The Relative Variations in the Extents of Bases and in the Heights of Prominences accompanying Variations in their Areas. By P. R. Chidambara Iyer, B.A.

The profile areas of prominences on the sun's limb, their heights above the chromosphere, and the extents of their bases on the chromosphere are being systematically measured at Kodaikanal, and data of the mean daily areas, mean heights, and mean extents are available for each half-

* *Ap. J.*, 70, 11, 1929.
† *Ap. J.*, 62, 387, 1925.

year from 1905 to 1928. These data are published regularly in the half-yearly bulletins of prominence summaries issued from Kodaikanal. From the year 1923, under the auspices of the International Astronomical Union, Kodaikanal has been incorporating statistics derived from photographs of foreign observatories also, and, accordingly, the abstract for each half-year published in Table I. in the prominence bulletins from that year onwards contains the means derived from the data of all the co-operating observatories. For the sake of uniformity, however, the figures used in this investigation are those from the Kodaikanal records only.

The method of derivation of the data discussed here may be briefly summarised. The daily prominence photographs are examined for their quality and corrections are applied to incomplete or imperfect records, such that the total number of days in a half-year on which photographs were secured get counted as a smaller number of effective days. The mean daily areas are derived by dividing the total profile areas in each half-year by the appropriate number of effective days, while the sum of the greatest heights reached by individual prominences and the sum of the lengths of their bases divided by the total number of prominences observed give the mean height and the mean extent respectively.

It occurred to me that a parallel study of the changes in the extents of the bases and in the heights, accompanying changes in areas, might yield fruitful results, by revealing the nature and magnitude of some of the forces that come into play in the fluctuations of solar activity as reflected in the prominences. For instance, if, as the solar cycle advances, we get taller and taller prominences, we can legitimately infer that there is an increasing force or thrust acting outwards from the sun. The bases of prominences increasing in extent might, on the other hand, indicate that an increasing force is acting tangentially to the surface of the sun, or in other words, that the phenomenon of an increase in solar activity is essentially one of spread, its magnitude in the direction of longitudes being revealed by the increased extent in the prominence bases.

The bases are usually expressed in degrees on the circumference of the sun, whereas the heights are measured by the angles which they subtend at the earth. In order to make the bases comparable with the heights, the former were converted into equivalent apparent angles, on the basis of the sun's apparent semidiameter being taken as 16 minutes of arc. The following table contains the mean daily areas in square minutes and the mean bases and mean heights in minutes of arc from 1905 to 1928.

[Table

Years.	Mean Daily Areas of Promi-nences, sq. min.	Percentage Departure over Previous Half-Year.	Mean Extent of Base, min.	Percentage Departure over Previous Half-Year.	Mean Height, min.	Percentage Departure over Previous Half-Year.
1905 I. half	4·80		·550		·522	
II. „	4·46	− 7·1	·466	−15·3	·523	+ 0·2
1906 I. „	4·94	+10·8	·444	− 4·7	·522	− 0·2
II. „	2·59	−47·6	·349	−21·4	·497	− 4·8
1907 I. „	4·81	+85·7	·497	+42·4	·525	+ 5·6
II. „	3·71	−22·9	·452	− 9·1	·472	−10·1
1908 I. „	6·67	+79·8	·502	+11·1	·473	+ 0·2
II. „	3·93	−41·1	·527	+ 5·0	·437	− 7·6
1909 I. „	4·60	+17·0	·441	−16·3	·462	+ 5·7
II. „	3·68	−20·0	·480	+ 8·8	·428	− 7·4
1910 I. „	4·51	+22·6	·421	−12·3	·442	+ 3·2
II. „	3·61	−20·0	·371	−11·9	·452	+ 2·3
1911 I. „	2·83	−20·5	·326	−12·1	·450	− 0·4
II. „	3·00	+ 6·0	·304	− 6·7	·452	+ 0·4
1912 I. „	2·48	−17·3	·293	− 3·6	·473	+ 4·6
II. „	2·43	− 2·0	·335	+14·3	·477	+ 0·8
1913 I. „	2·42	− 0·4	·310	− 7·5	·487	+ 2·1
II. „	1·92	−20·7	·315	+ 1·6	·460	− 5·5
1914 I. „	2·93	+52·6	·321	+ 1·9	·442	− 3·9
II. „	3·34	+14·0	·522	+62·6	·518	+17·2
1915 I. „	5·27	+57·8	·985	+88·7	·517	− 0·2
II. „	5·29	+ 0·4	·968	− 1·7	·708	+36·9
1916 I. „	3·88	−26·7	·815	−15·8	·608	−14·1
II. „	3·65	− 5·9	·739	− 9·3	·572	− 5·9
1917 I. „	5·36	+46·8	1·041	+41·1	·643	+12·4
II. „	4·95	− 7·6	·999	− 4·0	·625	− 2·8
1918 I. „	5·00	+ 1·0	1·094	+ 9·5	·572	− 8·5
II. „	3·23	−35·4	·870	−20·5	·535	− 6·5
1919 I. „	3·36	+ 4·0	·834	− 4·1	·483	− 9·7
II. „	4·05	+20·5	·915	+ 9·7	·573	+18·6
1920 I. „	4·33	+ 6·9	·868	− 5·1	·540	− 5·8
II. „	4·27	− 1·4	·910	+ 4·8	·502	− 7·0
1921 I. „	4·62	+ 8·2	1·063	+16·8	·540	+ 7·6
II. „	3·55	−23·2	·901	−15·2	·520	− 3·7
1922 I. „	3·17	−10·7	1·088	+20·8	·557	+ 7·1
II. „	3·28	+ 3·5	1·096	+ 0·7	·573	+ 2·9
1923 I. „	4·58	+39·6	1·094	− 0·2	·577	+ 0·7
II. „	4·18	− 8·7	·971	−11·2	·562	− 2·6
1924 I. „	4·87	+16·5	1·096	+12·9	·577	+ 2·7
II. „	5·56	+14·2	1·269	+15·8	·610	+ 5·7

Years.	Mean Daily Areas of Prominences, sq. min.	Percentage Departure over Previous Half-Year.	Mean Extent of Base, min.	Percentage Departure over Previous Half-Year.	Mean Height, min.	Precentage Departure over Previous Half-Year.
1925 I. half	5·24	− 5·8	1·138	−10·3	·588	− 3·6
II. ,,	6·88	+30·3	1·470	+29·2	·662	+12·6
1926 I. ,,	8·18	+18·9	1·615	+ 9·9	·703	+ 6·2
II. ,,	7·65	− 6·5	1·540	− 4·6	·657	− 6·5
1927 I. ,,	7·73	+ 1·0	1·744	+13·2	·665	+ 1·2
II. ,,	5·50	−28·8	1·297	−25·6	·593	−10·8
1928 I. ,,	7·30	+32·7	1·947	+50·1	·670	+13·0
II. ,,	7·13	− 2·3	1·763	− 9·5	·663	− 1·0

The progress of the values of the mean daily areas, mean bases, and mean heights is represented in fig. 1, in which the ordinates on the left give square minutes for areas and those on the right give minutes of arc for the mean bases and mean heights of prominences. The heavy line represents the mean daily areas, the thin line the mean bases, and the broken line the mean heights. The diagram shows that, while both bases and heights exhibit sensitiveness to the changes in areas, the response made by heights is much less than the response made by the bases. To show this to better advantage, the percentage departures of the three quantities for each half-year over the previous half-year have been worked out and given in columns 3, 5, and 7 of the foregoing table and also represented in fig. 2. The departures in areas, bases, and heights are shown by the heavy, thin, and broken lines respectively. It is seen at once that, while the points on the curve for the departures in heights keep comparatively close to the X axis, those on the departure curve of the bases are in general farther above and below the X axis.

In order to discover the exact degree of relationship between the three series of data discussed here, the method of correlation was applied. There were 48 pairs of comparison in each instance. The coefficient of correlation r obtained for areas and bases was $+\cdot784$, with a probable error of $\pm\cdot037$, and the coefficient r' for areas and heights was $+\cdot746$, with a probable error of $\pm\cdot043$. This indicates a high degree of relationship of both bases and heights to areas, but slightly less in the case of heights. The deviations y and y' from the average of the mean bases and mean heights respectively accompanying a deviation x from the average of mean daily areas were then determined, and the results $y = \cdot2294x$ and $y' = \cdot0379x$ were obtained. From this we find that y is 6·05 times y'; that is to say, any deviation in the height of prominences is on the average accompanied by 6·05 times as much deviation in their bases.

We have here an interesting result, which gives us an insight into at least some of the features characteristic of the cycles of solar activity. It is well known that corresponding to the periodicity in sunspots there is also a periodicity exhibited by the profile areas of prominences. The high coefficient of correlation between the average heights and the mean

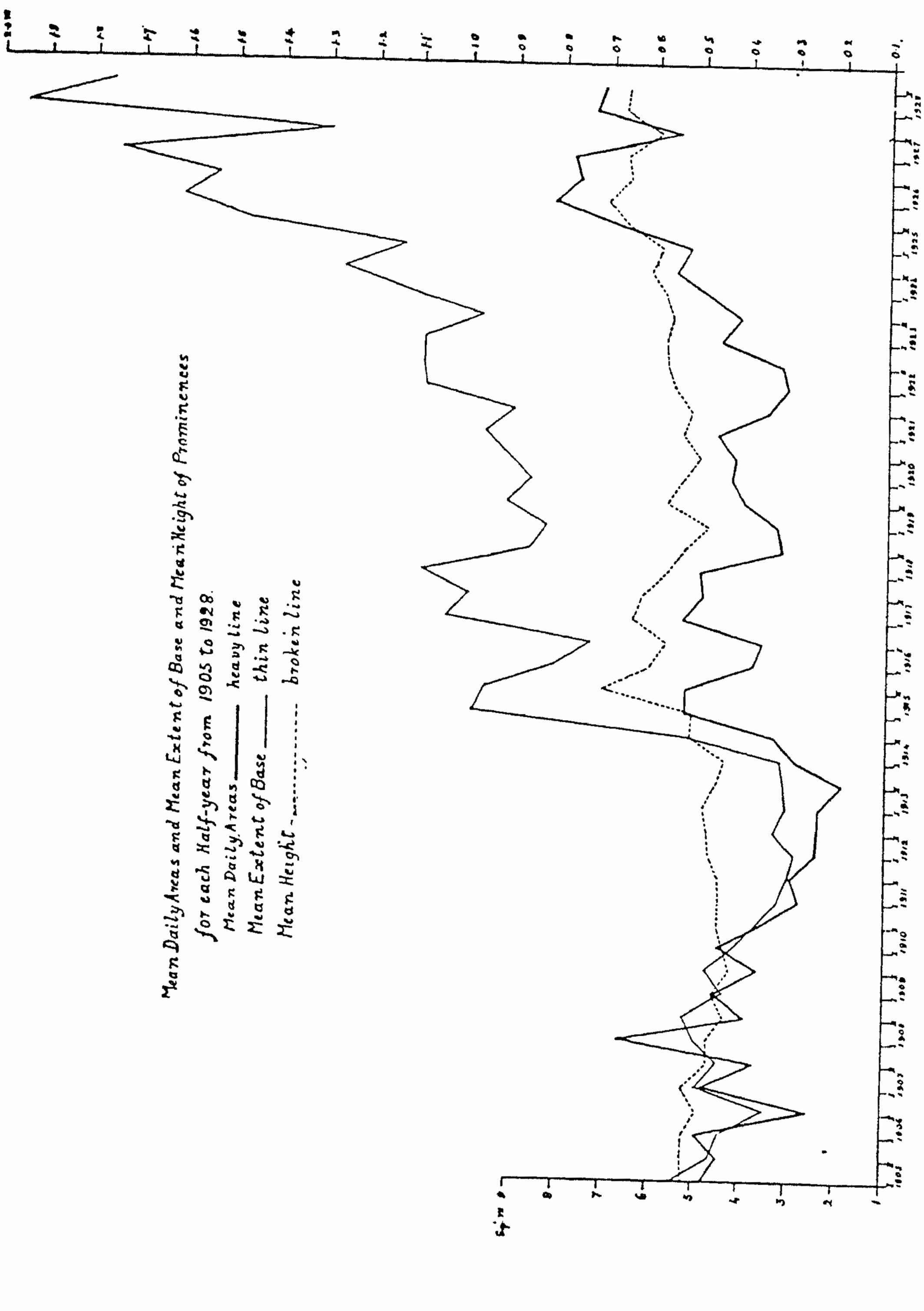
Mean Daily Areas and Mean Extent of Base and Mean Height of Prominences
for each Half-year from 1905 to 1928.
Mean Daily Areas ______ heavy line
Mean Extent of Base ______ thin line
Mean Height .... broken line

Fig. 1.

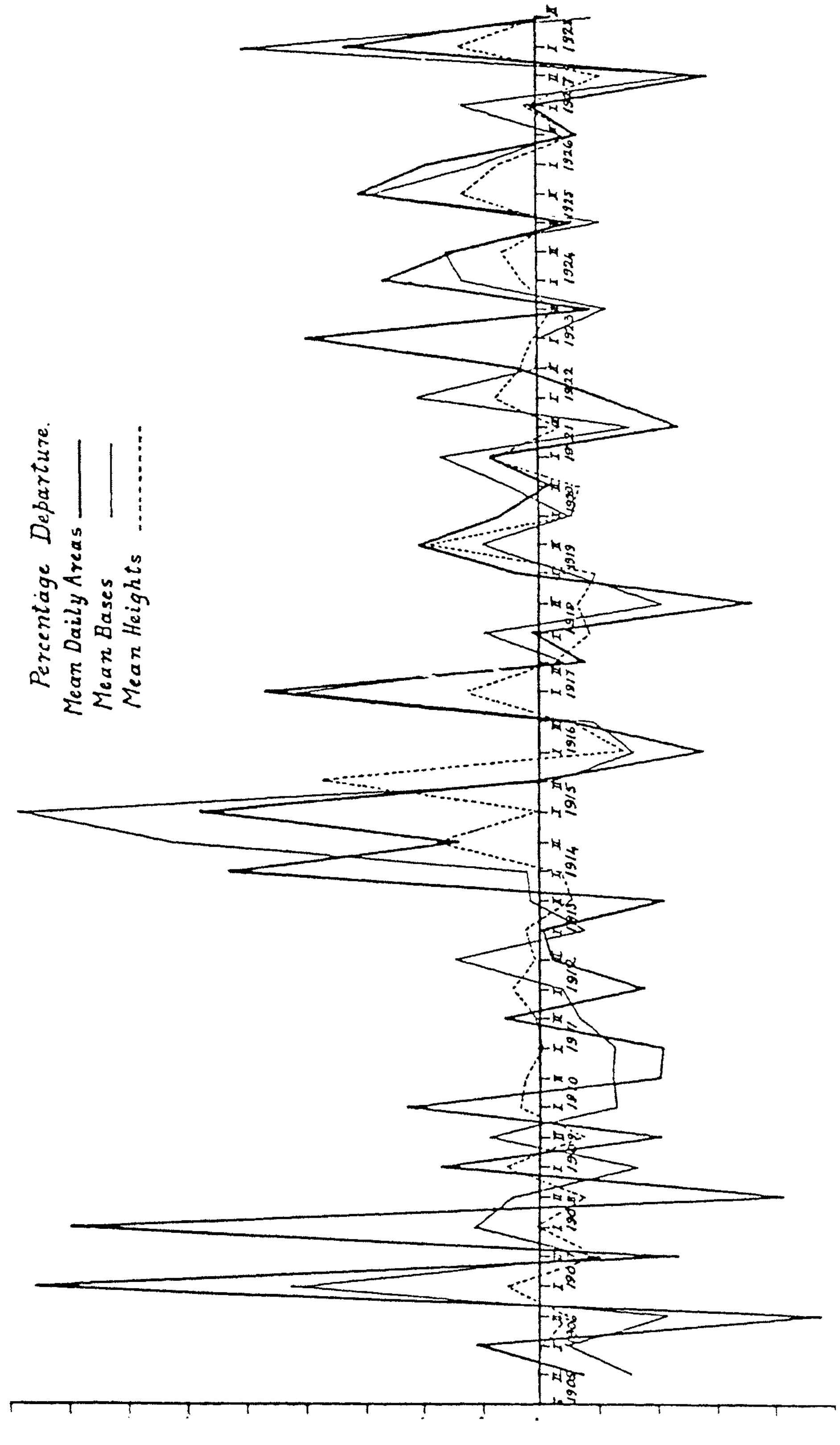
Percentage Departure.
Mean Daily Areas
Mean Bases
Mean Heights

FIG. 2.

daily areas of prominences points to a similar periodicity in the average heights to which prominence matter is heaved up above the chromosphere. The natural inference seems to be that an increasing force directed outwards, whose component radial to the sun we are enabled to detect, ejects matter from the sun to greater and greater heights until the maximum activity is reached, when it begins to drop gradually to a minimum, as is evidenced by the decreasing heights of the prominences. Simultaneously with this outward projection, and with the same regular periodicity, there is also taking place, tangentially to the solar surface, a movement of matter with a force whose component along solar longitudes exhibits fluctuations which amount to six times the fluctuations in the heights of prominences. The fact that "prominence activity moves from low to high latitudes and dies out at the poles" * is probably also an indication as to the direction of the spreading movement, namely, from low latitudes towards the poles.

The idea of a pulsation naturally suggests itself to us, but a pulsation embracing two simultaneous phases. There is the heaving up and subsidence of material belonging to the outermost layers of the sun, and there is also a wavelike spreading and dying out, the latter being the more prominent feature of the two. If, as is suggested,† the sun is really a variable star with a very long period and a small range in brightness, the kind of pulsation of which we have direct evidence here seems to be the inevitable explanation for its variability. If this is so, we have secured a valuable key to the general question of stellar variability. The chances appear to be that pulsation, as Professor Eddington maintains, is the mechanism involved in certain classes of variable stars, but a slightly modified pulsation which also brings into play forces tangential to the stellar surface. From the curves in fig. 1, it would appear as though each of these pulsations in the sun consists of a series of secondary pulsations.

A glance at fig. 1 will show that, while the curve for the mean bases rises and falls correspondingly to the phases of the solar cycle, the mean height steadily increases. To a less extent this is also the case with the other two curves. It looks as though prominences once generated in a cycle do not die out completely; that is, matter ejected during a cycle is not completely reabsorbed into the body of the sun or lost in space, but a considerable residue is left behind which is being built upon during the next cycle, a process of gradual accumulation of prominences being thus indicated. Whether this is part of the evolutionary processes going on in the sun or is but a temporary state of things time alone can decide with certainty, but a separate investigation may throw some useful light on the question.

In conclusion my thanks are due to Dr. T. Royds, the Director, for the kind encouragement and valuable suggestions given to me during the investigation.

* J. Evershed, *Kodaikanal Observatory Memoirs*, 1, pt. 2, p. 64, 1917.

† *General Astronomy*, by Spencer Jones, p. 338.

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