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March 3, 1870.

Lieut.-General Sir EDWARD SABINE, K.C.B., President, in the Chair.

In accordance with the Statutes, the names of the Candidates for election into the Society were read as follows:—

William Baker, C.E.
Edward Middleton Barry, R.A.
Rev. Francis Bashforth, B.D.
Bernard Edw. Brodhurst, F.R.C.S.
Samuel Brown, P.I.A.
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George Charles Wallich, M.D.
A. T. Houghton Waters, M.D.
Samuel Wilks, M.D.
Capt. Charles William Wilson, R.E.
John Wood, F.R.C.S.

The following communications were read:—

I. "Results of the Monthly Observations of Dip and Horizontal Force made at the Kew Observatory, from April 1863 to March 1869 inclusive." By BALFOUR STEWART, F.R.S., Superintendent of the Observatory. Received January 26, 1870.

1. In a communication made to this Society by the President, Sir E. Sabine, and published in the Philosophical Transactions for 1863, page 273, we have the results of the monthly observations of Dip and Hori-

zontal Force made at Kew for the six years ending March 1863. In the present communication it is proposed to reduce in a similar manner the results of the following six years.

The mode of observation has already been so fully described by Sir E. Sabine that no further account of it is necessary; suffice it to say that in October 1863 Mr. Chambers left the Observatory for India, and that Mr. George Whipple took his place as Magnetical Assistant. Mr. Whipple has since continued to observe every month with the utmost care and assiduity, employing the same instruments that were used by his predecessor, and the same methods of observation and reduction. A smaller number of observations by other instruments and other observers have likewise been made, but it has been thought desirable to limit this discussion to the series made by the regular observer. I ought likewise to state that both the dip-circle and unifilar stood in need of slight repairs, and that they were put into the hands of opticians for this purpose; the first observation with the repaired dip-circle being that of January 1869, and with the repaired unifilar that of December 1868.

I. Dip.

2. In Table I. we have a record of the observed values of dip made with circle No. 33 by Barrow, each observation being the mean of two made with the two needles belonging to that circle.

Table I.—Observed values of the Magnetic Dip at Kew.

	1863.	1864.	1865.	1866.	1867.	1868.	Mean of 6 years.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′
April	68 15·1	68 9·4	68 7·7	68 5·8	68 3·8	68 3·4	68 7·53
May	11·0	8·7	6·6	5·9	2·9	1·1	6·03
June	10·1	10·1	9·8	4·8	2·3	1·1	6·37
July	10·8	10·8	10·0	4·9	2·6	1·8	6·82
August	14·6	9·6	9·4	4·0	1·8	1·9	6·88
September	68 13·2	68 10·0	68 10·1	68 7·0	68 0·2	68 3·4	68 7·32
	68 12·47	68 9·77	68 8·93	68 5·40	68 2·27	68 2·12	68 6·83

	1863–64.	1864–65.	1865–66.	1866–67.	1867–68.	1868–69.	Mean of 6 years.
	° ′	° ′	° ′	° ′	° ′	° ′	° ′
October	68 11·8	68 11·0	68 9·9	68 6·5	68 2·8	68 5·6	68 7·93
November	11·8	8·5	8·9	7·8	5·6	67 59·9	7·08
December	11·2	9·6	7·5	4·2	2·9	[68 0·8]	6·03
January	10·3	9·5	7·4	6·5	3·1	68 1·8	6·43
February	10·7	7·1	7·7	4·1	2·7	2·8	5·85
March	68 9·9	68 7·4	68 7·0	68 3·8	68 0·7	68 2·0	68 5·14
	68 10·95	68 8·85	68 8·07	68 5·48	68 2·97	68 2·15	68 6·41
	68 11·71	68 9·31	68 8·50	68 5·44	68 2·62	68 2·13	68 6·62

The number within brackets is interpolated.

3. The absolute values of the dip corresponding to the beginning of October in each of the years comprehended in the above Table and the secular change in each year are as follows:—

From April 1863 to March 1864	68° 11′·71		
" " 1864 " " 1865	68 9·31	secular change	−2′·40
" " 1865 " " 1866	68 8·50	" "	−0·81
" " 1866 " " 1867	68 5·44	" "	−3·06
" " 1867 " " 1868	68 2·62	" "	−2·82
" " 1868 " " 1869	68 2·13	" "	−0·49
Mean of the six years corresponding to middle epoch, April 1, 1866	68 6·62	with a mean annual secular decrease of 1′·92.	

4. The annual variation or semiannual inequality may be shown to be as follows:—

TABLE II.

Date.	Corrections for secular change.	68° 6′·62 ± secular change.	Observed values.	Observed *minus* calculated. April to Sept.	Observed *minus* calculated. October to March.
July 1, 1863 ...	+5′·28	68° 11′·90	68° 12′·47	+0′·57	′
Jan. 1, 1864 ...	+4·32	10·94	10·95	......	+0·01
July 1, 1864 ...	+3·36	9·98	9·77	−0·21	
Jan. 1, 1865 ...	+2·40	9·02	8·85	......	−0·17
July 1, 1865 ...	+1·44	8·06	8·93	+0·87	
Jan. 1, 1866 ...	+0·48	7·10	8·07	......	+0·97
July 1, 1866 ...	−0·48	6·14	5·40	−0·74	
Jan. 1, 1867 ...	−1·44	5·18	5·48	......	+0·30
July 1, 1867 ...	−2·40	4·22	2·27	−1·95	
Jan. 1, 1868 ...	−3·36	3·26	2·97	......	−0·27
July 1, 1868 ...	−4·32	2·30	2·12	−0·18	
Jan. 1, 1869 ...	−5·28	68 1·34	68 2·15	......	+0·81
Mean differences between the observed and calculated values in the respective semiannual periods				−0·27	+0·27

5. We therefore deduce from these six years' observations the existence of a semiannual inequality, in virtue of which the dip is on an average 0′·27 lower in the six months from April to September, and 0′·27 higher in the six months from October to March than is due to its mean value.

This result is in the same direction as that found by Sir E. Sabine for the six years ending March 1863, but is less in amount than the latter, that determined from the first six years exhibiting a range of 1′·31, while that determined from the last six years only exhibits a range of 0′·54.

6. As already mentioned, the observations for the first six years were

nearly all made by Mr. Chambers, and those for the last six years nearly all by Mr. Whipple.

From the first six years we deduce a mean dip equal to 68° 20′·07, corresponding to middle epoch April 1, 1860, and from the latter six, a mean dip equal to 68° 6′·62, corresponding to middle epoch April 1, 1866, while the secular change deduced from the first series is 2′·00, and that deduced from the last series 1′·92, the mean of these two values being 1′·96.

If we apply this mean value of the secular change to the mean result corresponding to the epoch April 1, 1860, in order to bring it to the epoch April 1, 1866, we obtain

$$68^\circ\ 20'{\cdot}07 - 11'{\cdot}76 = 68^\circ\ 8'{\cdot}31,$$

whereas that deduced from the second series corresponding to this epoch is 68° 6′·62.

The former of these is 1′·69 higher than the latter, and it may be desirable to investigate the cause of this difference.

7. In the first place, it cannot I think be due to any personal equation in the observer. Of late I have made occasional observations with the circles and needles used by Mr. Whipple, with the view of determining whether there is any personal peculiarity in the dip observations of either of us.

The mean of 12 such dips taken by me is .... 68° 3′·95
while the mean of 12 comparable dips taken by Mr. Whipple is 68° 3′·85
showing a difference of not more than 0′·1, which small difference may probably be occasioned by accidental disturbance rather than by personal peculiarity.

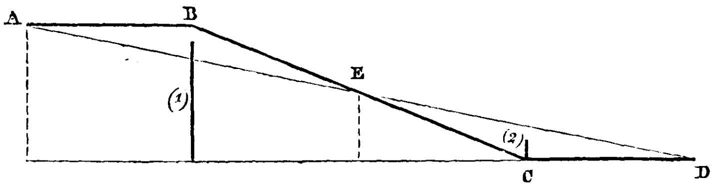
During the time when Mr. Chambers was at Kew no comparative observations were made with this particular object in view, and I cannot find a sufficient number of strictly comparable dips to determine with certainty what was the mean difference, if any, between his readings and mine. The result would, however, seem to indicate that his reading is rather lower than mine, certainly not more than half a minute, but probably much less.

There is therefore no reason for supposing that Mr. Whipple reads the dip to an appreciable amount lower than Mr. Chambers, so that the difference of 1′·69 cannot be accounted for by this supposition.

8. Sir E. Sabine has remarked as follows (rPoceedings of the Royal Society, Nov. 30, 1865, p. 491):—“The general effect of the disturbances of the inclination at Toronto is to increase what would otherwise be the amount of that element; therefore if the disturbances have a decennial period, the absolute values of the inclination (if observed with sufficient delicacy) ought to show in their annual means a corresponding decennial variation, of which the minimum should coincide with the year of minimum disturbance, and the maximum with the year of maximum disturbance.” At Toronto, where the true secular change is very small, the effect of this

superimposed variation is very visible, so that the yearly values of the inclination appear to increase up to the period of maximum disturbance and to decrease after it. At Kew, the general effect of disturbances is probably the same as at Toronto, that is to say, tending to increase the inclination; but the secular change being considerable, and tending to decrease the inclination, the joint effect of the secular change and the superimposed variation might be expected to appear in a diminution of the yearly secular change for those years during which the disturbances are increasing from their minimum to their maximum value, and in an increase of the yearly secular change for those years during which the disturbances are decreasing from their maximum to their minimum.

The law of diminution of the dip at Kew due to the conjoint action of these two causes, may thus be graphically represented in the following exaggerated curve—



where B represents the epoch of maximum, and C that of minimum disturbance.

Also, we may regard A B E as denoting the first six years' results, and E C D those of the second six years, the epoch of maximum approximately falling about the middle of the first six years' observations, and the epoch of minimum about the middle of the second.

Now the slope of the line A E D represents the average secular change, also (1) represents the mean of dips deduced from the first series of six years, and (2) the mean of those deduced from the second series, (1) being above the line of average dip, and (2) being below it. From this it is evident that, in order to bring (1) to the same epoch as (2), we should have to apply to (1) a greater than the average secular change. But before this reasoning can be used to account for the difference of 1'·69, we must examine whether, as a matter of fact, in the Kew observations the secular change is less than the mean during periods of increasing disturbance, and greater than the mean when the disturbances are decreasing.

9. Taking the two series of six years as comprising the most regular and reliable observations made at Kew, and deducting the mean dip for 1857, in the Table prepared by Sir E. Sabine, from that for 1868 in Table I. of this paper, we find a mean secular change of 2'·07.

On the other hand, the actual yearly changes and their differences from the mean are as follows :—

TABLE III.

Date.	Observed secular change.	Observed *minus* average secular change.
	′	′
1857–58	2·31	+0·24
1858–59	1·15	−0·92
1859–60	2·12	+0·05
1860–61	1·87	−0·20
1861–62	2·53	+0·46
1862–63	3·18	+1·11
1863–64	2·40	+0·33
1864–65	0·81	−1·26
1865–66	3·06	+0·99
1866–67	2·82	+0·75
1867–68	0·49	−1·58

If we take the first three and the last two of the above differences as belonging to the years when the disturbances were increasing, we find a secular change less than the average by a mean of 0′·29; and if we take the remaining six differences as belonging to the years when the disturbances were decreasing, we find a secular change greater than the average by a mean of 0′·24.

It would therefore appear that the Kew observations present a peculiarity similar to those at Toronto, so that the difference of 1′·69 between the two sets of observations may probably be accounted for by this cause.

10. We may, in fact, exhibit the peculiarities of the graphical representation given above by means of the actual results. Thus, if we take the first year's dip (1857), or 68° 24′·87, and deduct from it every year 2′·07 (which is the average secular change), we shall obtain a series of yearly values representing the yearly positions of the line A E D; and if the diagram truly represents the facts, the observed yearly values ought to range above the line for the first six years, and under it for the second six.

We may see by the following Table that this is actually the case:—

TABLE IV.

Observed yearly values (1).	Yearly values of A E D (2).	(1)–(2).
° ′	° ′	′
68 24·87	68 24·87	0
22·56	22·80	−0·24
21·41	20·73	+0·68
19·29	18·66	+0·63
17·42	16·59	+0·83
14·89	14·52	+0·37
11·71	12·45	−0·74
9·31	10·38	−1·07
8·50	8·31	+0·19
5·44	6·24	−0·80
2·62	4·17	−1·55
68 2·13	68 2·13	0

On the whole, therefore, we have good evidence of a behaviour at Kew analogous to that at Toronto.

11. The probable error of a single monthly determination of the dip, derived from the seventy-two monthly determinations given in Table I., and after the application of the correction for secular change and annual variation, as derived from the results of these observations, has been made, is $\pm 0'{\cdot}96$. There is, however, reason to believe that this probable error is increased to some extent by periods of disturbance, some of them of cons derable duration, which exhibit themselves when the residual errors have been deduced after the method indicated above. In order to test this, I have formed a series of seventy-two yearly values of the dip corresponding in epoch to the various monthly values of Table I.

These yearly values will, of course, average the semiannual inequality, while each yearly value may possibly be supposed to be affected to some extent with the same sort of disturbance which affects the monthly value to which it corresponds. Were both affected in precisely the same way by these disturbances, the differences between the monthly and yearly values would only be occasioned by the semiannual inequality and by errors of observation. It is, however, too much to expect that all effects of disturbance will be eliminated from the differences by this method; nevertheless we may naturally expect that they will be reduced in amount.

12. Grouping these differences together in six monthly periods, we obtain the following results corresponding to those given in Table II:—

Table V.

Date.	Observed *minus* Calculated.	
	April to September.	October to March.
July 1, 1863	−0·20	
January 1, 1864	....	−0·05
July 1, 1864	−0·13	
January 1, 1865	....	−0·15
July 1, 1865	+0·26	
January 1, 1866	....	+0·32
July 1, 1866	−0·71	
January 1, 1867	....	+0·68
July 1, 1867	−0·95	
January 1, 1868	....	+0·55
July 1, 1868	−0·14	
January 1, 1869	....	+0·30
Mean	−0·31	+0·28

It will be seen from this Table that the irregularities of the two last columns of Table II. are very much reduced by this process, while the result remains nearly the same.

The probable error of a single observation is also reduced, and becomes (when the correction for annual variation is applied to the individual differences determined by this process) ±0′·87, instead of ±0′·96, which it was before.

II. Horizontal Force.

13. In Table VI. we have a record of the observed values of horizontal force made with the Kew unifilar by Mr. Whipple, each observation being made and reduced precisely after the manner of those described by Sir E. Sabine in his analysis of the first six yearly series.

Table VI.

Monthly values of the Horizontal Component of the Earth's Magnetic Force at Kew, calculated from the results of observations of deflection and vibration with Collimator Magnet K.C.I.

	1863.	1864.	1865.	1866.	1867.	1868.	Mean of 6 years.
April	3·8201	3·8240	3·8277	3·8338	3·8449	3·8464	3·8328
May	3·8199	3·8260	3·8251	3·8373	3·8459	3·8504	3·8341
June	3·8198	3·8246	3·8258	3·8383	3·8469	3·8495	3·8341
July	3·8260	3·8331	3·8330	3·8410	3·8427	3·8414	3·8362
August	3·8243	3·8264	3·8246	3·8384	3·8445	3·8511	3·8349
September	3·8205	3·8314	3·8298	3·8386	3·8467	3·8475	3·8358
	3·8218	3·8276	3·8277	3·8379	3·8453	3·8477	3·8346
	1863–64.	**1864–65.**	**1865–66.**	**1866–67.**	**1867–68.**	**1868–69.**	**Mean of 6 years.**
October	3·8142	3·8274	3·8271	3·8354	3·8446	3·8470	3·8326
November	3·8214	3·8243	3·8325	3·8410	3·8494	3·8503	3·8365
December	3·8218	3·8293	3·8360	3·8396	3·8475	3·8539	3·8380
January	3·8239	3·8276	3·8364	3·8443	3·8511	[3·8521]	3·8392
February	3·8242	3·8353	3·8335	3·8405	3·8492	3·8504	3·8388
March	3·8229	3·8319	3·8357	3·8403	3·8469	3·8521	3·8383
	3·8214	3·8293	3·8335	3·8402	3·8481	3·8510	3·8372
	3·8216	3·8284	3·8306	3·8391	3·8467	3·8493	3·8360

The value within brackets is interpolated.

14. The absolute values of the horizontal force corresponding to the beginning of October in each of the years comprehended in the above Table, and the secular change in each year are as follows:—

From April 1863 to March 1864	3·8216	
		secular change +0·0068
„ „ 1864 „ „ 1865	3·8284	
		„ „ +0·0022
„ „ 1865 „ „ 1866	3·8306	
		„ „ +0·0085
„ „ 1866 „ „ 1867	3·8391	
		„ „ +0·0076
„ „ 1867 „ „ 1868	3·8467	
		„ „ +0·0026
„ „ 1868 „ „ 1869	3·8493	
Mean of the six years corresponding to middle epoch, April 1, 1866	3·8360	With a mean annual secular increase of 0·00 55.

15. Forming now the following Table similar to Table II., we fail to detect in it any trace of semiannual inequality.

Table VII.

Date.	Correction for secular change.	3·8360 ± secular change.	Observed values.	Observed *minus* Calculated.	
				April to September.	October to March.
July 1, 1863	−0·0152	3·8208	3·8218	+·0010	
January 1, 1864 ..	−0·0125	3·8235	3·8214	....	−·0021
July 1, 1864	−0·0097	3·8263	3·8276	+·0013	
January 1, 1865 ..	−0·0070	3·8290	3·8293	....	+·0003
July 1, 1865	−0·0042	3·8318	3·8277	−·0041	
January 1, 1866 ..	−0·0014	3·8346	3·8335	....	−·0011
July 1, 1866	+0·0014	3·8374	3·8379	+·0005	
January 1, 1867 ..	+0·0042	3·8402	3·8402	....	·0000
July 1, 1867	+0·0070	3·8430	3·8453	+·0023	
January 1, 1868 ..	+0·0097	3·8457	3·8481	....	+·0024
July 1, 1868	+0·0125	3·8485	3·8477	−·0008	
January 1, 1869 ..	+0·0152	3·8512	3·8510	....	−·0002
Mean difference between the observed and calculated values in the respective semiannual periods				+·0000	−·0001

16. Again, from the first six years we have a mean value of the horizontal force equal to 3·8034, corresponding to the middle epoch April 1, 1860, and from the latter six years' observations given above, we have, as has been shown, a mean value of horizontal force equal to 3·8360, corresponding to epoch April 1, 1866; also the secular change deduced from the first six years is +·0053, while that deduced for the second six is +·0055, the mean of the two being +·0054.

If we apply this mean value of the secular change to the mean result corresponding to epoch April 1, 1860 in order to bring it to epoch April 1, 1866, we obtain 3·8034+0·0324=3·8358, a value which agrees as nearly as possible with that deduced from the second series, and corresponding to the same epoch which, as we have seen above, was 3·8360.

17. The coincidence of these two values naturally leads us to imagine that the secular change of the horizontal force does not present the same peculiarity as that observed in the case of the dip, and exhibited in the diagram.

In order to test this, let us form for the horizontal force the following Table, similar to Table III.

Table VIII.

Date.	Observed secular change.	Observed *minus* average secular change.
1857-58	·0051	−·0003
1858-59	·0057	+·0003
1859-60	·0056	+·0002
1860-61	·0058	+·0004
1861-62	·0044	−·0010
1862-63	·0051	−·0003
1863-64	·0068	+·0014
1864-65	·0022	−·0032
1865-66	·0085	+·0031
1866-67	·0076	+·0022
1867-68	·0026	−·0028

If we take the first three and the last two of the above differences as belonging to years, when the disturbances are increasing, we find a secular change only less than the average by a mean of ·00008; and if we take the remaining six differences as belonging to years when disturbances are decreasing, we find a secular change greater than the average by a mean of ·00007; both being differences which form such an extremely small proportion of the whole change that they may be neglected.

18. Or again, if we take the first year's horizontal force (1857) or 3·7899, and add to it every year ·0054, which is the average secular change, we shall, as before, obtain a series of values representing the yearly positions of the line A E D in the diagram, from which we may construct the following Table similar to Table IV.

Table IX.

Observed yearly values.	Yearly values of A E D.	
(1)	(2)	(1)−(2)
3·7899	3·7899	0·0000
3·7950	3·7953	−0·0003
3·8007	3·8007	0·0000
3·8063	3·8061	+0·0002
3·8121	3·8115	+0·0006
3·8165	3·8169	−0·0004
3·8216	3·8223	−0·0007
3·8284	3·8277	+0·0007
3·8306	3·8331	−0·0025
3·8391	3·8385	+0·0006
3·8467	3·8439	+0.0028
3·8493	3·8493	0·0000

From this Table we fail to perceive a trace of the behaviour exhibited by the dip in Table IV.

Apart, therefore, from all theoretical considerations, we have reason to believe that, as a matter of fact, the behaviour exhibited in the diagram holds for the dip, but does not appreciably manifest itself in the case of the horizontal force.

19. The probable error of a single monthly determination of the horizontal force derived from the seventy-two monthly determinations given in Table VI., and after the application of the correction for secular change has been applied, is ±0·0021. There is, however, reason to believe that, as in the case of the dip, the probable error is increased to some extent by periods of disturbance, and the same method may be applied to test this as was applied to the dip observations. Forming, therefore, a series of seventy-two yearly values of the horizontal force, corresponding severally in epoch to the seventy-two monthly values of Table VI., and deducting each from the corresponding observed monthly value, we obtain, as before, a series of seventy-two differences; and we derive from these the following modifications of the last two columns of Table VII.

Table X.

Date.	Observed *minus* Calculated.	
	April to September.	October to March.
July 1, 1863	+·0016	
January 1, 1864	....	−·0014
July 1, 1864	+·0012	
January 1, 1865	....	+·0006
July 1, 1865	−·0019	
January 1, 1866	....	+·0006
July 1, 1866	+·0004	
January 1, 1867	....	−·0009
July 1, 1867	+·0005	
January 1, 1868	....	+·0008
July 1, 1868	−·0008	
January 1, 1869	....	+·0008
Mean	+0·0002	+0·0001

Thus we see, as in the case of the dip, that the irregularity of the numbers in these columns is much diminished, the result being, however, left the same as before. Finally, if we deduce the probable error of a single observation by means of the series of differences so obtained, we find this to be ±0·0018 instead of ±0·0021, which it was before.

III. Total Force.

20. We find in Table VI. that the mean of the April to September values of the horizontal component of the force in the last six years is 3·8346, corresponding in epoch to January 1, 1866; and in Table I. that the mean of the April to September values of the dip in the same six years is 68° 6′·83.

We find also that the mean of the October to March values are for the horizontal force 3·8372, and for the dip 68° 6′·41, corresponding to epoch July 1, 1866.

We may reduce these to a common epoch by applying to the former dip the correction $-0'{\cdot}96$, this being the proportional secular change (as shown by these six years) necessary to reduce the former epoch to the latter. The former dip will therefore become $68^\circ\ 6'{\cdot}83 - 0'{\cdot}96 = 68^\circ\ 5'{\cdot}87$.

Reducing in the same way the horizontal force, we have

$$3{\cdot}8346 + 0{\cdot}00275 = 3{\cdot}83735.$$

The values thus become as follows:

	Hor. force.	Dip.
From the April to September observations (reduced to epoch July 1, 1866)......	3·83735	68° 5'·87
And from the October to March observations (corresponding to the same epoch)	3·83720	68° 6'·41

The total force derived from the first series will therefore be 10·28717, and that derived from the second series 10·29080, showing thus a difference of 0·00363 in British units as the measure of the greater intensity of the terrestrial magnetic force in the October to March period, than in the April to September period. This is in the same direction, and very nearly of the same amount, as that determined by Sir E. Sabine from the first six years, which exhibited a similar difference of 0·00317 in British units.

Thus we find that the two series agree in showing nearly the same semiannual variation for the total force, while the first period exhibits the greatest semiannual variation of the dip. It ought, however, to be borne in mind that the two series bear a different relation to the disturbance period, the maximum of disturbances occurring about the middle of the first series, and the minimum near the middle of the second.

II. "Spectroscopic Observations of the Nebula of Orion, and of Jupiter, made with the Great Melbourne Telescope." By A. Le Sueur. Communicated by the Rev. T. R. Robinson, D.D. Received January 27, 1870.

In one particular the spectroscopic observations of the nebula of Orion are not void of interest; they show distinctly that considerable nebulosity exists *within* and about the trapezium. The image at the slit is sufficiently large to well separate the stars of the trapezium, so that when two of these are, as it were, threaded on the slit, a clear space lies between them; this in the spectroscope gives the well-known lines with little, if at all, less brilliancy than the general bright nebula.

The small comparison-mirror being removed, the available slit is ·4 inch high, equivalent in the case of the Cassegrain image to about 43″ arc; with an image condensed about three times (which is the usual arrangement and still allows sufficient separation), the slit may, therefore, be made to considerably overlap the trapezium contour, and thereby, at the same time as the trapezium, light from the brightest part of the nebula is under inspection; it is curious to see that the spectral lines run with almost continuous brightness throughout the height of the slit.