to wind.

The performance of the time-balls at the Admiralty Signal Stations and of the Westminster Clock is shown by the following table of the errors of the return-signals received at Greenwich :—

Error of Return Signal.							Portsmouth.	Portland.	Devonport.	Westminster.
Not greater than	$0^s\cdot2$	-	-	-	-	-	280	235	266	40
Between	$0^s\cdot2$ and $0^s\cdot5$	-	-	-	-	-	14	12	16	53
„	$0^s\cdot5$ „ $1^s\cdot0$	-	-	-	-	-	3	1	1	66
Greater than	$1^s\cdot0$	-	-	-	-	-	0	0	0	91

On the 250 days of observation the error of the Westminster Clock never exceeded $3^s\cdot0$. The clocks at Portsmouth, Portland and Devonport are corrected daily by the 10^h signal; the Westminster Clock is not corrected daily.

IX.—Personal Establishment :—

The permanent staff at the present time is constituted as follows :—

Chief Assistants.—Mr. Jackson, Mr. Jones.

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

Clerical Assistant.—Mr. Outhwaite.

Junior Assistants (Higher Grade).—Mr. Bowyer, Mr. Davidson.

Junior Assistants.—Mr. Acton, Mr. Burkett, Mr. Cullen, Mr. Edney, Mr. Furner, Mr. Jeffries, Mr. Melotte, Mr. Newton, Mr. Stevens, Mr. Witchell.

Mr. Jones has been lent from January 3 to the Optical Branch of the Inspection Department of the Woolwich Arsenal. Mr. Edney has been lent to the Hydrographic Department, Admiralty, from 1915 June 21; and Mr. Witchell from 1915 September to 1916 April 17.

Mr. and Mrs. Maunder since January 1916 have given voluntary assistance in the Solar Department. Mr. Maunder was temporarily reinstated in his former post on April 1.

Mr. Burkett holds a Commission in the London Yeomanry and has been absent from the commencement of the war.

Of the 26 Computers who were employed at the commencement of the war, 17 volunteered for military service. Their places are being kept open, and they are receiving their salaries less military pay. It is with great regret that I have to report the death of one of the above, Mr. Kilby, after an operation at Salonika. At the present time 8 boys are employed at the Observatory as Computers.

M. Jonckheere, Director of the Lille Observatory, has been at the Observatory throughout the year engaged on observations of double stars, and on the compilation of a catalogue of double stars which is being published by the Royal Astronomical Society.

In the course of the year, six Belgian refugees have been employed at the Observatory. Four of these have now left, and two, both wounded soldiers, are still here.

The staff of workmen now employed at the Observatory consists of a foreman of works with a joiner and a labourer, a foreman mechanic with a boy assistant, a gate-

porter, a messenger, a night-watchman, a gardener, a labourer, and two charwomen. One joiner and two labourers are absent on naval service. Their places are being kept open and they are receiving their wages less military pay. The assistant mechanic has left temporarily and is now employed at Woolwich Arsenal. The gate-porter, night-watchman and one messenger are naval reservists, and their places are temporarily filled.

X.—General Remarks :—

The scientific work of the Observatory has necessarily been somewhat curtailed, but it has been found possible to keep up all observations of the Sun, Moon, and planets; sun-spots; latitude; magnetic and meteorological registers; observations which would otherwise be permanently lost. The reductions are in some cases behindhand and must be brought up to date later.

Both the scientific staff of the Observatory and the workmen have made every effort to cope with the additional work caused by the absence of their normal assistance. Thanks to their efforts the diminution of the output of the Observatory is not so great as might have been anticipated.

F. W. DYSON.

Royal Observatory, Greenwich,
1916 May 23.