Kodaikanal Observatory.

BULLETIN No. XXVIII.

ON THE RELATIVE NUMBERS OF PROMINENCES OBSERVED ON THE EASTERN AND WESTERN LIMBS.

THE brief discussion of some prominence observations given by Mrs. Maunder near the close of her well-known paper "An apparent Influence of the Earth on the Numbers and Areas of Sun Spots"* suggested to me the desirability of examining the very full material supplied by the visual and photographic records of the Kodaikanal Observatory during the years 1904—1912, supplemented by visual records made at Kenley during the period 1894—1905 inclusive.

In the ordinary course of tabulation of the Kodaikanal observations it has not hitherto been the practice to separate east from west either in respect of numbers or areas. In order to study the distribution east and west it has in consequence been necessary to go over the whole material day by day and year by year counting up the numbers entered east or west of the sun's axis and checking the totals against the totals given in the annual summaries published in the Observatory bulletins.

The results of this count are given in Table I.

TABLE I.

Numbers of prominences observed east and west of the sun's axis.

Year.	East.	West.	E.—W.	Percentage of east prominences.
1904	1362	1358	+ 4	50·07
1905	2492	2258	+ 234	52·46
1906	2578	2263	+ 315	53·25
1907	3061	2756	+ 304	52·61
1908	3277	2971	+ 303	52·43
1909	3389	3049	+ 340	52·64
1910	3645	3116	+ 529	53·92
1911	3180	2824	+ 356	53·00
1912 (half year)	1669	1528	+ 141	52·20
Total and mean percentage ...	24653	22126	+ 2527	52·70

Excepting the year 1904 this table exhibits a remarkable and unexpectedly constant preponderance of eastern prominences, which average 52·70 per cent. of the whole number recorded. The excess shows also with a greater uniformity than might have been expected when individual months are taken. Thus out of the 102 months examined 88 yield an excess of eastern prominences and 14 only show either equality or an excess of western prominences.

* Monthly Notices, Royal Astronomical Society. LXVII, 451.

The eastern preponderance is not therefore of an accidental nature since it holds month by month and year by year. It is however necessary before accepting it as a fact to enquire very carefully into the methods of observation in order to make certain that the results are in no way affected by any kind of systematic bias in favour of the eastern limb, either in observing the prominences in the spectroscope or in photographing them.

The instrument employed for the visual work is a 3-prism "Evershed" spectroscope attached to a 6-inch equatorial refractor. It is mounted with the collimator axis parallel to, but not coincident with, the axis of the 6-inch lens, the distance between the two axes equalling approximately the semi-diameter of the sun's image. This facilitates the rapid survey of the entire limb, because the spectroscope slit remains tangent to the limb at all position angles on rotating the instrument. The eccentric position has the drawback however that it allows photospheric light which is scattered by one edge of the object glass to enter the slit together with the diffuse light of the sky, and this tends to increase the luminosity of the background on which the prominences are seen. It is quite possible that more of this scattered light may enter the slit in one position of the spectroscope and less in the opposite position, and considering the ease with which faint prominences are rendered invisible by increasing the intensity of the background, systematic bias in favour of one limb might be produced in this way.

Another source of uncertainty is connected with the fact that the great majority of the observations are made during the morning hours with the telescope west of the pier. In this position the eastern limb is easier to observe than the western merely on account of the more convenient angle which the observing telescope makes with the horizontal.

A test of the actual working of the spectroscope has failed to show any obvious change in the intensity of the spectrum background on which the prominences are seen, when the instrument is rotated. It is however impossible to say how far the different observers may have been influenced by the inconvenient angle involved in observing the west limb.

With regard to the photographic records, the instrument employed is the Cambridge spectroheliograph, and photographs have been obtained on nearly all the days which were clear enough for visual observations. The prominences are also sometimes recorded on days when, owing to thick cirrus cloud, visual work is impossible. The photographs are obtained in the "K" line of calcium, whilst the visual observations are made in the hydrogen line α. No material differences have however ever been found between the drawings and photographs when the records have been obtained simultaneously. Hydrogen prominences without calcium, or calcium prominences without hydrogen, have never been certainly recorded at Kodaikanal. The photographs usually show a greater extension of the fainter details and intricate structure of the prominences, owing no doubt to the better contrast obtained with the narrow slit of the spectroheliograph compared with the widely opened slit used in the visual observations.

I have carefully considered all the conditions in working the spectroheliograph but have entirely failed to discover any reason for a systematic bias in favour of the east limb, and an examination of the plates themselves dispels any doubts on the point. The prominence images are always shown with equal distinctness in all parts of the limb when the sky is uniform.

The photographic records began early in the year 1905 and during the first three years photographs were obtained on about 80 per cent. of the days when visual observations were made. During the later years, 1908—1912 inclusive, photographs have been secured on practically all the days when visual observations were made, and on some additional days when the condition of the sky was unfavourable for visual work the prominences have shown faintly on the disc photographs.

The position angles and heights of all prominences shown on either the disc or limb photographs have been measured and tabulated together with the visual observations, so that the numeration includes everything that has been recorded visually or photographically.

If the visual observations have been subject to systematic bias in favour of the east limb the photographs must have made good all those prominences which were missed by the observers on the west limb, and

I can only conclude that the figures are to be relied on as indicating a real preponderance in numbers of eastern over western prominences.

The preponderance of the eastern prominences is also shown by comparing east and west in two other independent series of observations. During the twelve years 1894—1905 inclusive, I observed the prominences systematically at my private observatory at Kenley, and the results of separating east from west are given in the following table :—

TABLE II.

Year.	East.	West.	E.—W
1894	551	561	— 10
1895	487	487	0
1896	268	264	+ 4
1897	444	401	+ 43
1898	304	303	+ 1
1899	352	344	+ 8
1900	158	147	+ 11
1901	240	251	— 11
1902	258	223	+ 35
1903	355	309	+ 46
1904	653	623	+ 30
1905	438	461	— 23
Total . .	4508	4374	+ 134

Percentage east 50·75.

The observations of Signori Mascari and Riccò at Catania for the same years yield according to Mrs. Maunder's summary .—

East.	West	E.–W
3480	3365	+115

Percentage east 50·84

These two series of observations are in good agreement in showing a small average excess of eastern prominences during the twelve years ending with 1905. I attach no significance to the variations from year to year, because the annual numbers are too small to give reliable averages.

The much smaller eastern excess shown by these figures as compared with the Kodaikanal series suggested the possibility that the average size of the prominences recorded may affect the result. At Kodaikanal all prominences exceeding 10″ in height are recorded, whilst at Catania prominences under 30″ in height are not recorded. At Kenley no limiting size was adopted, but, owing to the use of small instruments, prominences between 10″ and 20″ would often pass unnoticed unless exceptionally bright. The effect of including the smaller prominences on the mean daily numbers observed is shown in the following comparison for the year 1905 .—

	Mean daily numbers of prominences recorded at—		
Year.	Kodaikanal.	Kenley.	Catania.
1905	14·9	9·4	3·0

The large proportion of small prominences recorded at Kodaikanal would affect the eastern excess if we assume with Mrs. Maunder that the earth tends to extinguish a prominence during its transit across the visible disc. For it is evident that where mere numbers are concerned the larger prominences might be expected to show a smaller eastern excess than the smaller prominences, because the latter would much more readily succumb altogether to the extinguishing influence, whilst the former would merely diminish in size.

In order to obtain further evidence on the point I have tabulated independently from the Kodaikanal results all the larger prominences observed during seven years, defining a "large" prominence as one which extends for 2° or more on the solar limb and a "small" prominence one in which the base is less than 2° in extent. The results of this rough classification are set out in Table III

TABLE III.

Large prominences.

Year	East	West.	E.—W.
1905	884	746	+ 138
1906	646	642	+ 4
1907	922	921	+ 1
1908	925	892	+ 33
1909	976	921	+ 55
1910	888	847	+ 41
1911	631	637	− 6
Total	5872	5606	+ 266

Percentage east 51·16.

Small prominences.

Year.	East.	West	E.—W
1905	1608	1512	+ 96
1906	1932	1621	+ 311
1907	2138	1835	+ 303
1908	2352	2082	+ 270
1909	2413	2128	+ 285
1910	2757	2269	+ 488
1911	2549	2187	+ 362
Total	15749	13634	+ 2115

Percentage east 53·60.

The eastern excess is here found to be over three times greater for the small prominences than for the large, thus verifying the surmise that it is mainly the small prominences which are responsible for the very remarkable results shown in Table I.

To complete the comparison so far as is possible with other independent series of observations I have continued the tabulation of the Catania results as published in the Memorie della Società degli Spettroscopisti Italiani up to the end of 1911 as is shown in the following table :—

Year.	East.	West.	E.—W.
1906	229	240	− 11
1907	454	375	+ 79
1908	354	350	+ 4
1909	383	277	+ 106
1910	313	204	+ 109
1911	153	144	+ 9
Total	1886	1590	+ 296

Percentage east 54·26.

The comparatively large excess of eastern prominences here shown, which is greater than the average excess of the small prominences observed at Kodaikanal, is not in accordance with the foregoing conclusion as to small *versus* large prominences It appears to me however that this result is somewhat illusory owing to the small numbers involved The average is greatly affected by the very large excess shown for the years 1909 and 1910 which is certainly accidental The fact of the eastern excess is however a further verification of the main result of the Kodaikanal numeration.

Profile Areas of Prominences.

At Kodaikanal in addition to the tabulation of numbers, heights, and heliographic positions, the profile areas of the prominences are estimated, but, as in the case of the numbers, the eastern prominences have not until the year 1911 been separated from the western Having occasion however to redetermine the areas for 1905 for another purpose I can give the results for that year and for the twelve months ending July 1912 expressed in tenths of square minutes of arc they are as follows :—

	East	West	E.—W.	Percentage east.
1905	6874	6303	+ 571	52·16
1911 July to December 1912 January to June ...	3848	3958	− 110	49·55
Totals, and average percentage east.	10722	10261	+ 461	51·10

At Kenley an estimate was made of the magnitudes of the prominences, and, although the figures cannot be converted into square minutes of arc, they represent profile areas and are useful for comparison with the above. I give below the Kenley magnitudes for the twelve years 1894–1905 :—

Year.	East.	West.	E.—W.
1894	7193	7292	− 99
1895	5394	5405	− 11
1896	2039	2625	− 586
1897	4443	4032	+ 411
1898	3619	3998	− 379
1899	3086	2815	+ 271
1900	1466	1669	− 203
1901	2020	1987	+ 33
1902	2220	1866	+ 354
1903	3781	3066	+ 715
1904	6575	6265	+ 310
1905	3748	3747	+ 1
Total ...	45584	44767	+ 817

Percentage east 50·45.

From the foregoing results it appears that areas are much less subject to the law of eastern excess than numbers; also that much greater irregularities occur in the annual results, the excess being often in favour of the west limb. A small average excess of prominence area for the east limb is nevertheless indicated.

The effect of Heliographic Latitude on the eastern excess.

It occurred to me that the eastern excess might be in some way connected with the velocity of rotation of the sun. It might for instance be assumed that owing to frictional resistance by matter outside the sun and not partaking in the solar rotation, the "preceding" sides of the prominences facing in the direction of

rotation, might be hotter and brighter than the " following " sides; so that on the west limb we see the fainter back sides so to speak, and on the east limb the brighter front sides. This would in effect cause an apparent preponderance of numbers or areas at the east limb because many prominences otherwise so faint as to be at the limit of visibility would be seen at the east limb and not at the west.

This hypothesis has the recommendation that it obviates the necessity for assuming an influence due to the earth on masses of gas many times greater in volume than the earth itself. If there is any truth in it we should expect to find a marked diminution in the eastern excess on passing from the equatorial region where the rotation velocity is greatest, to the polar zones where it is least As it is essential in a case of this kind to deal with the largest possible numbers, I have divided the whole number of prominences observed in the five years 1907—1911 into two portions, viz., those observed in the equatorial regions up to latitude 30°·5, and those found in higher latitudes. This is equivalent to selecting prominences having velocities of rotation lying between 2 and 1·65 kilometers per second, and between 1·65 and 0 kilometers per second. The results are given below:—

	East.	West.	Percentage of eastern prominences.
Low latitudes—0° to 30°5	7355	6568	52·75
High latitudes—30° 5 to 90°	9196	8151	53·00

This result is uncompromisingly against the above hypothesis since it shows a greater eastern excess for the high latitude prominences than for those in low latitudes.

Influence of the Planets.

If the earth has a marked effect in changing the distribution of prominences on the sun, similar effects may be looked for in the case of the other planets. It appears very improbable that the insignificant tide-raising forces of the planets could be in any way effective: if such were the case Jupiter would have the greatest influence, the tidal force at the sun's surface due to this planet being 2¼ times that of the earth. The Venus tide is nearly as great, the force being about double that of the earth, whilst for Mercury it would be slightly less than that of the earth. The effects of the remaining planets would be negligible.

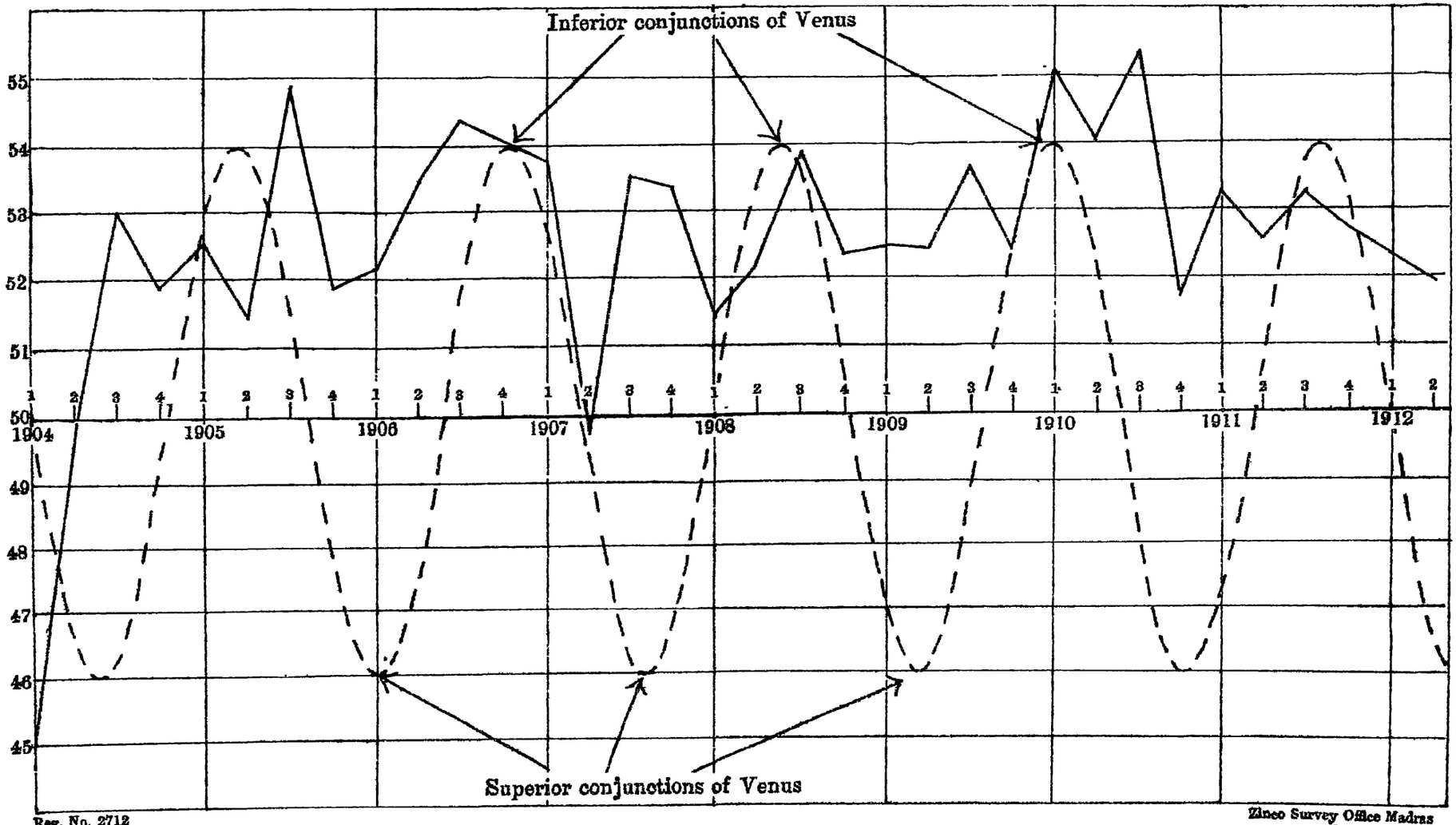
If the effect were proportional to mass and inversely proportional to the distance squared Jupiter would of course have a greatly preponderating influence nearly twelve times greater than that of the earth. The Jupiter effect would produce an alternate excess of prominences on the east and west limbs with a period of thirteen months, corresponding with his synodical period.

On plotting the percentages of eastern prominences over the whole period of 8½ years, taking quarterly averages, an irregular curve is obtained which is reproduced in the accompanying diagram. It is obvious from this that no alternation between east and west exists, and, excepting during the first quarter of 1904 and the second quarter of 1907, the excess has been continuously on the east side. Evidently mass is not an important factor, and the question remains as to whether any planet other than Jupiter affects the percentages.

In seeking to find evidence of planetary influence I assume that the greatest positive effect (that is *eastern* excess) would occur for the outer planets when at opposition; and the greatest negative effect when in conjunction with the sun; for the inner planets when at inferior and superior conjunctions respectively. At intermediate positions the cosine function of the angle at the sun between planet and earth, or the difference of heliocentric longitudes, might be taken to represent the effect. In the diagram the broken line represents the cosine curve for Venus, the only planet, excepting possibly Saturn, which appears to influence the prominence curve in the slightest degree. It will be seen that there is a distinct tendency for smaller values of the eastern excess when this planet is near superior conjunction with the sun and larger values when in inferior conjunction.

If the prominence numbers are summed up for all the periods when the difference of heliocentric longitude of Venus and the Earth was 30° or less, and also for the periods when it was between 150° and 180°; in

PERCENTAGE CURVE OF EASTERN PROMINENCES



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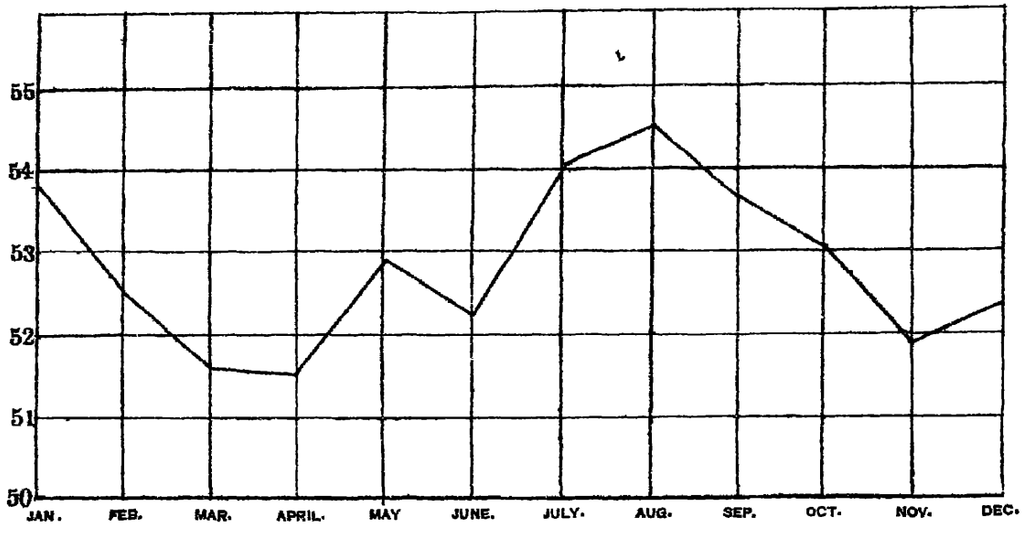
PERCENTAGE CURVE OF EASTERN PROMINENCES
AVERAGE OF 8½ YEARS 1904—1912.



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1913.

other words when Venus was near inferior and near superior conjunctions respectively, the following results are obtained :

	East.	West.	Percentage east.
Venus near inferior conjunctions	3914	3348	53·90
Venus near superior conjunctions	3980	3592	52·56

The difference in the percentages is small and perhaps of no real significance. It favours a slight action of Venus similar in effect to that of the earth.

In the case of Jupiter the prominence numbers near oppositions and near conjunctions, with the same limiting heliocentric angles, yield a negative result as follows :

	East.	West.	Percentage east.
Jupiter near oppositions	4112	3679	52·78
Jupiter near conjunctions with the sun ...	4069	3609	53·00

Here the eastern preponderance is slightly greater when the planet is on the opposite side of the sun to the earth than when it is on the same side as the earth, but the difference is too small to be considered significant.

For Mercury the synodical period of 116 days is too short for comparison with the quarterly prominence averages. There is no apparent connection between the prominence curve and the cosine curve for Mars.

As the numeration of prominences is a somewhat arbitrary proceeding and there must often be considerable uncertainty as to whether a prominence should be entered as one or several, I find it difficult to believe that the variations in the curve have much real significance ; still there seems no reason why the numeration should differ as between east and west even if the habit of the observer changes in course of time. Each point on the curve represents on the average a total of 725 eastern and 651 western prominences.

There is besides the Venus effect, an apparent coincidence between the points of maximum in the curve and the oppositions of Saturn. As this planet's synodical period is very little greater than a year this may be merely an indication of an annual periodicity. In order to show how the eastern excess varies throughout the year I have taken the average of all the percentage values obtained for each month of the year The accompanying diagram exhibits the rather striking annual variation which results. There are well marked maxima in January and August, and minima in April and November. Apparently the greatest eastern excess occurs when the earth is nearest to and furthest from the sun.

The prominence numbers for the months December and January have been added for the entire period of 8½ years and compared with those for the months June and July. The percentage of eastern prominences is found to be nearly the same and above the average for all the months, the figures are :

	East.	West.	Percentage east.
January and December (Perihelion)	4175	3661	53·28
June and July (Aphelion)	2578	2270	53·18

The smaller numbers observed near aphelion are probably due to the less favourable observing conditions during the monsoon months.

Summary.

(1) The Kodaikanal observations show that for the period 1904—1911 inclusive the eastern prominences numerically exceeded the western for each of the eight years, and that the proportion of the eastern excess was nearly constant over this period. The average percentage of eastern prominences including the first half of 1912 was 52·0.

(2) The observations at Kenley and at Catania during the period 1894—1905 inclusive show a numerical excess of eastern prominences, these averaged 50·8 per cent. of the whole number recorded. The Catania observations for the period 1904–1911 inclusive show a larger excess of eastern prominences which averaged 54·26 per cent. of the whole number.

(3) The larger prominences recorded at Kodaikanal during the seven years 1905—1911 inclusive show a much smaller eastern excess than the smaller prominences, the percentage of eastern prominences being 51·16 for the former and 53·60 for the latter.

(4) The mean profile areas of prominences observed at Kenley during the period 1894—1905 inclusive, and at Kodaikanal for the years 1905 and 1911—1912 show a small average excess of eastern areas. The eastern excess is much smaller than for the numbers, and in several years the west limb area exceeds that of the east limb.

(5) It is shown that there is no appreciable difference as regards numerical eastern preponderance for prominences occurring in the equatorial regions up to latitude 30°·5 and those occurring in higher latitudes.

(6) There is slight evidence of planetary action similar in effect to that of the earth in the case of Venus only among the major planets.

(7) There appears to be an annual periodicity in the eastern preponderance with maxima in January and August and minima in April and November.

In conclusion I have pleasure in acknowledging the very effective assistance rendered by Mr. S. Sitarama Aiyar in the heavy work of numeration and tabulation of the results.

KODAIKANAL,
2nd October 1912.

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Director, Kodaikanal and Madras Observatories.

SUPPLEMENTARY NOTE.

(*a*) The "metallic" prominences observed during the whole period since 1904 show a much greater preponderance of east over west than is indicated in Table I which includes all classes of prominences.

In the nine years 1904—1912 inclusive 424 metallic prominences were recorded, and of these 254 or 59·9 per cent. were on the east limb.

As the great majority of these prominences were associated with sunspots it may be inferred that spot disturbances are more active on the east limb than on the west as regards eruptions of metallic vapours.

(*b*) Prominences showing displacements of the hydrogen lines also show a much greater eastern preponderance than is shown in Table I. These disturbances occur in all latitudes up to the poles and the majority are not associated with spot disturbances. The total number recorded in the nine years ending December 1912 is 559, of which 319 or 57 per cent. were on the east limb. Eastern prominences therefore appear to be more liable to violent movement than western.

The displacements are probably due in most cases to motion in the line of sight and it is of interest to note that displacements towards the red end of the spectrum indicating recession from the earth preponderate over displacements towards the blue. Of the whole numbers recorded 61 per cent. were in the direction of increased wave-length.

It may be remarked that the excess of eastern metallic prominences, and of prominences showing movements in the line of sight, results from observations made at the telescope, as photographs of these phenomena have not hitherto been attempted. There remains the possibility therefore of bias in favour of the east limb as mentioned on page 510.

As regards the preponderance of displacements towards the red it is possible that pressure shifts may play some part in these disturbances, although this appears improbable in cases where the lines are shifted bodily and not diffused towards the red.

KODAIKANAL,
23rd December 1912.

J. EVERSHED.

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