Kodaikanal Observatory.

BULLETIN No. XXXIII.

PROMINENCE PERIODICITIES.

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The half-yearly data of prominences and Hα markings prepared for the Kodaikanal Observatory Bulletins lead one to suspect regular variations of short period in them. In order to investigate the matter more fully it was resolved to construct the periodogram of prominences in the same way that Schuster has done for sunspots.*

2 Any investigation of periodicities must be based on fairly complete and uniform data. At Kodaikanal visual observations have been maintained on a uniform plan since February 22nd, 1904, and the spectroheliograph has been in continuous use from December 1904, since when both visual and photographic observations have been available. The observations from January 1905, may therefore be taken as a sufficiently uniform series and have been used in this investigation. As for their completeness it may be stated that since 1905, the average number of days in the year on which the prominences observations have been made is 298, the lowest being 269 in 1906, and the highest 312 days in 1910.

3. The total prominence areas for each month for the years 1905 to 1912, have been got out from the observatory records, and the mean daily areas obtained by dividing by the effective number of days of observation in each month. This effective number of days has been arrived at by marking a day on which the conditions of observation were not good as $\frac{3}{4}$, $\frac{1}{2}$ or $\frac{1}{4}$ day according to the quality of the sky and definition at the time of observation. The data are given in Table I.

TABLE I.

Kodaikanal { Total Prominence Areas in Square Minutes / Effective number of days of Observation / Mean daily Prominence Areas in Square Minutes } for each month.

Year.	Jan.	Feb.	Mar	April.	May.	June.	July.	Aug.	Sept.	Oct	Nov.	Dec.
1905	116·8 24½ 4·76	127·6 24 5·31	167·7 25¼ 6·62	103·4 23¼ 4·45	123·0 25¼ 4·86	81·1 19¾ 4·10	100·6 19½ 5·16	127·2 20½ 6·21	77·0 16 4·81	111·8 18½ 6·02	79·9 15¼ 5·23	101·0 24¾ 4·09
1906	144·4 26 5·55	167·4 25¼ 6·50	140·4 26¾ 5·25	122·3 23½ 5·20	127·4 25¾ 4·95	39·5 12½ 3·16	36·1 12¼ 2·95	32·0 11¼ 2·85	48·6 18¼ 2·66	50·3 19½ 2·58	30·6 13¾ 2·22	68·8 16½ 4·16
1907	149·3 27 5·51	150·9 26½ 5·70	181·5 29¾ 6·10	120·8 22½ 5·38	136·2 28¼ 4·82	54·3 16¼ 3·34	64·1 12¾ 5·03	69·1 12¾ 5·42	94·6 21 4·50	107·6 18¾ 5·72	58·3 13 4·49	106·0 25½ 4·15
1908	168·7 25½ 6·61	136·8 21½ 6·36	254·6 25 10·20	226·9 27¼ 8·33	203·8 28¾ 7·10	103·6 16¼ 6·37	58·8 11 5·33	111·4 21¼ 5·25	77·0 19¼ 4·00	107·2 17¼ 6·20	121·3 24½ 4·95	101·3 21½ 4·70
1909	119·8 21½ 5·57	138·2 24¼ 5·70	157·2 28¼ 5·56	124·2 24 5·18	116·2 22 5·29	76·6 15¼ 5·01	36·9 9½ 3·88	86·1 15½ 5·55	100·4 21 4·79	89·0 21½ 4·14	90·6 21¾ 4·16	101·4 23¾ 4·26
1910	97·0 22 4·40	124·2 23½ 5·29	182·0 30 6·06	110·4 29 3·81	179·4 26¾ 6·70	55·8 13¼ 4·21	81·9 13¾ 5·95	55·0 13½ 4·07	64·5 15½ 4·16	90·4 20½ 1·40	91·5 17 5·38	125·2 30 4·17
1911	72·8 23½ 3·10	86·0 25¼ 3·40	75·2 28¼ 2·66	105·1 24¼ 4·34	58·2 23 2·53	58·1 16½ 3·53	27·5 9¼ 2·98	67·2 20 3·36	63·2 19½ 3·24	72·8 19 3·83	86·2 16¼ 5·15	70·4 16¼ 4·33
1912	93·6 27½ 3·40	91·2 24¾ 3·69	60·4 25½ 2·37	63·6 22 2·89	45·5 22 2·07	40·4 7¼ 5·57	27·4 8 3·42	51·4 12½ 4·11	47·6 18 2·65	34·0 11½ 2·95	51·2 14½ 3·54	70·6 22¼ 3·17

* Schuster, Phil Trans. Roy. Soc. A vol. 206, p. 69, 1906.

4. The periodogram reproduced in Fig 1 on page 30 was obtained from the mean daily areas for each month from 1905 to 1912, by first calculating the Fourier coefficients of the periods of 12, 13, ...up to 22 months, and the first, second, and in some cases the third sub-periods. The ordinate of the periodogram is then proportional to the product of the sum of the squares of the Fourier coefficients and the time interval to which the Fourier analysis has been applied.* As the interval 1905 to 1912 does not include more than 5 complete periods of 19 months the curve was carried only so far beyond this point as to show whether the incipient rise was continued. The ordinates of the periodogram, and the phases at 1905·04 are given in Table II, the phase being 0° when the period has its maximum.

TABLE II.

Ordinates of the Periodogram (S) and Phases φ

Period in months	S.	φ	Period in months	S.	φ
3¼	30	1°	8	748	1°
4	249	153°	8½	228	236°
4⅓	0	295°	9	174	53°
4½	82	28°	9½	36	197°
4·8	132	231°	10	23	16°
5	49	14°	10½	406	209°
5¼	166	105°	11	2130	37°
5½	64	314°	12	2806	61°
5¾	122	178°	13	3790	5°
6	588	104°	14	3331	295°
6⅓	2150	29°	15	1012	212°
6½	716	318°	16	182	38°
6⅔	105	289°	17	30	295°
7	248	263°	18	368	1°
7¼	1343	108°	19	729	141°
7½	1675	57°	20	455	249°
7¾	1060	22°	21	209	50°

It is seen that the prominence periodogram shows the presence of three periods of large intensity, two nearly homogeneous, of 6⅓ and 7½ months and a third, which is provisionally fixed at 13⅓ months as being probably the highest point of the band.

The times of maxima are as given below in Table III.

TABLE III.

Period.				Times of Maxima.
13⅓ months	...	...	...	1912 October 4 $\pm$ n 13⅓ months.
7½ ,,	...	...	...	1912 August 22 $\pm$ n. 7½ months.
6⅓ ,,	...	...		1912 June 21 $\pm$ n. 6⅓ months.

5. Before proceeding to discuss this periodogram, it is necessary to consider whether the periods indicated above have not been introduced into the data in deriving the mean daily areas. It is clear that unless the days of incomplete observation have been exactly allowed for, a periodicity in the number of days of observation will cause the same periodicity in the daily areas, of an intensity depending on the exactness with which the allowance can be estimated. It was consequently foreseen that there might appear in the daily areas from this cause, at least one period, namely 12 months owing to the annually recurring monsoons. In order to remove all doubts as to what periodicities might be introduced in this way, I have constructed the whole periodogram of the effective number of days of observation. This curve, which is also given in Fig. 1, has a peak at 12 months, which shows that unless the allowance for partial days has been strictly exact, the prominence periodogram ought to be raised or lowered at this point. The curve of effective days of observation also shows peaks as subperiods of the annual period, namely at 6·0 months and 4·0 months, but these are inconsiderable.

* Schuster Proc. Roy. Soc. A. vol. 77, p 136, 1906.

I have shown therefore that the periods in the mean daily prominence areas of $6\frac{1}{3}$, $7\frac{1}{2}$ and $13\frac{1}{3}$ months are not due to periodicities in the number of days of observation. Consequently it is of no immediate importance to estimate the effect of a possible under- or over-allowance for the days of incomplete observations, but whether the allowance has been under- or over-estimated can be tested by considering the phases of the period in the number of days of observation and of the *resulting* period in the daily areas. For, during poor observing months when the number of days of observation is small, the effective number of days is too large if the allowance for partial days is under-estimated and consequently the daily areas too small. That is, the areas are too small when the number of days of observation is small, or in other words the phases are coincident. Similarly, when the allowance is over-estimated the phases are opposite. For instance, if I under-estimate the effect of partial days by making no allowance at all, the phase of the annual period in prominences is 56°, nearly coincident with 53° for the number of days of observation, whereas after making the estimated allowance it is 61°. It seems therefore that the allowance may still be under-estimated.

It should be pointed out that the scale of the periodogram of effective number of days of observation in Fig. 1 is an arbitrary one

6 The best proof of the reality of the periods which have been found in the Kodaikanal daily areas is their presence in the prominence data of other observatories. The "Memorie della Società degli Spectroscopisti Italiani" contain prominence data which, although dependent on less frequent observations and not including prominences less than 30″ high, extend for many years back. The mean daily frequencies for each month from 1881 to 1912, deduced from observations at Palermo and Catania, have been analysed and the resulting periodogram shows distinct peaks at the same points as the Kodaikanal curve, as shown in Fig. 1. Although the ordinates are much smaller than in the Kodaikanal curve, indicating that the periodicities may not have been active during the whole interval 1881—1912, and although other peaks (not shown in the figure) are present, those results strongly confirm those deduced from the Kodaikanal observations. In further confirmation we have the fact that the phases agree as well as could be expected for each of the three periods. This is shown in Table IV.

TABLE IV.

Period	Phase at 1905 04 Kodaikanal	Phase at 1905 04 Palermo-Catania.
$13\frac{1}{3}$ months	340°	12°
$7\frac{1}{2}$,, ...	57°	138°
$6\frac{1}{3}$,, ...	29°	59°

7. It is desirable to give an idea of the amplitudes of the three periods which have been found in the Kodaikanal observations. The average of the mean daily prominence areas for the whole interval is 4·64 square minutes and the amplitudes are the following percentages of this average, the range being double the amplitude :—

Period	Amplitude as percentage of average of mean daily areas.
$13\frac{1}{3}$ months	13 6 %
$7\frac{1}{2}$,, ...	9·1 %
$6\frac{1}{3}$,, ...	10·1 %

We can obtain some idea of the ratio of these amplitudes to that of the 11 year period in prominences. The Palermo-Catania series extend over a sufficiently long interval to give an approximate value at least, of the amplitude of the 11 year period, and by a comparison of Kodaikanal and Catania observations during the years 1905 to 1912, it is seen that the 11 year period has a slightly smaller amplitude in Kodaikanal *areas* than in Catania *frequencies*. The amplitude of the $13\frac{1}{3}$ month period in the Kodaikanal data is, as a result of this comparison, about $\frac{1}{3}$ that of the 11 year period and the amplitudes of the $6\frac{1}{3}$ month and the $7\frac{1}{2}$ month periods are each about $\frac{1}{4}$.

8. Two of the periods found are near planetary periods of revolution. The sidereal period of Venus is 7·38 months and the synodic period of Jupiter 13·11 months; the synodic period of Venus is 19·19 months, but the slight rise of the periodogram at this point has probably no real significance. Considerations of

phase show, however, that these coincidences are probably accidental. The maxima of the period of 7·38 months occur when Venus is about its ascending node, and the maxima of the 13·11 month period, when Jupiter is in eastern quadrature. If the coincidences are real, the causal connection must be an obscure one in view of these facts.

9. I have shown that three periodicities namely of $13\frac{1}{3}$, $7\frac{1}{2}$ and $6\frac{1}{3}$ months exist in the prominence areas as observed at Kodaikanal from 1905 to 1912 and have obtained some confirmation of them from the long series of Italian observations. Other independent prominence data which are sufficiently complete and continuous are, however, highly desirable in order to establish firmly the reality of these periods.

THE OBSERVATORY, KODAIKANAL,
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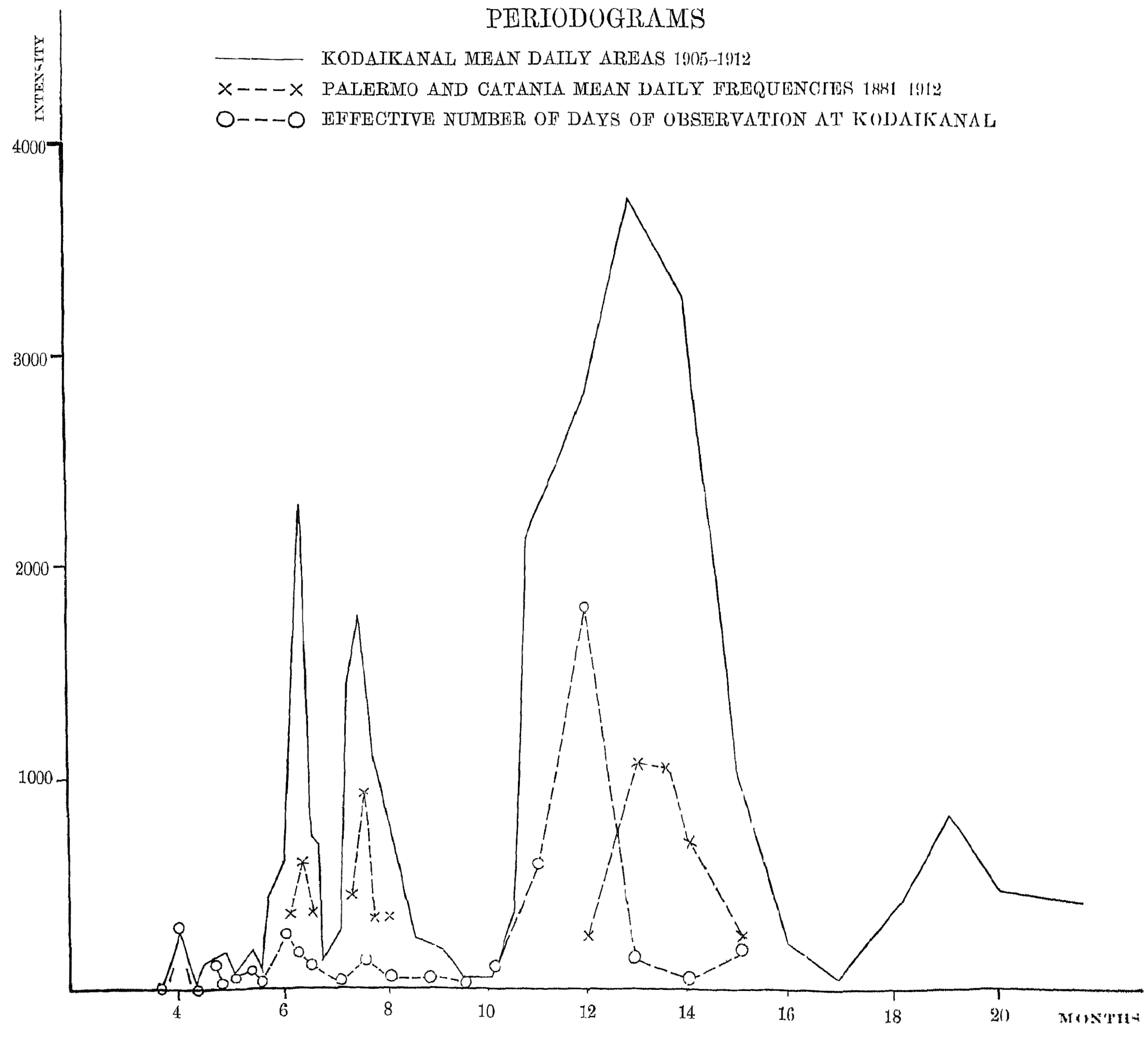

FIG. 1