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THE APPARENT EFFECT OF PLANETS ON THE DISTRIBUTION OF PROMINENCES

BY

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In Kodaikanal Bulletin No. XXVIII, Mr. Evershed has shown that during the years 1904—1912 a larger number of prominences has been observed on the eastern limb of the sun than on the western, according to the observations made at Kodaikanal as well as those made at Catania and Kenley. This led to the supposition that the earth exerts an extinguishing influence during the transit of prominences across the disc thus producing an unequal distribution at the two limbs, and similar effects were looked for in the cases of the other planets. Mr. Evershed concluded that there was slight evidence of planetary action similar in effect to that of the earth in the case of Venus only among the major planets.

2. It seemed to us that the periodogram method of Schuster * would afford a means of deciding definitely and conclusively for, or against, planetary influence For, if any planet exerts an appreciable influence on the relative numbers on the east and west limbs, there will not only be a well marked periodicity coincident with the synodic period of revolution of the planet but also a second criterion will be afforded, namely, the phase of the period must bear some interprotable connection with the relative positions of the earth, sun and planet.

3. The periodogram which is reproduced in Fig. 1 on page 38 was constructed from the Kodaikanal observations of the number of prominences seen on the eastern limb, expressed as a percentage of the total, for each month of the years 1904—1913, June. The two Fourier co-efficients were calculated for periods of 12, 13, 14, ... up to 24 months and of the first and second sub-periods of each. The ordinate of the periodogram is then proportional to the product of the sum of the squares of the Fourier co-efficients and the time interval to which the analysis has been applied.* The ordinates of the periodogram and the phases at 1904 January 15 (0^{o} at maximum) are given in Table I

TABLE I.

Ordinates of Periodogram (S) and Phases (ϕ) at 1904·04.

Period in months.	S	ϕ	Period in months.	S.	ϕ	Period in months	S.	ϕ
3½ ...	0 03	306°	7 ...	0 07	3°	13 .	1 33	177°
3⅔ ...	0 79	134°	7⅓ ...	0 34	249°	14 ...	0 11	97°
4 . .	0 12	359°	7½ ...	0 11	164°	15 ...	0 03	148°
4⅓ ...	0 84	242°	7⅔ ...	0 08	359°	16 ...	0 00	289°
4⅔ ...	0 30	299°	8	0·34	220°	17 ...	0 17	179°
4⅘ ...	0 19	178°	8½	0 15	29°	18 ..	0 11	106°
5 . .	0 27	167°	9 .	0 06	313°	19 ...	0 02	135°
5⅓	0·19	312°	9½ . .	0 17	242°	20 ...	0 28	265°
5⅔ ..	0 11	86°	10	0 00	272°	21 ..	0·45	211°
6 ...	0 34	20°	10½ ...	0 20	334°	22 . .	0 46	155°
6⅓ ...	0 58	235°	11 .	0 68	285°	23 ...	0 21	153°
6½	0 11	141°	11½ ...	0 77	255°	24 ...	0 09	97°
6⅔ ...	0 20	171°	12 ...	0 87	226°			

* Schuster, Proc. Roy. Soc., A-77, 136, 1906.

The periodogram (Fig. 1) shows maxima at 13, $4\frac{1}{3}$ (second sub-period of 13 months), $3\frac{3}{4}$, 6, and about $21\frac{1}{2}$ months. Of these, the 13 months period is possibly the only real one.

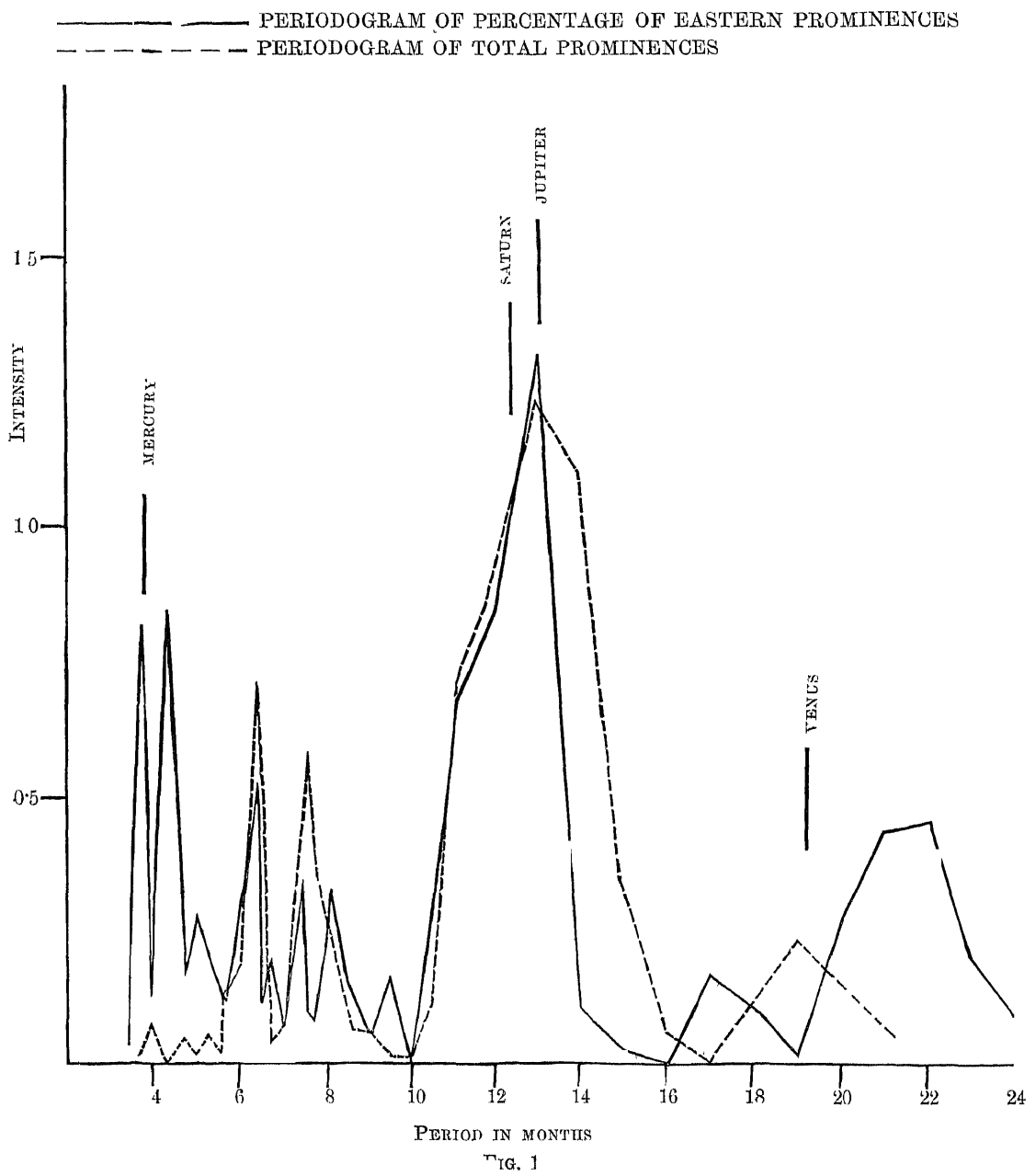

FIG. 1

The synodic period of revolution of several planets are marked in the figure and at these points there would be a peak in the curve if the corresponding planet exerts any influence on the relative number of prominences on the east and west limbs.

It is seen that the ordinate of the periodogram is large near the periods of Jupiter (13·11 months) and of Mercury (3·81 months). The more distant planets Saturn, Uranus and Neptune have their synodic period slightly larger than 12 months, whilst the influence of the earth, if variable, would give rise to an annual period. The effect, if any, of the planets Saturn, Uranus, Neptune and Earth is therefore superposed in the band whose highest point is at 13 months.

Mr. Evershed obtained evidence of a slight indication of an influence exerted by Venus, but the evidence of the periodogram is entirely against it, for at 19·19 months, the synodic period of Venus, there is no suggestion whatever of a rise in the curve. This contradiction requires some explanation which probably lies in the fact that Mr. Evershed considered only the times near superior and inferior conjunctions whereas

the method of harmonic analysis includes the whole revolution. In fact, a gradual extension of the limits between which the values are taken very soon reduces the apparent effect of Venus The following table shows that when the prominence numbers for times between 56° on each side of the positions of conjunction are taken the apparent effect of Venus is practically zero.

Distance of limits on each side of positions of conjunction	Average per cent. of eastern prominences near inferior conjunction.	Average per cent of eastern prominences near superior conjunction.	Difference.
19°	53 61%	52 19%	1·42%
30° *	53 90% *	52·56% *	1 34%
37°	52·82%	52 31%	0·51%
56°	52 60%	52 61%	−0 01%

It is, however, not inconsistent with these facts that the combined effect of Venus and Earth becomes appreciable only when their difference in longitude is very small when a rapid increase of effect might take place, quickly dying away again as the planets separate. We have therefore constructed Fig. 2, giving the average number of eastern prominences during the revolution of Venus, to show that such an effect cannot be large.

CURVE OF PERCENTAGE OF EASTERN PROMINENCES DURING SYNODIC REVOLUTION OF VENUS

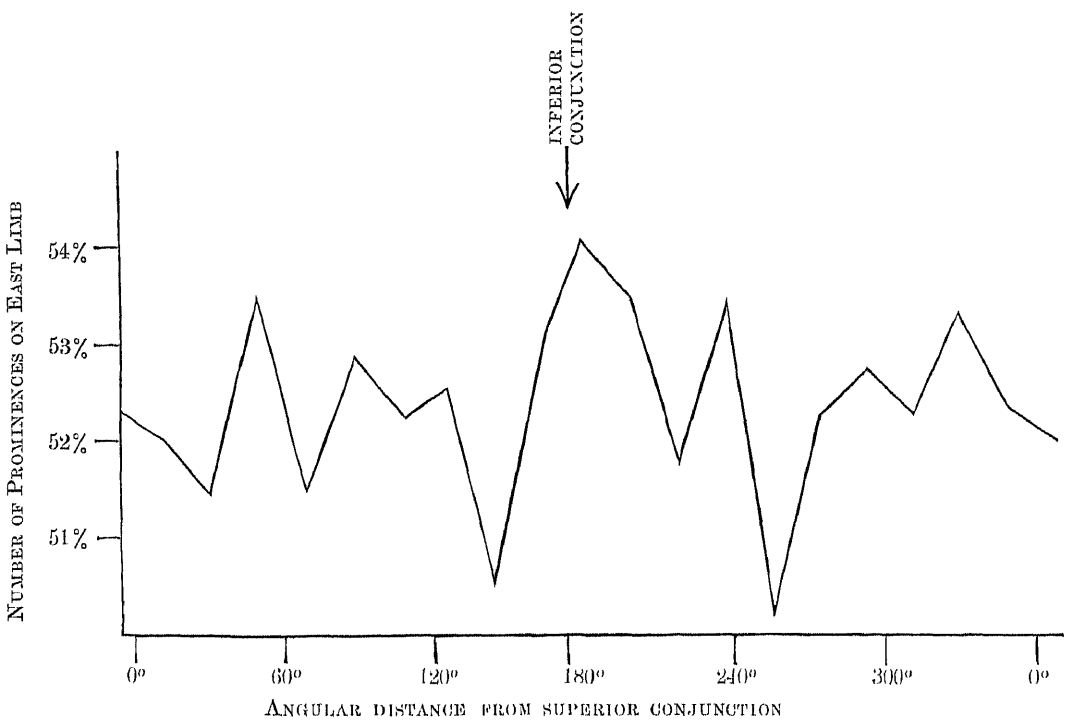

FIG. 2

The remaining results deduced by Mr. Evershed are interpreted by the periodogram as follows :—

(*a*) The absence of any effect due to Jupiter is due to the fact that the 13 month period has its zero values about the times of conjunctions of Jupiter (its maxima occurring about the times of quadrature as determined below).

(*b*) The apparent effect of Saturn is due to its period (12·4 months) falling within the 13 month band, as also does the annual period.

* Given by Evershed, Kodaikanal Observatory Bulletin, No. XXVIII.]

4. Considerations of phase will now give some indication of the probability of the apparent effect of Jupiter and Mercury being real.

The phase of the Jupiter period (13·11 months) can be calculated from the phase of the trial periods near it, and is, at the date of 1904 January 15, about 165°. Consequently the maxima occur at the times 1904 July $1 \pm n \times 13{\cdot}11$ months. If there is a real effect of Jupiter similar to that supposed to be exerted by the earth, we should expect the dates of maxima to be near the times of the oppositions of Jupiter. The oppositions occur, however, at 1904 October $19 \pm n \times 13{\cdot}11$ months. So large a lag as this, 260° or 9·5 months, does not seem probable. The times of maxima are, indeed, nearly coincident with the dates of western quadrature of Jupiter and it is difficult to suppose a real influence of Jupiter such that the planet would exert its maximum effect in this position.

The phase of the 3·81 month period of Mercury can be determined less accurately than that of Jupiter but would be at the same date 1904 January 15, about 61°, the maxima occurring, therefore, at 1904 February $1 \pm n \times 3{\cdot}81$ months. The maximum effect of Mercury would be expected at the times of inferior conjunction, 1904 January $17 \pm n \times 3{\cdot}81$ months which represents a lag of 47°, or 15 days. It is not likely, therefore, that there is a real effect due to either Jupiter or Mercury.

Further, if the effect of a planet is proportional directly to its mass and inversely to some power of its distance from the sun (as for instance a tidal effect), then since the supposed effect of Mercury is comparable with that of Jupiter, the effect cannot diminish more rapidly than as the inverse third power of the distance, and consequently we should expect the effect of Venus also to be appreciable. This is seen from Table II The absence, however, of any effect due to Venus as indicated above, points against the reality of planetary influence.

TABLE II.

*Relative Effect of Planets.**

Planets.	Effect $\propto$ m/d.	Effect $\propto$ m/d^2	Effect $\propto$ m/d^3 (Tidal force)	Effect $\propto$ m/d.^{4}
Mercury...	0 14	0 37	0 95	2 44
Venus	1·12	1 54	2 13	2 95
Earth	1·00	1·00	1 00	1 00
Mars	0·07	0·05	0 03	0 02
Jupiter	60 45	11·62	2 23	0 43
Saturn	9·86	1·03	0 11	0 01

We have concluded from this evidence that it is not likely that any of the planets have an influence on the relative number of prominences on the eastern and western limbs, and that therefore an influence exerted by the earth is improbable.

5. The band in the periodogram from 10 to 14 months at once reminded us of the similar band in the periodogram of the total prominence areas.† In order to facilitate comparison, the periodogram of the total prominence areas has been added to Fig. 1, on a suitable scale. There is a striking similarity between the two periodograms in that the main feature of each is a band at 13 months. The sub-period ($4\frac{1}{3}$ months), is absent from the total prominences but the peak near 6 months is reproduced. Let us now consider the phase of the periods common to the two periodograms. Since they both relate to almost exactly the same time interval the phases of the same trial periods are strictly comparable whatever the true periods may be. The phases of the periods of eastern prominences have been reduced to the epoch 1905 January 15, for comparison with those of the total prominences taken from Table I of the Kodaikanal Bulletin No. XXXIII. The differences of the phase are given below in Table III for the 13 month period and Table IV for the 6 month period.

* A similar table is given by Schuster, Proc. Roy. Soc. A-85, 309, 1911.

† Royds, Kodaikanal Observatory Bulletin No. XXXIII.

TABLE III.

Phases of Period near 13 *months.*

Trial Period	11 months.	11½ months.	12 months	13 months.
astern prominences . .	253 °	237°	226°	205°
Total prominences . .	37°	89°	61°	5°
Difference of phase ..	216°	148	165°	200°

TABLE IV.

Phases of Period near 6 *months.*

Trial Period.	6 months.	6½ months
Eastern prominences	20°	276°
Total prominences	101°	29°
Difference of phase	276°	247°

For the 13 month period, which is the most certain in both periodograms, the phases differ by approximately 180°, but this is not so for the 6 month period though the values are in this case less trustworthy. This fact does however, point to the existence of a real connection between the two periodograms.

If the 13 month period in the relative number of eastern prominences is due to Jupiter, we should expect that it would be permanently active, whilst one of us has shown* that the 13 month period in total numbers has a small average intensity over a long interval from 1881—1912 according to the Italian data. Consequently we can test whether the connection between the two periods is a real one by examining whether the period in eastern prominences also disappears during the long interval. The Italian data are not so complete as may be desired for the purpose, giving frequently very large or very small values for the percentage at the eastern limb, but the evidence does point to the disappearance of the 13 month period since the average intensity over the years 1881—1912 is only ⅓ of that over the years 1904—1912.

6. It is perhaps necessary to make clear that the similarity of the two periodograms in Fig. 1 cannot be due to accidental variations in the number of eastern prominences. When there is the largest number of prominences, *i.e.*, at the times of maxima of the 13 month period, the number of eastern prominences would, if their variations were accidental, tend to approach their average value. At the times of minima of prominence activity, however, the eastern prominences would tend to have their large and small values and not systematically one or the other. Consequently the average intensity of the 13 month period due to accidental variations would be small.

The presence of the 13 month period in eastern prominences, opposite in phase to that in the total, means that the 13 month period is more intense in western prominences than in eastern. The amplitude in western prominences is not sufficient alone to cause the observed amplitude in the total prominences which amounts to 13·6 per cent. of the average value.

7. Some light is thrown upon the subject by studying the relative numbers of prominences north and south of the equator, for in this case also there is a systematic excess on the one side, namely, on the southern where there appear an average of 51·78 per cent. of the total number. The periodogram of the percentage number on the north of the equator at both limbs was constructed exactly similarly to that of the eastern prominences. The periodogram is shown in Fig. 3 below. It is at once obvious that there are no definite periodicities in the relative numbers north and south of the equator and that therefore the variations are chiefly accidental. This shows clearly, if proof were needed, that accidental variations in the number

* Royds, Kodaikanal Observatory Bulletin No. XXXIII.

of the eastern prominences, which would not be greater than in the number of the northern prominences, could not produce the similarity of its periodogram with that of the total numbers.

PERIODOGRAM OF PERCENTAGE OF NORTHERN PROMINENCES

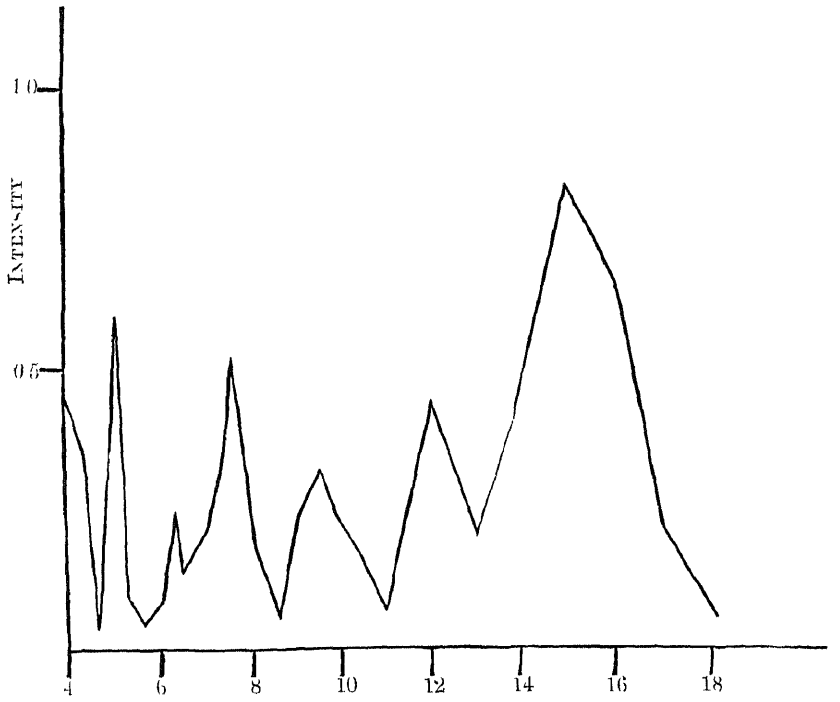

FIG. 3.

To what, then, is the southern excess due? Clearly not to planetary influence since there are no periodicities of less than 19 months present The cause may lie within the sun itself and may possibly be due to the maxima of long period variations occurring during the time interval considered (1904—1913 June) but whose ultimate cause is still undetermined.

8. Relating to the excess of prominences on the eastern limb we have now the following facts awaiting explanation :—

(*a*) An average excess on the eastern limb for the years 1904—1912 discovered and discussed by Mr Evershed.*

(*b*) A periodicity of 13 months in the variation of the eastern excess, probably identical with the 13 month period in the total number of prominences but opposite in phase. Periods of $4\frac{1}{3}$ months (second sub-period of 13 months) and $3\frac{2}{4}$ months are also present but less important.

Although we have concluded that these periodicities are not due to planets, and consequently that an effect due to the earth is improbable, the *observed* systematic excess on the one limb, or any periodicity in its variations, must be associated with the earth's direction. In the absence of any influence exerted by the earth we are driven to the conclusion that the effects observed are produced by the rotation of the sun (and would be observed from whatever direction the sun were viewed) although Mr. Evershed deduced evidence on certain assumptions which pointed to the opposite conclusion. If the rotation of the sun is the true cause we do not see any obvious explanation of the 13 month periodicity and, although long period variations may be also present whose maxima occur during the interval considered, we should expect the eastern excess due to this cause to be permanent.

For the further study of these problems there is a lack of sufficiently complete prominence data for a long interval of time. It is greatly to be desired that not only should observations be made as frequently as possible, but that prominences below 30″ in height should be recorded in order to obtain values for the prominence activity of the sun as nearly true as possible.

* Evershed, *loc. cit*

9. The similarity of the two periodograms seems to us to confirm the reality of the chief features of the periodogram in the total areas of prominences, for we know of no *a priori* reason except that stated in the second paragraph of section 6, why the percentage number on one limb should be dependent on the total. The confirmation is the more remarkable since the total prominence area per day depends on the number of days of observation, which introduces an element of uncertainty from which the percentage observed in the eastern limb is free, as the number of days of observation does not in this case come into consideration.

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