MEMOIBS

OF THB

KODAIKANAL OBSERVATORY

JOHN EVEESHED, F.E.s.
Director

VOL. I. PAKT II.

RESULTS OF PROMINENCE OBSERVATIONS

BY

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RESULTS OF PROMINENCE OBSERVATIONS.

INTRODUCTION.

"Petals of damask roses with, the sun shining through." was Professor Langley's description of prominences seen at a total eclipse ; and during those precious fleeting moments one has scarcely time to note more than the wonderful colour, contrasting with the black of the moon's body. The first observer who has left us any record of them is the Swede Vassenius, who saw at the eclipse of 1733 what he described as pink clouds floating in. the moon's atmosphere; and as at that time no reason was known why the moon should not. haye an atmosphere like our own, the observation did not rouse much attention.

A century later, after the eclipse of 1842, astronomers began to discuss whether .the red objects .that many had then seen were clouds on the moon, or mountains on the sun, or nothing at all but optical illusions. When eclipses could be photographed, it was proved that prominences are flames seen at the sun's edge, and a few years later, in 1868, there followed the thrilling discovery of Janssen and Lockyer, that they can be seen at any time, without waiting for an eclipse, and travelling perhaps many thousands of miles to observe it. Day after day, sitting quietly in his own 'observatory, the astronomer can see the wonderfully varied forms of these huge' flames,' can measure their motions, and investigate their composition. Nothing can be more entrancing than to gaze at a great cloud, glowing as if with sunset colour, and full of intricate detail, which slowly changes, and presently grows dim and fades away, or to watch a number of fine sharp rays which shoot up, curl over, and disappear, while others take their place. The invention of the spectro-heliograph, which was attempted by more than one astronomer, and successfully accomplished by Professor Hale in 1892, made it possible to photograph prominences daily, and not only at the sun's edge but also on jthe disc. In photographs, the colour and brilliance is missing, but the forms lose nothing of their strangeness and beauty, and we have permanent and unerring records which can be studied and compared together at oar leisure.

Admiration and wonder grows as we realize the vast extent of those forms,, and begin to speculate upon how they arise, what interplay of forces controls them, and what happens after they have become invisible to us.

Within a few years after the great discovery made by Lockyer and Janssen, Secchi's beautiful drawings, Young's vivid descriptions, and the pioneer researches of Huggins and Lockyer inspired many others to devote attention to prominence*; ami in 1890 Mr. Evershed constructed a small spectroscope and set It op in ids observatory at Kenley. in Surrey, and here he continued to observe *Mii draw* prominences until in 1906 he was appointed to the Kodaikanal OWrvatory. *Vh** Kenley observations precede and overlap the Kodaikanal eWrvationB of prominences, and we shall here draw upon the earlier series to supplement the later.

At Kodnikanal, systematic observations of prominences were organized in 1903 by Mr. C. P. Butler, then Acting Director of the Observatory, but they were' oalj made with eight settings of the position circle. Prom 1904, February 21, under the Director, Professor C. Michie Smith, the drawings and descriptions repressiited the entire limb of the sun, and heights as well as positions of all visible prominences were calculated, so that at this date the complete record may b* said to have begun. In 1905, as skill increased with practice, the record became mow detailed and reliable; the spectroheliograph was installed and daily photographs were taken which *were* compared with the drawings. The plates were not very good at first, and the slits were found to be unsatisfactory; in March 1908 a new camera slit was made by Mr. Evershed, and the qualitv of the speetroheliograms greatly improved. At the end of 1914 the Observatory was in possession of an eleven years' prominence record, increasing- in accuracy after the first few years, and interrupted only by bad weather The average number of effective days[1] for each year during this period was a little ow 280 the year 1906 being the worst in this respect, for the total*' number of effective days in that year was only 253, while in the three following years the numbers were high and almost equal, being 296, 29,8 and 296, respective^ for 1 on7 MIS and 1909, and in 1910 the highest number was reached, *lf*, *Bot*

The observations, photographic and visual, were made by the'following

Prof. C. Michie Smith	S. Sitarama Ayyar
Mr. J. Evershed	*KJ. Nagaraja Ayyar
Dr. T. Boyds	A. Y, Subrahmanya Ayyar
K, V, Sivarama Ayyar	A. ' Narayana Ayyar

and for a few months in 1907 S. Muttuswami

The total number of prominences recordpd d,,rm g this inclusive--was nearly sixty thoasand J S) *TM*r-TMi to 1914

The object of this Memoir is to review thi, ai menW by the Director's Kenley observations 2^ *"?' Te o0 rd, supple- ears y, «* eWeu thousand additLal p ^ e ^ f c TM *?**" additional •P by M«. Bvershed under BapervisL of X Di ^ memo " ^ been drawn help of Filaments, and undertook a large snare of t tabulation. Mr. G. Nagaraja ominences and the Long

[1] In reckoning the number of "effective days", only those on which a good record of the entire limb is secured are counted as whole days; those on which the record is imperfect are counted as half or quarter days.

Ayyar has also given some assistance in tabulating and drawing curves. In five separate sections we deal with the distribution and frequency of prominences in different years, and in different solar regions, north and south, east and west; the gases of which they are composed, and their movements in the line of sight; their forms and changes; and their connection with sun spots and other phenomena. In the sixth and last section we draw some general conclusions from the sum of the observations, and suggest some problems which arise out of them.

The illustrations on eleven of our plates are reproduced from enlargements of photographs taken at Kodaikanal, and most of them are here published for the first time. The frontispiece represents an entire limb of the sun, with two remarkable prominences opposite one another, of contrasting types; plates II, III and IV contain views of eruptive prominences, some of which are printed as negatives in order to show most clearly the fine detail3 ; plate Y shows some detached clouds, plates VI and VII some prominences which underwent striking and rapid changes ; plates VIII and IX illustrate the varied forms assumed by prominences seen at the limb, while plates X and XI show how they appear on the disc, the hydrogen and calcium spectroheliogram3 revealing forms both brighter and darker than the background. The twelfth plate contains some of the more interesting prominences from Mr. Evershed's "Kenley drawings.

On all the plates, and throughout the text, whenever time is given, Indian Standard Time for Kodaikanal observations is to be understood : this is 5^h 30^m in advance of Greenwich Civil Time.

I.—DISTRIBUTION AND FREQUENCIES OF PROMINENCES.

1. Distribution in Time.—The period covered by Kodaikanal records is the length of an average sunspot cycle, and a comparison of sunspot and prominence activity during this time gives some interesting results. In 1905 sunspot maximum seemed to have arrived, but after a slight fall in 1906 activity rose again, and a secondary maximum was reached in 1907; the next two years showed but little abatement of vigour; a rapid decline followed in 1910, but minimum was not readied until 1913; in 1914 recovery set in. Thus our period begins one year before sunspot maximum, and ends one year after minimum : the first six years were prolific in simspots, the last five (and especially the three years 1911 to 1913) were comparatively barren.

The corresponding changes in prominence activity can be seen at a glance by consulting the pairs of curves 1 and 2? 3 and 4, on diagram I, where the full lines indicate prominence activity, the broken lines sunspot activity. All the prominence data are taken from Kodaikanal records, but as these are incomplete for 1904, the prominence curves do not include this year; sunspot numbers are also taken from Kodaikanal records, but sunspot areas (whole spots corrected for foreshortening) from Greenwich Photo-heliographic Results. And here we should like to say how much *we* owe to the Greenwich publications, which have been invaluable throughout this work, owing to their fullness, and the excellent arrangement, which makes reference easy.

It is seen at once from diagram I that sunspot areas and sunspot numbers give essentially the same curve, the only difference being that maximum and minimum are more marked in the former, because sunspots are much larger and longer-lived at the same time that they are more frequent. On the other hand, prominence numbers and prominence areas differ greatly. The prominence number curve does not widely depart from a straight line, and it continues to rise slightly until the year 1920, reaching its maximum three years after secondary sunspot maximum, exactly when the sunspot curve is tracing a very rapid fall. Minimum however occurs in all four curves in the same year, 1913.

The flatness of the prominence number curve is mainly due to the fact that at Kodaikanal all prominences down to the smallest visible are recorded, not only those of 30″ and over, as at Catania and other observatories, and small prominences are numerous at all times. Even in minimum years the sun's whole circle may sometimes be seen to bristle with minute jets.[1] The only valid reason for omitting to tabulate low prominences appears to be the labour entailed in visual observations, but in the case of photographs the time taken in cataloguing all shown on the plates is not very much greater than would have to be given to examining all and deciding which to reject, and many low prominences are extensive and bright, so that it seems to be quite as important to note these as narrow faint streaks of slightly greater height. Moreover, in some lines of research (such as a comparison of the east and west limbs of the sun) an enumeration of all prominences, small as well as great, brings out some specially striking results. The custom has therefore been retained of recording every prominence seen or photographed, however small.

The flatness of the prominence curve when activity is deduced from numbers and its distant resemblance to the curve of sunspot activity, are the two chief features to be noted in curve No. 3 (diagram I). When we turn to curve No. 1 prominence activity deduced from profile areas, the case is different. Although still somewhat flatter than the sunspot curve, the full line is here seen to be a fairly faithful copy of the broken line, having a prolonged maximum with a double peak, followed by a two years' pause on the downward path ... ree ... ars ... of a rise. But ... of the curve is

[1] See for instance Kodaikanal Observatory Bulletin No. XXIX, page 2, where attention is drawn to the large number of prominences recorded during January 1912, a month entirely free from sunspots, in the year before sunspot minimum. On certain days more than 40 prominences had been counted, "the limb presenting a remarkable appearance with prominences in all latitudes, including the polar regions, where they were numerous though of small size."

that though minimum is reached in the same year as sunspot minimum, the early-part of the curve shows a lag of one year behind sunspots. Sunspot maximum was in 1905 to 1907 with a dip in 1906; prominence maximum was 1906 to 190S with a dip in 1907; and the sunspot pause in 190d and 1909 is imitated exactly by the prominence pause in 1909 and 1910.

This lag did not occur in the prominence area curve of the preceding cycle, as may be seen in diagram II, where the pair of lines in the upper part show the relations of sunspot and prominence activity durifig the years 1890 to 1904 It is drawn to the same scale as diagram I, and the sunspot data are again taken from Greenwich records, but the prominence data are from Mr. Evershed's Kenley observations, reduced sq. as to be comparable with the Kodaikanal data. As they consist of drawings only, and are based on much fewer observations, they cannot claim an equal value with those of Kodaikanal, and the curve is more irregular. There is however here also a close resemblance to the sunspot curve. The sunspot maximum of 1893 was higher than that of 1905, and the sides of the single peak are symmetrical : both these features are repeated in the prominence curve. There is a pause in the descending sunspot curve after]896, and here the prominence curve not only pauses bat asconds again slightly ; the minimum in both oases is reached in the year 1901. Prominence maximum, however, is reached earlier than sunspot maximum, and is longer sustained.

On the other hand, the observations of the Italian observers, published in the Memorie della Società degli Spettroscopisti Italiani, do show a lag of prominence activity, for Dr. .Eoyds has shown that, according to these, prominence maximum, occurred about one year after sunspot maximum, both at the maximum of 1893 and in the previous sunspot cycle.[1] And Mascari, who noted the fact that when sunspots attained their (primary) maximum in 1905 prominence maximum did not come till the beginning of 1906,[a] states that prominence minima also occur later than sunspot minima. He gives^the following dates, taking the sunspot figures from Wolfer, the prominence figures from his own records, and those of Tacchini and Riccò :—

Sunspot minima ...	1878'9	1889'6	190i'7
Prominence minima ...	1879, First quarter.	1890, First quarter.	1902, Last quarter.

All these Italian prominence data, however, are based upon numbers, which are much less satisfactory as a test of activity than areas, since, as we have already pointed out, it is in size more than in numbers that prominences vary from year to year. Moreover, areas are found to give more consistent results than numbers, partly perhaps because it is not always easy to decide whether a group of prominences shall be counted as one or several. Judging by areas, it appears that prominence maximum preceded the sunspot maximum of 1893 and followed

[1] Kodaikanal Observatory Bulletin, No, XXXIV—" A comparison of the Periodicities in Prominences and Sunspots," by T?. Eoyds.

[4] Memorie deila Sooieti degli Spefctroncopisti Ifcaliani, XXXV,.. 137.

the «,*»«. of 1905-07, b* that * i — in *» Mjl. - -To « £ £ sunspots, that is in 19(and 1913. To ascari has attempted to do, is not always possible, because of constant fluctuations.

Nor should it be forgotten that phases in the sunspot cycle are often, reached earlier by one hemisphere than the other. During the two cycles tinclor diHmifl-slon the northern hemisphere always anticipated the southern. Maximum «uni*pofc activity in the north was reached fa 1892, but southern activity continued to mowiwe so greatly that, though northern was decreasing, the general maximum of the whole sun came in 1893; similarly the northern hemisphere reached its minimum in 3809, but it continued very low until 1901, as if waiting for the southern to join it, so that 1901 was the year of general Minimum.[1] Notwithstanding tho fact that the two hemispheres thus started fair, both beginning to rise in activity in the year 1902, the northern was again the first to reach maximum, viz., in 1905, while the southern delayed until 1907 (causing the double-peaked maximum of this cycle, see diagram I). Northern minimum came in 1912, but again it waited for the southern minimum of 1913, and next year sunspot activity in both hemispheres began to rise together.

This last northern minimum *ma,y* be said to have lasted for eleven months, for not a single northern spot was seen from January to November 1912 inclusive, immediately after which, in December, two high-latitude northern spots appeared, which were evidently the first of the new cycle. But in the south during this year as many as 19 spots appeared, all in low latitudes. Next year, 1913, not a single *southern* spot was seen from May to October inclusive, after which, ID November and December, three high-latitude spots began the new cycle in this hemisphere.[3]

As with sunspots, so with prominences: the northern hemisphere always anticipated the southern. Northern maximum occurred in 1892, but here, although southern activity continued to increase and came to its maximum in 1898, this increase was not quite Enough to compensate for the northern decrease, so that the general prominence maximum extends over the two years 1892 and 1898 (see diagram II). Northern minimum was reached in 1901," and remained very low d rt5 tb /- Soatlleriiminimiim ^ 1902> So tbat here also tlie *™ ^misphercm started fair again, being nearly equal in this year. Yet the aext northern maximum arnved m 1906 and the southern not till 1908, causing the double peak which follows a ... ast northern minimum arrived in 1912 ... , and in the same way

[1] Stsnspofc areas ia the north suddenly dropped fmm nn -n- * 1596, »f»UQQ, a»d *n in 1901*, going up to *42 J S 21* \ *21* \. *m,,1Onihd* of ^ Stm,8 visibl «d ^ « ^98 to *2B in* three *ymn.* Ti»e eor^poMiag *mhm* for th *Zll^JT*™ *Zt* ^^ * for ih. *7mt* tf a u r a for *the* sooth. ^etnispiere «re 266, 88, *4,9, t%* ar.d JH, *to* that 3001 wa«

[3] Only oae *inagniSmnt* spot, seen for one day, had appeared in high southern latitudes before, Ti,., in March 1913.

the northern hemisphere once more waited for the south, so that in 1914 both were on the up grade again together, and nearly equal. It will be interesting to see whether, in the coming cycle, the northern hemisphere again outruns the southern. It has now done so with sunspots for 34 years, for in the cycle preceding those we are discussing, the rise after minimum, the maximum, and the decline, all occurred earlier in the north than the south.[1]

On the whole it appears that these two forms of solar activity, sunspots and prominences, run through much the same changes in the same period of eleven years, reaching their respective maxima in approximately the same years, pausing at the same time on their downward path, and reaching their minima in the same years. The correspondence is equally close if we consider the northern and southern hemispheres separately. The main difference between the sunspot and prominence curve is that whereas sunspots almost touch zero at their time of minimum, prominences never fall so low.

This fact is closely connected, with the distribution in latitude of the two phenomena, which we must now compare.

2. *DldrihiMon in Latitude.*—The law of sunspot variation in latitude is well known. At the time of minimum, when spots are few and small, they begin to appear in latitudes of about 35° north and south, and these two zones gradually approach one another, reaching a latitude of about 15° when maximum is attained and spots are most large and active; after this they decline, and finally die out near the equator : before they have quite disappeared a new cycle begins in latitude 35°, and this follows the same course as the dying cycle.

Prominences, on the contrary, are found in all latitudes from the equator to the poles, and in 1892 Mr. Evershed drew attention to two strongly marked zones of prominence activity in latitudes 40° to 50°, which were indicated by his observations of 1890, and persisted in 1891, but with a change of position, having increased their latitude to between 50° and 60°. These therefore were completely outside the aunspot zones, and were moving in the opposite direction, polewards instead of equatorwards. There were at the same time other zones of prominence activity, at about 30° north and south; these were separated from the high-latitude zones by regions of small activity. In later communications to the Journal of the British Astronomical Association, in which observations of the Spectroscopic Section of the Association were added to his own, Mr. Evershed showed that the high-latitude zones continued to progress polewards until in 1893 and 1894 they closed over both poles. The southern wave became much more active than the northern, and was the first to reach the pole, in the latter half of 1893.[2] This was the year, as we have seen, of sunspot maximum.

3 Monthly Notices of the Royal Astronomical Society, LXIII, 452. See concluding remarks and diagram.

a Astronomy and Astrophysics XI, 426, and Journal of the British Astronomical Association, Vols. II, IV, No. 6, Vol. V, JSTo. 7.

Kodaikanal observations show that there was a similar "dash to the pole" at the next maximum, but that between these two epochs prominences almost ceased at a very definite limit of 50° to 60°. Beyond this, large prominences are absent, and only short-lived jets occur, which are probably the roots of the short polar rays often seen in the corona.

This and other features of prominence distribution are shown in diagrams III- to VI, where prominence activity in the two solar hemispheres is figured separately, the northern curves on the left, the southern on the right: the abscissae indicate solar latitude, the ordinates ihe mean daily profile areas of all prominences recorded in each year. The areas are found for each zone of 5° of latitude and are indicated by the points of inflexion on the curves, these points being joined by a continuous line in order to give a clearer representation of the distribution. On the scale of the printed diagram an ordinate of f inch, shown by a horizontal line, represents an area of *y$t1a.* of a square minute of arc. These curves are deduced from Kenley observations during the years 1890 to 1904, and from Kodaikanal observations during 1905 to 1914.

The most striking feature in this series of curves is the importance of the high-latitude zone of activity in both hemispheres, and the rift which usually separates it from the zones of low latitude. Then, as the curves are examined year by year, it is seen that the history of the low and high latitude zones is quite different, for they do not reach their greatest height simultaneously nor die out together.

In our first year 1890 (the year following sunspot minimum), prominence activity was altogether low, and in the south' it was chiefly concentrated in one zone about latitude 45°; but in the next four years, although this zone becomes extremely active as it moves up to the pole, it is rivalled and even surpassed (in 1892) by a rapidly developing low-latitude zone. In 1895 (after sunspot maximum) this high-latitude southern zone has suddenly and completely dis-appeared, and there remains only a feeble low-latitude zone of activity. The northern hemisphere has a history almost but not quite the same, for here an incipient low-latitude zone already puts in an appearance in 1890, beside the marked mid-latitude zone which corresponds with the single zone in the south; and here this zone reaches its greatest development a year earlier than its southern counterpart, viz., in 1892 instead of 1893. Both however reach their greatest extension polewards in 1894, the northern having its maximum at 90° or thereabouts, the southern between 70° and 80°. (It is difficult to determine the true positions of prominences when in very high latitudes, but they were frequently seen during this year at the position angle of the poles, particularly the south pole.)

After this, prominences stop consistently and abruptly, in botji hemispheres, at about 60°, until we are nearing the next maximum, and in the two years 1895 and 1896 there is no marked zone anywhere, but activity is fairly well sustained in low latitudes. In 1897 new high-latitude zones appear in both hemispheres at 52°, narrow and strong, and for six years these remain much the same, oscillating about latitude 50°, while the low-latitude zones diminish, die at sunspot minimum, and revive in 1903.

In 1904 we have a similar distribution to that of 1892, for the four, zones are all active and approximately equal; the high-latitude zones are already developing towards the poles, and in the years of maximum which follow we have a repetition, with modifications, of what happened in the maximum years of 1893 and 1894. The high-latitude zones progress rapidly towards the poles, diminish and die there, the northern in 1906, the southern not until 1908, and after this polar prominences are again very rare. The peaks at + 52° in 1907 and — 52° in 1908 are abortive waves, for they are gone in the following year in each case; but a new persistent high-latitude zone is seen at + 58° and — 48° in 1910, and varies but little (especially in the south, where it is very marked.) to the end of our period in 1914

Meanwhile the low-latitude zones, as in the preceding cycle, are strong during maximum years, sometimes developing double or multiple peaks ; but they diminish and die out gradually as minimum is approached, so that the years 1912 to 1914 resemble the years 1901 and 1902, and the year 1890 in the southern hemisphere (all times of sunspot minimum), in possessing only one zone of prominence activity, at about 50°. It should be noted also that when prominences extend to the poles they are also numerous across the equator : thus, in the maximum years 1892 to 1894, and 1905 to 1908, the curves are unusually high at the equator, but they continue high here for some years after the polar prominences have ceased, equatorial prominences only becoming very scarce from 1899 to 1903 and from 1911 onwards, that is during years of minimum.

The movements in latitude of the four zones from 1890 to 1914 are shown on diagram VII, which has been constructed from the yearly curves of diagrams III to VI. The progress of the high-latitude zones is very clear, the poleward march at sunspot maximum, the subsequent disappearance, reappearance, and persistence without much change of latitude until next maximum, when they again rush to the poles, disappear, and reappear; but the trend of the low-latitude zones is not quite so clear, for there are greater irregularities in the latitude variation, and sometimes these zones are multiple. On the whole, however, these zones, which always remain within sunspot regions, seem to approach one another, and die out near the equator at minimum, as sunspots do. A few sporadic zones, which do not appear to play a part in the history of these main zones, have been inserted as dots on the diagram but not connected by lines with the others.

These results are in agreement with the law of prominence distribution discovered by Prof. Bicc5 in 1891,[1] and confirmed by Sir Norman Lockyer

1 Memorie della Society degli gpettro«copistiltaliani, XX, 135.

and Dr. W. Lockyer in a paper read before the Royal Society ia March 1903.[1] Prominence frequency had been studied by them in 1902 in ™*f™ with magnetic storms and other terrestrial phenomena, and they found that outbursts of prominences in high latitudes (similar to that observed by Mr. JQrershed in 1893) took place regularly at about the time of sunspob maximum, the observations on which the investigation was based being those of Taoohini made in Eoroe from 1872. Further investigation of prominence frequencies according to latitude were then made by Messrs. Lockyer, combining Tacchini's observations with those of Kicco and Mascari at Catania, so as to cover the period 1872 to 1901, viz., nearly three solar cycles; and the law discovered may be briefly stated as follows :—

There are two main zones of prominence activity in each hemisphere of the sun. One appears after minimum in latitude ± 24°, and increases in intensity, reaching its maximum at the same time as the sunspot maximum,- then ifc declines, and finally disappears by' coalescing with the other before sunspot minimum. Thus it has the same maximum and minimum as sunspots, and occurs within sunspot latitudes. The other appears at latitudes 40° fco 50° soon after sunspot maximum, decreases in intensity till minimum, then increases again, and moves rapidly polewards, finally fading out in latitudes 70° to 80° at about the time of maximum. On the whole therefore prominence activity moves from low to high-latitudes and dies out at the poles, while sunspot activity moves from high to low, and dies out at the equator.

It will be observed that, Messrs. Lockyer take the view that the low«ktitude zone coalesces with the high-latitude, while we are inclined to think, from our observations of the last two cycles, that it moves toward the equator and dies out there, like sunspots; but they point out the occasional difficulty, which, we have also encountered, of identifying this zone from year to year, especially when it is multiple. We should also ascribe a higher initial latitude to this zone, for it usually begins at about 30°, and once at 37°, on our curves, a position agreeing closely with the latitude of sunspots at the beginning of a new cyole.

Astronomers have so often found that solar phenomena, after following a definite law for a certain length of time, suddenly begin to vary in a disconcerting fashion, that it is a satisfaction to find prominences repeating, in the last cycle, their march of the three previous cycles. And we look forwafd with some confidence to sea, at the next maximum, the low-latitude prominence zones grow strong, and the high-latitude zones rush up to the poles.

Ife is ea^ t0 see BOW whJ the prominence curve does not fail so low at minimum m the eleven-year cycle as the sunspot curve, which was the main difference we noted in diagrams I and IL This is due to the high-latitude zone

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[1] Proceedings of the Royal Society, LXXI, 446, and Monthly Notices of the Royal Astronomical Society, LXIII, Appendix No. 2 "Solar Prominence Circulation." S5T *»'»aoo*f Ifanarfrfdell. Society degliBp^n^ooptott Italiani, XXXli and Mascari ibid.,

of activity. For although prominences are very active in a zone which is restricted to sunspot latitudes, which rises to maximum activity with sunspots, and dies at sunspot minimum, they are also very active in another zone, which is entirely outside sunspot regions, and this zone does not die out at sunspot minimum, but at or shortly after sunspot maximum. Another striking difference between the two zones is that while one begins in latitude 30° and travels towards the equator, like sunspots, the other begins in latitude 45° and travels to the pole.

Have we here two different kinds of prominences? Certainly there is no obvious difference, and it is impossible to conclude that all the low-latitude prominences are directly associated with sunspots, because their numbers are far too great, and also, as we shall see presently many of them avoid sunspot longitudes, occurring only where the sun's surface is free from spots. There is however a difference in form which is so frequent that we are led to think there must be some fundamental difference between, low-latitude and high-latitude prominences, either in origin or in the forces to which they are afterwards subjected. To this question we shall return in sections IV and V,

3. *Distribution of Prominences compared with Types of Corona.*—Dr. Lockyer has shown that there is a connection between the forms of corona observed at eclipses and the latitudes of prominences.[1] He divided all coronas observed between 1857 and 1901 into the three typical forms suggested by Sir Norman Lockyer, viz., "polar" when the streamers are in nearly all solar latitudes including the poles ; "equatorial" when they are specially concentrated in two great wings east and west near the equator, and there are marked rifts at the poles; "intermediate" when four large streamers appear, one in each quadrant, about half way between the pole and the equator. Dr. Lockyer showed that the positions of these streamers corresponded with the positions of the prominence zones active at the time, "polar" coronas appearing when prominences extended to the poles, "equatorial" coronas when there was only one zone of prominence activity in each hemisphere at about latitude 40°, and "intermediate" coronas when there were two zones of prominence activity in each hemisphere. The prominence data were taken from the Italian observers, including observations by Respighi, Secchi, Tacchini, Ricco, and Mascari.

By the kindness of Mr. W. H. Wesley, Sir William Christie, and the Astronomer Royal, Sir Frank Dyson, we have received photographs of Mr. Wesley's beautiful eclipse drawings of 1898, 1900, 1901, and 1905, and are able to compare the coronal streamers of these years with the prominence zones on our curves. For the eclipse of 1908 we are able to refer to Mr, McClean's report of the Flint Island Expedition.

The corona of 1898 is clearly of the "intermediate" or "square" type, with a large streamer, or rather a synclinal bundle of streamers, in each quadrant. The

[1] "On a Probable Relationship between the Solar Prominences and the Corona," W. J. S. Lockyer, Monthly Notices of the Royal Astronomical Society, LXIII, 481 (June 1903).

curved base of this bundle, looking like a humped shoulder, is specially well defined where it meets the conspicuous "polar rays" ; the other shoulder, near the equator, Is less clear. The pole is notmarked on these photographs, but if we assume that it is at the centre of the polar rays, the polar shoulder of each bundle is at latitude 60°. Turning now to the Kenley prominence curve for 1898 (diagram IV), we see that there are two zones of activity in each hemisphere, but that the high-latitude zone in each case is the more intense, and very sharply bounded at 60°, whereas the feebler low-latitude zone is not so sharply bounded, for prominences continue across the equator. It appears then that the synclinal bundle of streamers in each quadrant of the corona corresponds with the regions of chief prominence activity, the boundaries coinciding with the boundaries of the prominence zones.

The coronas of 1900 and 1901 are also distinguished by great streamers, whose poleward boundary is clearly defined, but in a slightly higher latitude than before ; but the equatorial boundaries are no longer recognisable : thus the whole corona takes on more the "equatorial" or "wind-vane" shape, having only one broad streamer on the east and one on the west, both extending right across the equator. Our prominence curves show (diagrams *IY* and *V)* tliat in these two years the high-latitude zones were more intense than before, but equally clearly bounded at 60°, but the low-latitude zones grow less intense, and in 3901 are practically non-existent. This was the year of sunspot minimum.

In 1905 we have a totally different type of corona. It is impossible to locate the poles, for streamers are equally developed every where: it is what has been called the " dahlia" type of corona, with synclinal bundles of rays resembling dahlia petals all round the disc. And our prominence curve now shows (diagram Y) high-latitude zones reduced in intensity and overflowing the poles, low-latitude zones increased in intensity and overflowing the equator, prominences in fact round the whole sun's disc. It is the year of sunspot maximum.

Our prominence observations so far, therefore, confirm Dr. Lockyer's theory that there is a connection b'etween prominence latitudes and coronal types. For when prominences no longer cease at latitude 60° but extend across the poles, there is also no rift in the coronal streamers (filled only by the short polar rays), but streamers extend across the poles; and a greater or less activity in prominences in equatorial regions coincides with a greater or lessWelopment of coronal streamers in the same regions. There is also an agreement between the poleward limit of prominences and the poleward limit of coronal streamers, both of which are usually sharply defined; the agreement was close in 1898, but only approximate in 1900 and 1901. The prominence curves, of course, represent the average condition tTll wh an T\Z7} T6ih6 COrOna iS S6en onl^on one da? • but afc ^ti~ of while T r • • <I eclipses Prommences ^re very rare beyond latitude ± 52°, the limit of the coronal streamers appears to be at about ± *67°*

There are many illustrations of the corona of January 3, 1*908, in Mr McCleansHeport, including a composite drawing by M, Wesfey, made W t h e best photographs. It was in two ways a peculiar corona, for the polar rifts, which were unusually small, were unlike one another, and they were not symmetrical with the sun's axis. Mr. Wesley points out that while the south polar rift, extending over 30°, was fairly well marked, the north polar rift", extending over 40°, was to a large extent obscured, long streamers taking the place of the short polar rays. This was especially the case on the eastern side, RO that the northern rift lies really to the north-west, and similarly the southern rift is displaced to the south-east. These rifts unsymmetrical- with regard to the poles seemed so extraordinary to Mr. Wesley that the position of the sun's axis was once more calculated but was found correct. On the whole, the corona appeared to be of intermediate type, but approaching the maximum type, for streamers were well developed in the equatorial regions, and in fact all round the disc except at the south pole, although the four high-latitude synclinal groups could be clearly differentiated.

This corona, then, is a test case for prominences, for if their presence coincides with the presence of coronal streamers, and their absence with rifts, we ought to find in 1907 and 1908 that prominences are abundant all round the disc except in south polar regions, wliere they should almost cease at about —75°, and this pole would contrast with the north pole, where they should be well developed. We might also expect to find that, in agreement with the lopsided corona, the prominences would encroach on the polar regions on the eastern side of the northern hemisphere more than on the western, and on the western side of the southern polar regions but not on the eastern.

The prominences of this period are so disobliging that exactly the reverse is the case. Our curves for 1907 and 1908 show that they are indeed well developed across the equator, but they stop short in the *northern* hemisphere instead of the southern at 70°, and overflow the southern pole; and there was no temporary change in this condition near the time of the eclipse. In the month preceding January 3, 1908, the south polar prominences (above 65°) exceeded the north polar prominences in area more than ten times. Also the areas in the north-east polar, region, instead of being greater than the north-west, were little more than half as great: the south-east and south-west were nearly equal.

If Mr. MeClean's corona is correctly oriented, therefore, the distribution of streamers in the polar regions does not agree with the distribution of prominences at the time.

4. *Distribution of Prominences compared with Magnetic Storms.*—On diagrams I and II curves are shown which represent the yearly frequency of great magnetic storms, as recorded at Stonyhurst. It will be noted that there is a general resemblance to the curves of sunspot and prominence areas, but it cannot be said that the resemblance is much closer to one than to the other. Some observers have stated that the maximum of magnetic storms falls before, some that it falls later, than sunspot maximum: the double maximum of 1892^1894 with a peak each side

of the marked sunspot peak in 1893 looks like a good-natured effort to please both; and the magnetic maximum of 1907, prolonged into 1908, so that it corresponds with the secondary sunspot maximum and also with the secondary prominence maximum, seems equally well arranged to suit both those who connect terrestrial magnetism with sunspots and those who connect it with prominences.

Sir -Norman and Dr. Lookyer noted in January 1903[1] that the maximum number of prominences in polar latitudes (60° to 90°), as deduced from Tacchini's observations, and the maximum number of magnetic storms classed by Ellis as "great," occurred together, and slightly before the Bimspot.maxima of 1883 and 1893. Our observations agree in placing the maximum area of prominences in latitudes above 60° in 1892, although prominences reached their highest latitudes later (see diagram III), and the maximum of great magnetic storms was also reached in 1892 (see diagram II), that is, a year before sunspot maximum., But the following maximum does not show this relation : the maximum area, of prominences in latitudes above 60° does indeed occur in 1903 and 1904, that is, before *the* sunspot maximum of 1905; but magnetic storm maximum arrived, neither with polar prominence maximum, nor earlier than sunspot maximum, but, later than both, in 1907.

On the other hand, this latest maximum agrees very well with Father Cortie's theory that magnetic storm maximum must occur after sunspot maximum, because the average heliographic latitude of sunspots is then declining towards db 7°, a position in which they are most effective in causing magnetic disturbances, since radial lines emanating from them would then strike the earfch.[2] During the primary sunspot maximum of 1905, and in 1906, the mean latitude of sunspots was higher than db 13°, but in 19,07 it descended to 10° in the northern hemisphere : it continued of course to descend until sunspot minimum was reached, but at the same time sunspots were diminishing in number and activity. The year 1907, therefore, according to Father Cortie's theory, was the most favourable for mag-, netic storms, since the activity and the position of sunspots then combined to give them their greatest effect on terrestrial, magnetism,

• The theory fails, however, with the earlier maximum, for this ^ favoured the Messrs. Lockyer, as we have just seen, in occurring before sunspot maximum; and the secondary magnetic maximum, in 189-fc (see diagram II) cannot help Father Cortie, for mean sunspot latitudes were still* 12°"2 in the northern hemisphere and 15°*5 in the southern. The rise in the curve in the year 1898 might be thought to favour him, since mean sunspot latitude in that year was 10°"5, but in the preceding year ifc was 8°'O and sunspots were more numerous also, yet the magnetic curve then shows a dip. "Great" and " Very Great" magnetic storms do not occur very often, so the numbers may be thought too,

[1] Proceedings of the Royal Society, LXXI, *2H,* and Monthly Notices of the Hoyal Astronomical Society,' I/XIII, Appendix No. 1, "Tlie Relation between Solar Prominences and Terrestrial Magnetism."

[2] Monthly Nbtiftea of the.Eoyal Astronomical Society, Nov. 1912, Jan. 1013^ and April 1913.

small for comparison with sunspots, but if the curve be constructed including also the " moderate " Stonyhurst storms, there is not much difference, except that the secondary maximum falls in 1895 instead of 1894, when mean sunspot latitude is still 13°-5, and the later rise in 1898 is more marked.

It seems that all we can say with confidence from an inspection of these curves is that the three phenomena, sunspots, prominences, and magnetic storms all fluctuate in accordance with an eleven year cycle and the minima occur in the samo year. The magnetic, maximum appears from the later observations to correspond much more closely with the maximum of metallic prominences than with prominences in general or with sunspots, but many more cycles would need to be compared to establish more definite relations.

It is well known that a magnetic storm often happens when a large and active sunspot crosses the sun's disc, so that the connection here seems very close; but not all large sunspots are thus accompanied, and it is probable that they must bo active in a certain way, and in a certain position with regard to Earth, in order to be associated with a magnetic storm. One form of sunspot activity is the appearance of eruptive prominences in its neighbourhood, and an observation at Kodaikanal suggests that although the magnetic field discovered by Prof. Hale to exist in sunspots is too weak to cause a magnetic storm on earth, this field may be greatly increased at times when exceptionally brilliant prominences form over the spot, indicating a great uprush of gases. For on one occasion during the passage of a large sunspot, an eruptive prominence above it (seen on the disc), a magnetic storm on earth, and a magnetic storm in the spot, were all observed at the same time.[1]

5. *Distribution of Prominences Bast and West.*—Having surveyed the distribution of prominences in latitude, we now pass on to consider their distribution on the east and west limbs of the sun.

The latitude of a prominence defines its position with regard to the sun's axis of rotation ; but position east or west indicates merely its aspect from Earth on a given elate. It was not supposed therefore that a comparison of eastern and western prominences would have any significance. But,after the publication of Mrs. Maunder's paper on " An apparent Influence of the Earth on the Numbers and Areas of Sunspots,"[2] it was evident that such a comparison was important, for she had shown that sunspots predominate on the eastern side of the sun, adding also a few figures which indicated that this is true of prominence^ also; and she suggested that Earth appears to have an extinguishing effect on solar activity, so that sunspots and prominences tend to die out as they cross the visible disc. All prominences observed at Kodaikanal from 1904 to the first half of 1912 Were therefore divided into east and west, and it was shown in Kcdaikanal Observatory Bulletin. XXYIII (published in 1912) that there was a remarkably constant

[1] See page 107. [2] Monthly Notices of the Royal Astronomical Society, LXVII, 451,

excess o£ east over west, the mean percentage for tlie period amounting to 52'70, Only in the year 1904 was it very small, 50*07.

The Oatania prominence records of Mascari and Kiccò for the years 1894 to 1905 showed, according to Mrs. Maunder's summary, an eastern percentage of 50*84. The Kenley records of 1890 to 1904 show an eastern percentage of 50*80. That these figures, which are so closely similar, are lower than the Kodaikanal figure, is evidently due to the fact that very small prominences are omitted, because of the small Kenley instrument and the Oatania custom of neglecting prominences below 30" ; for when the Kodaikanal prominences were divided into large and small, it was found that the eastern percentage was less striking with the large; it was less also when prominence areas, instead of prominence numbers, were taken. This'fact finds an easy explanation by supposing that the apparent damping effect of crossing the visible disc only diminishes the area of large prominences, but entirely obliterates small ones.

But immediately after this conclusion had been reached, the eastern excess suddenly fell. In the second half of 1912 the numbers on east and west limbs were almost equal, the eastern percentage being[1] only 50*54, and the areas actually showed a western excess. The proportion in 1913 was almost the same, and in the first half of 1914 there wais for the first time a slight western excess in the numbers. In the second half of 1914, the eastern percentage of numbers was 50'45.

In Kodaikanal Observatory Bulletin XXXIII it was shown that between 1905 and 1912 there was a 13-month period of slight variation in the excess of east over west : it now seems probable that the excess varies over long periods also. For in 1904 the numbers east and west were nearly equal (1,362 eastern prominences and 1,358 western); in the next 7-J years the proportion on the east was always over 52 per cent, the highest being 53*92 in 1910; then in the second half of 1912 it suddenly dropped again to be nearly equal, and the mean for the 2-J years July 1912 to December 1914 was 50-30.[1]

It is interesting to find that the eastern excess had been noted ten years before the publication of Mrs. Maunder's paper by the Eussiaa astronomer Sykora of Dorpat Observatory. Writing in August 1897, he showed that during the seventeen years 1880 to 1896, prominences had been more frequent on the east than on the west limb, the mean percentage east being 51*5. Sykora found an explanation in the sun's rotation,[2] Riccò suspected instrumental causes,[3] and then the unexpected discovery seems to have been forgotten.

The explanations offered by these earlier astronomers occurred also to the observers at Kodaikanal, but after investigation both were found to be inadequate. Although the visual observations at Kodaikanal may possibly be affected by

[1] The eastern percentage of prominence numberB for the year 1915 is 49*58.

[5] Memorie della Society Aegli SpefctrosopisM It»liani, XXVI, 161. See also ibid., XX7II, 33.

[s] Ibid., XXVIII, 189.

the position angle of the spectroscope, the photographs certainly are not: for there is nothing in the construction of the spectroheliograph which could cause a larger number of prominences to be photographed on the east limb than on the west, and the plates show no difference in distinctness all round the disc. And as regards solar rotation, if this had an effect, e.g., if some resisting medium surrounding the sun should cause prominences to glow more brightly on their advancing than on their receding side, this effect ought to be greatest in equatorial regions, where the velocity of rotation is highest; but such was found not to bo the case. Prominences in low latitudes showed, on the contrary, a slightly smaller eastern excess than those in high latitudes.

Significant is the further discovery made at Kodaikanal in 1912, that prominences are apparently not only more numerous but more active on the eastern limb. " Metallic " prominences, i.e., those into which rise deeper-lying gases than are usually observed, and prominences showing displacements in the lines of their spectra, i.e., prominences in very rapid motion, show a specially large eastern preponderance. The eastern percentage for the former during the period 1904 to 1912 (inclusive) was 59"9 ; for the latter it was 57. In 1913 and 1914 metallic prominences were either wanting or too few for any conclusion to be drawn; but prominences with line displacements, which were very frequently observed, maintained an eastern excess to the end of 1914, though it was smaller, being 54 instead of 57 per cent during these two years. It is true that the records of these phenomena depend only upon visual observations, not upon photographs, so that it is not impossible they may be affected by observing conditions. The same cannot however be said of the prominences which are photographed on the disc as calcium absorption markings : these represent a small proportion of the total number of prominences, probably the denser ones, and they show a still higher eastern preponderance, the percentage east of the meridian during 1907 April to 1911 March being 61"9* It is also remarkable that their length is greater on an average in the eastern hemisphere.

It waa also noted in 1912, as bearing on > the same question, that line displacements in prominence spectra are more frequently towards the red than the violet, which indicates a direction away from Earth, as if the gases were repelled: in this, almost coincidently with prominence numbers, a change is noted, for in the latter half of 1913 and throughout 1914 the half-yearly records show for the first time an excess of displacements towards the violet.

Difficult as it is to accept the hypothesis that the insignificant planet Earth exerts a damping influence on the mighty forces at work on the sun, no better hypothesis has yet been suggested. Search has been made for evidence that other planets have the same kind of influence on the sun, but the final conclusion reached was that they have no such influence.[1]

1 Kodaikanal Observatory Bulletins XXVIII and XXXV.

n.—METALLIC PROMINENCES.

Prominences, as is well known, are composed of hydrogen, calcium and helium gasss. But during eclipses, when their bases can be seen, lines of sodium and magnesium and the enhanced lines of iron are also always visible, and these lines are sometimes visible under ordinary conditions when seeing is good. At times these low-lying gases rise higher than usual, and the two D's of sodium, the b group of magnesium, and b_3, 513G, and 4924 of iron appear in long stretches of chromosphere, or in the lower part of a prominence ; on rare occasions they reach considerable heights, spreading throughout the entire extent of large prominences. Occasionally also other iron and calcium lines, the fainter lines of helium, and lines of the following elements are seen : barium, cobalt, chromium, titanium, nickel, vanadium, manganese, lanthanum. Twenty, thirty, and even forty lines have been recorded at Kodaikanal in a single prominence, and on one occasion over fifty were seen.

These prominences,,usually called "metallic/[5] are exceedingly few compared with the sum total of prominences, and nearly always they are small; but they Seem to betoken an unusual form of activity on the sun, hence their investigation is of interest.

It is sometimes assumed that they occur only in association with sunspots, or at least only in sunspot regions, but the observations now under review prove that this is only true with limitations. Mr. Sitarama Ayyar's investigation of the Kodaikanal records shows that throughout the period 1904 to 1914 a considerable proportion of metallic prominences were found in high latitudes, the highest being 88° in the northern and 82° in the southern hemisphere. The total number observed was 515, and of these 103 or 20 per cent were in latitudes above 30°, and as many as 75 or 14 per cent above 40°, quite a number being found in polar latitudes.

All those, however, which rose to an appreciable height, and very nearly all those which had a considerable number of lines, or any unusual lines, in their spectra, were confined to sunspot latitudes. Out of the 515 metallic prominences, there were 68 which showed lines other than those of sodium, magnesium, and the commonest iron lines; and there were 37 which reached 10" or over in height. Of these 37, 21 were close to sunspots, and although some of the rest were ten or twenty degrees distant from any spot, they were invariably situated in regions covered by far-reaching faciilas, and may probably be considered as belonging to sunspot disturbances.

In the year 1904 there was a comparatively large number of prominences with many and unusual spectrum lines, and a very remarkable outburst of these in high latitudes occurred, for on Marcli 6, 7 and 11, five of this type were seen on the west limb in latitudes 34° to 80° south; yet only three times since has this kind of prominence been seen in latitudes above 30°.

The year 1905 was signalized by the highest metallic prominence, and also by a prominence showing the largest number of lines, which were ever witnessed at this observatory. On January 18, thirty-four lines were recorded between D and F, and at least twenty more were seen on the violet side of F, in a very bright prominence situated over a sunspot which was crossing the west limb at 9° south. Ten days Jater an enormous complex sunspot, which had already crossed the disc once, and was destined to appear again twice, was coming round the east limb at latitude 12° south, when Mr. Sitarama Ayyar saw here a great jet pouring northwards, 108" in height, and noted that its whole shape could be seen in most of the many lines he recorded : among these are lines of nickel and chromium and several of iron, as well as the usual lines of magnesium and sodium. In tie same year, on March 8, at 27° north on the east limb, almost the whole of a very bright eruptive prominence, 60" high, was seen in sodium and magnesium. It was a broad double jet, with a base of 4°.

The year 1906, which marks a dip between the two sunspot maxima, holds the same position here, for it comes between two years prolific in metallic prominences and is almost quiescent, only one prominence being observed with lines other than the common D's, b's, and Fe lines, and only one of appreciable height. This, however, was a notable one, as the whole of a very bright prominence,, consisting of two short thick columns, the base 4° and the greatest height 50", was seen in magnesium and iron. This was on February 5, on the west limb at 22° south. No sunspot was here, but a train of three spot-groups about 10° south of the equator had just crossed the west limb.

1907 was a year of marked maximum for high metallic prominences, the finest of which was seen on February 26 at 14° to 20° north on the west limb. The main part of a great outrush, 70" high, was clearly seen in Na and Mg when sunspot 6113 (Greenwich number) was crossing this limb at 14° north. This year was also a maximum for metallic prominences showing many or unusual lines, and one seen on February 18 showed no less than 42 lines. It was one of a whole series of metallic prominences which appeared on the west limb, from 20° south to 2° north, when a very large group of sunspots was crossing.

Although the number of this class of metallic prominences was sustained almost equally during the three following years, they then represent almost entirely prominences with faint helium lines only in addition to the commonest lines. The most remarkable in these three years (1908, 1909 and 1910) was seen on the east limb at 12° south on November 19,1910. It was very bright, eruptive, in the form of an irregular filamentary column 60" high, and with base 3° ; the column was visible in D_x, D_2, \, b_2, b_3, b_4 ; and at its base six other bright lines, of iron and helium, were seen. It was associated with sunspot 6914 (Greenwich number), but this was not a large spot, like those previously mentioned: it was a small group of a few small spots, which died out before reaching the meridian. In© mean latitude was 13° south.

In 1911, when the sunspot curve was very low, there was also a great falling off in metallic prominences, for only two had a considerable number of spectrum lines, and there was only one of measurable height. This one was very bright, 25" high, and with a base of 5° ; it was completely visible in D_t, B_a, and the four b's, and was evidently connected with a small aunspot which crossed the west limb at 15° south on December 29.

The minimum years of 1912 and 1913 produced no5 a single metallic prominence of measurable height, and only one with more than ten linos in its spectrum. 1914 also had no high metallic prominence, but the beginning of fclio new cycle was marked by two prominences showing as many as ten and eleven lines.

It is clear then that these special metallic prominences, that ia to say those which reached an appreciable height (10" and over), and those which had other lines in their spectra in addition to sodium, magnesium, and the enhanced lines of iron, had their maximum frequency at sunspot maximum, not at the maximum of prominences in general, for their numbers were much greatest in 1907 and as with sunspots there was a fall in 1906. Mr. Sitarama Ayyar also tabulated separately all metallic prominences which, besides the universal D_8, showed other helium lines in addition, and found evidence that these were aomewhat closely connected with sunspots, for they were absolutely confined to sunspot regions, the highest latitudes being 26° north and 23° south, and their mean latitude decreased from 17° in 19CU to 9° in 1910, in accordance with sunspots, which decreased in latitude from 16° to 10° between 1904.- and 1910. The frequencies for different years also show a close similarity to sunspot frequencies, small as the numbers are.. for there is the same fall in 1906 and rise in 1907, the numbers are sustained till 1910, and then drop to a minimum of zero in 1913) as may be seen in the table below;—

Table of Metallic Prominences

Year	Total number	Mean daily number	Above 10" in height or with. many lines	Wifcli helium linen other than D_3
1904	49	...	13	3
1905	80	0-282	11	3
1906	41	0162	1	0
1907	120	0-412	22	6
1908	92	0-322	15	8
1909	43	0-152	15	7
1910	31	0-102	15	8
1911	24	0-084	7	4
1912	13	0-048	3	3
1913	5	0-018	2	0
1914	17	0-162	2	1
Total ...	515	...	106	43

• Altogether, 154 metallic prominences were closely .associated with sunspote, chiefly long-lived spots with more than one apparition, which are usually more active than non-recurrent spots, and 100 of these spots showed reversals of *thoRa* line at some time or other when crossing the disc. But 154 out of a total of *oU* metallic prominences is not quite 30 per cent, and, as we have seen, not more than SO per cent were within sunspot regions. Yet it is interesting to find that the total yearly numbers of metallic prominences vary in the same way as the numbers of sunspots. In the above table every column, whether relating to metallic prominences in general, or only to those classes which are more closely related to sunspots, shows the same fall in 1906 before the maximum xs reached in 1907, and these two years are crucial. For 1906 marked a dip in the sunspot curve between two crests, and 1907 marked a similar dip in the prominence curve. This was shown on diagram I, fig. 1 ; and fig. 5 on the name diagram, which has been constructed from column 3 (Mean Daily Numbers of Metallic Prominences) in the table above, resembles the sunspot curves, and differs from the prominence curves.

The yearly mean latitude of metallic prominences, when all classes are included, varies quite-irregularly, not in accord with that of sunspots ; but this is owing to the irregular occurrence of small metallic prominences in. high latitudes. If only those which occur between the equator and latitude 30° are tabulated, thero is found to be a close agreement with sunspotg, as the following list will show. The figures are slightly higher with the metallic prominences than with the sunspots, but they always rise and fall together with the singlo exception of tho year 1910, when there is a slight rise in sunspot latitude while metallic prominences remain nearly stationary.

Tear	Mean latitude of meif^I*ominenoes at 30° and under	Moan latitude of attt«pot«* *
1904	23°-0	16°'6
1905	l5°-4	13°-1
1906	15°-7	14P-0
1907	14P-4,	12°-1
1908	12°'6	!0°*4
1909	l0°-5	9°-7
1910	10°-3	10°-5
1911	9°'6	6°-5
1912	10°-2	8°*1
1913	26°'0	23°'2
1914	20°-8	22°«0

Like sunspots, and like all other prominences, metallic prominences wore more abundant in the northern hemisphere than the south during the years 1905 and 1906, and afterwards predominance passed to the south. If we consider only

[1] The fignres in this column are taken from Greenwich records, except the last, which, is taken from Kodaikanal records, as Greenwich PhotoheJiographic Besults for 1914 are not yet published.

metallic prominences showing a considerable number of lines, this southern, predominance was indeed enormous, for out of *66* such prominences 48 were m the south, and it is remarkable that they extended from 0° up to 78° south, while the 18 northern prominences of this class only extended from 0° to 30° north. We have already seen that metallic prominences are more abundant on the east than on the west limb, the eastern percentage being 59-9: this, combined with their southern preponderance, results in the fact that during this period (1904 to 1914) there was a very marked excess in the south-east quadrant and defect in the north-west.

The conclusions to he drawn from this investigation of 515 metallic prominences may be stated as follows :—

(a) The connection between metallic prominences and suns pots is not so close or so universal as has often been supposed, for they occur all round the limb, even in polar latitudes ; but if we exclude slight elevations of the chromosphere, and consider only the prominences into which low-lying gases rise to measurable heights, or in which the common lines of sodium, magnesium, and the enhanced lines of iron are accompanied by other Iine3, these prominences are almost confined to sunspot latitudes, and are often situated so near sunspots that there is an evident connection. The sunspots so connected are usually large and active.

(o) There is a general connection between sunspots and all kinds of metallic prominences, indicating a common cause, for the sunspofc frequency curve resembles that of metallic prominences more closely than of the generality of prominences. The mean latitude of metallic prominences also, if those above 60° be excluded, varies from year to year similarly to the mean latitude of sunspots,

(c) That the sun is more active on the east than on the west side, which was suggested by the eastern preponderance in numbers of prominences as well as sunspots, is borne out by the metallic prominences, which show a still higher eastern percentage.

(d) The greater activity of the southern hemisphere than the northern, in the years 1907 to 1914, which is evidenced by the greater abundance of southern prominences and sunspots, is confirmed by metallic prominences, since they are not only more abundant in the south, but those which show other lines besides the most common preponderate enormously there, and are occasionally found high up in south polar latitudes.

III.—MOVEMENTS IN PROMINENCES.

1. *Movement due to the Sun's Rotation.*— Prominences, even those known as quiescent, are in a continual state of change, indicating motion in various directions, and the spectroscope often reveals motions in the line of sight; but there must also be a general motion shared by all prominences, since they are continually being carried from east to west by the sun's rotation. The speed of

Bolar rotation in known to vary in different latitudes, and also apparently at diffurent levels, for Adams Hound that the chromosphere rotates faster than the roversinfr layor or tho photosphere[1] It would be interesting to discover whether when ono nmcluw a at ill groator height, among the prominences, the average HpM*l of rotation *m* the samo an that of tho chromosphere, or faster still.

in 10U, tho IT and *K* lines in 01 prominence spectra were measured by Mr. KVWHIHHI with this objootr,[2] on platws which had been taken at different dates boiweon Novombor 1908 ami ,hum .1911. The latitudes of the prominences ranged from ntmr tho injunior to ft 2" north and aouth; thirty-one were on the east limb, and thirty on tho wont. Tho results are given below, together with Adams' VflofitifH for tho chromosphoro aud tho reversing layer at the same latitudes.

	Mnan	Mean height	Moan synodic velocity in km/sec		
			Promi-uonccs	Ha its. the ettromo-,sphere	Reversing layer
31 Eastern *\mmmww>Aw*	30°·7	40"	2-12	1'76	1-64
Mi Western prominences	31°·2	52"	1-98	1-75	1-63
General mean	31°	4,1)"	2-05	1-75	1-63

Tluw* vt4ocitio« are oquivalont to the following angular speeds per diem :—

Prominences	Chromosphere	Reversing layer
17°	14°·6	13°·6.

ti *U* (if oourdn only to bo oxpootod that individual motions in the prominences, all Umti'li " (inie.-wiml." pniminonoos woro selected, shotddintroduce a good deal of ViiriH.)' i». indivi.lui.1 CfKeK : Uie velocities vary from 0-56 to 4'24 km/sec, and on tin- i-u-'l i'i-lil, Hive volooiUns bi>low normal, on the west fifteen.

TI..- i.'.vr,ti,'ali<m iH only prdiminavy, but it indicates, so far aa it goes, tSr.t H.< wiL'Hlar Bp«..l of rotation in prominences at the level of about 4o is ,,nW|,nWv Vm..* tU,m tlmt of tbo clu-omosphcre. H thiB is <«»*****}* fn.nr, *u^uu,* of promin.nc, ^IH, &O curious ^ ^ ^ ^)h, |(i,,U,..- .1,, M..l,,r vnjK.uw ris,,, O.o barter their period of rotaton. Eclipse ,,| «,, , , ', ,. . .· . . . lica... U,o»gh h- alBO conation is needed, that the « law U..1.N i,. «),, «,«,..«, far Ownpboll in 1898 deduced » rotate 1 ^oc^y fo r the inuer corona „f »-l km'soc,.' The problem is, however, a difficult one, aa tne strongest line.

[1] Papers of the Mount Wilson Solar Observatory, vol. I, part 1, page 180.
[2] Annual Report of the Kodaikanal and Madras Observatories for 1911, page 5.
[3] Astrophysical Journal X, 186.

would probably be necessary to eliminate proper motions in the corona, which are suggested by the erratic movements shown to exist in prominences. Bosler's result, however, obtained by measurement of the new red coronal line at the eclipse of 1914, confirms Campbell's, for he finds a rotational velocity of 3-9-km/sec.[1] which would correspond to a considerably greater angular speed than that deduced above for the prominences.

A curious feature which has been observed in a number of prominence spectra photographed at Kodaikanal is that the lines, which are sharp and woll defined at the base of the prominence, become fuzzy at the top, an appearance suggesting turbulent motion at the height of one or two minutes of arc above the chromosphere.

2. *Movements North and South*—Mr. Slocum has investigated a number of prominences which have the appearance of being blown to one side, and camo to the conclusion that currents exist in the solar atmosphere which cause a tendency for prominences to move towards the poles in middle latitudes and towards the equator in high latitudes.[2] It is, however, exceedingly difficult to imagine that at the height reached by prominences any atmosphere of sufficient density can exist to produce currents ; and it is so common to see a prominence spreading out at the top, tree-like, in both directions, and neighbouring prominences bending in opposite directions, that it is difficult to believe that these forms are due to solar winds. (See plate VI, plate VIII, fig. 11, etc.)

The fine filaments which *jexy* often proceed from prominences, and which Mr. Slocum,, regards as the effect of north or south winds, are also frequently seen on both sides of a prominence, and they so often connect or nearly connect prominences together that they suggest an attraction of some kind.

In 1872 the same idea of solar winds occurred to Secchi, who believed, on other grounds, in the existence of a solar atmosphere above the chromosphere, and a circulation from the hotter equatorial regions to the cooler polar regions. His tabulation of prominences bending north and south proved, he thought, a general tendency to incline towards the poles and away from the equator ; but as his observations only extended over half a year, from July to December 1872, they were evidently insufficient.[3]

Although many prominences bend northwards and southwards, it is rather remarkable, and opposed to the theory of currents, that rapid motion in these directions is seldom detected. Wnyi drew attention to this,[4] and there have not been many instances at Kodaikanal. In a special type of prominence, presently

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[1] Comptes Rendus, OLX, 434.

* Astrophysics Journal XXXIII, 108, and XXXVII, 354, « Circulation m the Solar Atmosphere as indicated by Prominences.' See also Henroteau « On Convection Currents in High Kegions of the Solar Atmosphere » Monthly Notices of the Koyal Astronomical Society, November 1915. He deduoes the existence of currents from the foms and development of faoulse, and quotes both Slocum and Deslandres in support of his theory.

[8] Memorie della SocieU degli Spettroscopitsti Italiani, I, 43 and 44.

* Publications of the Haynald Observatory, VIIr, 114 and 115,

to be discussed, which consists mainly of jets and streamers shooting out from'a snnspot, it has occasionally been possible here to measure the upward motion, and this has been found to vary from about 2 to 80 kilometres per second, but a motion to north or south in these prominences greater than 3 kilometres per second lias not yet been measured. Yet movements in the line-of-sight amounting to IO0 kilometres per second are not uncommon at the sun's limb : the most rapid observed at Kodaikanal was in the chromosphere, on the west limb at 23° north, where on December 4_3 1906, a line shift was recorded of six angstroms,, equal, to 280 kilometres per second.

B. *Hitting and Falling Movements,*—The most striking instances of rapid motion in prominences occur in those unusual cases where a large mass rises to a great height above the chromosphere. Several of these have been recorded at Kodaikanal, but the best observed and in some ways the most remarkable was that of February 18, 1908.[1]

On thin day, a plate taken at 8^h 23^m showed only small prominences, none of which soomed specially bright or interesting. At 8^{11} 50^m a drawing showed a group of prominences moderately bright and only 50" high, but extending over 82", and at their northern end, where there were some bright condensations, the sodium and magnesium lines were bright. The position of this long group was from 17" to 4-9" south. Fourteen degrees further south, standing aloof, was a wniall bxit bright prominence 45" high.

This might have been the last observation, for photographs and drawings are usually finished by nine o'clock in the .morning, when the best seeing is past; but the second plate taken was considered rather poor, and a third was exposed at 9^h 38™, and as usual developed immediately, when to the astonishment of the photographic assistant a large form leapt to view in the developing dish. The long group was now 81" high, and immensely Bright. It is shown on plate II, fig. 1.

fortunately the sky was clear all clay, and the prominence which had begun to develop hi this sensational way was photographed twenty times before sunset. Its rise was slow at first, for at 11^h 13^m it was still only a little over 100", but the form was changing (plate II, fig. 2). It will be noticed that a pillar at the northern end (where the bright lines were seen) is not only higher, but has reared up so as to become more nearly vertical. It is attached to the main mass by what looks like a knotted rope, and delicate threads have been thrown out between the southern end and the bright little prominence which at first stood aloof, but seems now to have turned towards the great rising mass, and grown slightly higher. By four o'clock in the afternoon, the northern end of the mass had freed itself from the chromosphere (fig. 4); and after this the rate of rising became much more rapid, and the whole mass left the surface of the. sun, except that a cable

* Afitropliysioal Journal, XXVIII, 79.

connecting it with the chromosphere Bear the small bright prominence never broke (figs. 5. and 6). At two minutes past six, when the sun was about to set, and its face was obscured by the smoke of bush fires, a last photograph was secured, which showed that the prominence was still rising, and at a greater speed than ever: its base, which in the morning had been on the chromosphere, was about 200,000 km. above it, and its summit 400,000 km. Allowing for the poor definition of the last plate it seemed to be actually fainter and smaller, so that a short time longer would probably have showed its dissolution. By the next morning it had entirely disappeared.

The most remarkable features of this apparition are its great size, the suddenness of its development, and the fact that it rose with an accelerating speed. This can only be explained by supposing that some repulsive force was acting upon it the whole time, and more than neutralizing the force of gravity.

The following table shows how the prominence increased in height, and its speed of ascent:—

Indian Standard Time[1] H	M	Iieight in seconds of arc //	Approximate Velocity of Ascent Km/sec	Indian Standard Time[1] H	M	Height iu seconds of arc "	Approximate Velocity of Ascent Km/sec
9	38	81		16	7	202	
			12				24
9	57	100		17	14	337	
			1-2				37
11	9	107		17	3(5.	405	
			2-5				84
14	33	150		18	2	585	
			6-7				

A somewhat similar eruption took place on April 2, li-Jll, but in this case the end was seen, and not the beginning. For when the first plate was taken at 8^h 41^m the prominence was already bright and 2-J minutes of arc in height, and one end was floating free from the sun's surface. This very quickly reared up until at 10* 12^m it reached a height of 5' 40" and at 10^h 38^m of 7'. (See plate III, figs. 4 to 7.) But it had become faint, and presently became changed and scattered; some flying fragments, which were photographed at 10^h 52^m, 11^h 10^m, and 11^h 24^m, reaching greater heights than any prominence previously photographed at Kodaikanal, viz., 10' 10" above the limb. The rate of ascent cannot be measured on these later plates, since the fragments cannot be identified, but on four of the early plates, there is a small bright point which appears to move radially outwards with the following velocities :—

Time	Velocity in km per sec
Between 9^h 26™ and 10* 9^m	46
„ 10* 9^m and 10* 12^	69
„ 10* 12^m and 10* 38™	87

[1] 5fc 30^m in advance of Greenwich civil time. On most of the plates two exposures were made, at intervals of [a few minutes, and to obtain the greatest accuracy possiole the mean tiina and meau height of each pair of images waa taken. From these, the rate of ascent was then caloulated,

In this case also, therefore, the velocity was increasing, and though it maybe-only a coincidence, it is worth remarking that the same speed was attained at the same height, for in both cases the rate was between 80 and 90 km. per second when the prominence was about 7 minutes of arc in height.

On May 23, 1915, so splendid and so similar an eruption was photographed that it cannot be refused a place in this Memoir, although it belongs to a year later than our period. Figs. 1 to 3 of plate III show the great mass swiftly lifting one end'and swinging out from the sun; and here also we observe the tendency to remain attached to a low bright prominence (as with the rising prominence of .February 18, 1908, figured on plate II), and the same fading away of the upper portion after the height of *T* has been reached. In each of these three cases a part of the prominence rises, as if there were some eruptive force below it, and here it. seems also to have drifted north, finally coalescing with the small hook-like-prominonce which, remains unaffected by the eruption. Measurements of a point near the top of the prominence give the following rates of ascent:—

f£jmo E M	Height in seconds of arc	Velocity in km per sec
8 ' 34	176	
		69
8 48	256	
		63
9* 22	432	

Those three prominences were not near sunspots or nocculi, but the eruption, of March 1, 1910, may be seen at its inception (plate IV) looking like a thick jet rising directly out of a large flocculus, or as if a portion of the floccalus had itself been projected beyond the limb. The flocculus was accompanying sunspot 6817 (G-reenwich number), as it crossed the west limb at latitude 7° south. The exceedingly bright jet which, when measured on the flocculus plate, was only 15" high,, became in ten minutes a slanting streak 70" high, and on the prominence plate was seen to stand out from a number of smaller streaks which slaftted mostly in the opposite direction. Half an hour later the long streak had taken on a most remarkable form, giving the whole prominence an appearance like a tennis racket, the bright streak at the base forming the handle: it was now nearly 6' in height. By 9^h 13^m the upper part had mostly disappeared, although a portion had become very brilliant; by 10^h 5^{in} all had disappeared except the brighter part or handle of the racket; at 10^h 30^m and 14^h 20^m only jets of 60" and less were photographed in this region. Measurements of the first three plates show that, like two of the other great eruptions just described, this prominence was rising with increasing velocity, and attained the same maximum speed when approaching the same height.

Time H 'M	Height in. seconds* of ar0	Velocity in km per sec
8 0	15	
		66
8 10	,»•	
		8?
8 48 *	M5	

A velocity of 120 kilometres per second at the base of the prominence, in a direction towards the observer, was indicated by displacements of the hydrogen lines.

Once again, beside the large rising prominence, note a small bright prominence, pointing a finger, as it were, at the ascending mass, but itself increasing only slightly in height.

This eruption, however, differs from the other three, in that the original massive jet does not rise bodily from the sun's surface, nor swing out towards a vertical position : the force here appears to be of a more explosive nature, and tho prominence seems in fig. 3 (plate IV) to have simply burst into fragments.

Six other rapidly rising prominences maintained their original for m sufficiently long for successive measurements of height and velocity to be made ; but none of them could be observed for more than one or two hours, because of poor definition •or because they soon faded away. It is, moreover, difficult to be sure that an apparent increase in height proves a rise, because in earlier photographs the prominence may have been equally high but its upper part too faint to show-Tet it is at least noteworthy that in four of these cases the velocity #as apparently accelerating. They were as follows :—

1907, April 9.—A compact mass of interlaced filaments, extending from + 16° to •+• 38° on the east limb, was photographed three times, and*waa found to be rising: unfortunately conditions were too poor for obtaining further plates, and by the next morning it* was gone. The rates of rising were as follows :—•

Time H M	Height in seconds of arc	Velocity in km per sec
8 34	105	
		7
8 55	H7	
		12
9 13	135	

1907, July 4.—An intensely bright eruptive streak, detached from the chromosphere, and nearly vertical, was observed at 5° south on the "west limb. It was rising higher, and also drifting slightly north.

Time H M	Height in seconds ofarC	Velocity in km
8 10	200	
		48
8 14	240	
		226
8 18	315	

The next plate, taken at 8> 41-, was obscured by cloud, and the definition on all was not very good, so that the enormous velocity apparently attained b7 this prominence is perhaps exaggerated.

1908, February 4—A small mass, base 5°, at 60° south on the west limb, roae up from the sun's surface, becoming quite detached, and later was only seen as a few faint streaks. The velocity here seems to have remained practically constant.

Time	Height in seconds of arc	Velocity in km. per sec
U M		
8 49	65	
		6
9 16	80	
		7
9 55	105	

191.1, November 28.—At 51° south on the west limb there was a bank of prominences, over which a cloud floated at a height of 150" at 8^h 53^m. This rose in 1J hours to a height of 240" and then remained stationary. • The velocity of ascent was as follows :—

Yj mii	Height in seconds of arc	Velocity in km per sec
tr M		
8 53	150	
		7
9 18	165	
		12
9 54	200	
		18-8
10 22	240	
		Stationary.
10 35	240	

On the first and the two last of these plates tne prominence was faint.

1911, November 30.—Two days later, on the east limb at 23° south, a vertical cloud 4|- minutes in height stood over a very small prominence. This cloudy pillar was detached, but its base was not at first very high above the chromosphere. The whole rose very rapidly: in less than an hour the base was 2 minutes and the summit 5| minutes above the chromosphere, and in another hour the base was 3 minutes and the summit 7J minutes above. As it rose it became much fainter, and at first broader, but the last plate shows it as two faint long streaks* roughly parallel to one another and radial to the limb.

Time	Velocity in. fan per sec
Between 8^{11} 50«' and 9^h 37^m	16
Between 9^U 37^m and 10'' 21^m	27

We now come to the exceptional case in which the ascent was not accelerating in speed, but was in part uniform and in parb decreasing during two hours. On August 31, 1912, a very large cloud was suspended above the chromosphere at 15° to 35° south on the east limb, but was connected with it by very slender arch-like filaments. The details of these filaments underneath the main mass were rapidly changing and appeared at 9^h 45^m to be composed of minute bright points; but the great mass of the cloud rose slowly, without much change of form. It will be seen from plate V, fig. 1, that the under surface of the cloud where it stretches out towards tne south (left), and there abruptly ends, is very definitely bounded, and brighter than the upper surface : the rise of the lower surface was calculated from measures taken at this southern end ; the rise of the upper from its highest part near the northern end.

Time	Under Surface		Upper Snrfaco	
	Height	Bate of Ascent	Height	Bate of Ascent
H M				
8 11	40"		136-	
		6 km/sec		36 km/sec
9 11	70"		15b'	
		6 km/sec		24 km/sec
9 45	90"		162"	

A later photograph taken under cloudj conditions at 10^h 11^M showed that no marked increase *in.* height had occurred, but it is of course possible that a swift and sudden rise occurred later, just as happened with the first-mentioned of these prominences (February 18, 1908), which rose only slowly until after 4 p.m.,. and then showed a rapid increase in its rate of ascent. But it is exceedingly rare that prominence photographs can be taken in the afternoon at Kodaikanal, and the later history of this one is unknown. No trace of it was visible next morning.

These floating clouds, which are either completely detached from the chromosphere, or attached only by a few slender threads, are a very interesting form of prominence. A very singular one, whose base was 50" above the chromosphere, was observed by Mr. Evershed on April 6 and *7,* 1892 (see plate XII), its form and height remaining almost the same for at least 24 hours. A bright and very remarkable one, photographed at Kodaikanal and shown on plate V_s fig. 2, rose very quickly, but the record does not allow us to infer whether with increasing, diminishing, or uniform velocity. At 8^h 17^m it was in touch with the sun's surface, and was only 150″ in height; at 10^h II"[1] when the photograph here reproduced was taken, it was floating, as may be seen, at a, great height, and the summit was 4' above the sun's surface. By 11^h 30^m it had disappeared, except for a small fragment, which hovered at a height of 6'; and at $I4^h$ 34^m nothing was left.

Three other clouds are shown on plate V, figs. 3, 4 and 5. The first is bright and compact; the second is a long mass 90" high above the chromosphere, which rose and changed in form, reaching 120" at $I4^h$ 34^m; the third is connected with the chromosphere and with a small bright prominence by slender threads. These threads became thicker and more numerous daring the morning of December 6, but the cloud itself did not rise or change much in any way until the following morning, when it was found to have broken its connection temporarily with the small bright prominence and soared upwards, and it had also become mudh. smaller and fainter. New threads were thrown down later to the small prominence.

Another cloud, represented on plate V, figs. 6, 7 and 8, is seen to be definitely descending. This is rather an unusual case, for a large mass has not-often been seen to sink down bodily like this, although portions of prominences often descend, and threads are dropped by high prominences towards the chromosphere, or towards other prominences.

See for instance the strange and beautiful form in plate V, figs. 9, 10 and 11. At first it is standing entirely unsupported, a miracle of levitation ; an hour later two legs placed well apart are planted firmly on the sun's surface, and meanwhile an arm from aboye is lengthening, and stretching downwards.

Somewhat similar is the wonderful changing prominence of January 12,1909, which, like the last, has an appearance of soaring, yet does not soar. (See plate VI.) Here the lower part fades, instead of growing stronger, or possibly it has been driven up and absorbed in the upper broad portion, which in fig. 3 has grown distinctly denser and brighter; yet this upper part apparently cannot ascend in unison, but seems rather to be curling over and forced down; and in the last photograph (fig. 4) the stem is forming once more. The changing form suggests the simultaneous action of two opposed forces. Note also how the neighbouring bright prominence grows smaller and separates from the large one.

On plate VII, on the contrary, we see a fusion of prominences which at first were separate. In figs. 7 and 8, the tall slender prominence which at first is distinct from its neighbour, and spreading slightly in the opposite direction, later seems to be facing it, and the two are united. Changes are also talcing place in tho group near by (seen on the right in the same figures). In figs. 1, 2 and 3 what appears as a series of prominences with a detached member has become an hour later one threat mass. And in both these instances the prominence groups have increased in height. A wonderful transformation is shown in figs. 4, 5 and 6, where a prominence which is rising and growing changes its shape twice so completely that, but for its position being known, it would be unrecognizable.

These rising or floatiug prominences, besides delighting the eye with their extraordinary beauty, present problems of deep interest. What force, in spite of gravity, holds suspended great masses of gas, apparently in the void, so that they neither descend nor dissolve for hours ? What force, overcoming gravity, drives upwards great masses at an accelerating speed? This is no mere explosion, but the continued action of some repulsive force, probably the same that produces comets' tails, and keeps them always swinging out away from the sun.

Further, what becomes of the gases thus expelled ? Do they, after becoming diffuse and dark, fall back upon the sun ? or are they driven forth into space?

IV.—FORMS OP PROMINENCES.

1. *Large High Prominences.*—The forms of prominences are so many and varied that it seems impossible to find a system of classification which shall include them all. There are a few shapes which recur with some frequency and are

readily recognizable, such as Moating Clouds, Banks, Arches, Trees, Spikes, Pillars ; but besides these are a host of others which resemble nothing, and now and than one will be seen which quaintly recalls a Dog, an Ant-Eater, a Cauliflower, or a Bird's Wing. How are such strange shapes to be described or classified as those shown on plate VIII, figs. *7,* 8 or 12 ? Yet they are perfectly definite, and it should be noted that there is no such thing as a nebulous prominence. Cinder good conditions of seeing, every one is full of structure, and they are often sharply bounded. See for instance figs. 3 and 8 on plate VIII, where the outer limit is bright and sharp; and in fig. 1 on the same plate an inner boundary is equally clear. The distinction between "eruptive" and " quiescent " prominences tells us nothing about their shapes except that one is changing quicldy and the other slowly; at certain stages they may closely resemble one another; and tlio forms in both classes are endlessly varied.

Looking through these eleven years, however, it seems that the greater number of the large high prominences on our charts (those of one minute in arc and over) may be roughly divided into four classes. These sometimes run into *one* another, and where there was doubt about their class prominences have been omitted, but the rest have been tabulated, in order to see in what latitudes arid in what years they were chiefly found. The total number amounts to nearly 1200 ', and the four types are as follows :—Broad massive prominences, Tapering forms, Diffused forms, Prominences in rows.

(a) Broad massive prominences.—These have wide bases, 5° to 25°, either resting directly on the chromosphere or supported on a few slender columns, and they often show a horizontal structure. Examples of the first are plate VIII, figs. 1, 2, 4, 5 and 6, plate VI the prominence on the left side in all the figures, and plate Til, figs. 1, 2 and 3, the large prominence on the left, which at first looks like a church and afterwards like a peacock. An example of the second—massive prominences supported on stems—is the larger prominence of fig. 11, plate VIII.

These prominences are evidently of considerable thickness as well as breadth, for many remain visible for several days. Prom ten to twenty were counted in each year from 1905 to 1910, the greater number (about 70 per cent) being in sunspot zones but never above a sunspot; in ,the minimum years 1911 to 1913 they were very rare, but in 1914 suddenly reappeared in large numbers in latitudes 40° to 55°, enduring usually from two to eight days, and it is to this class that the high-latitude zone of activity in 1914 is chiefly due. The zone in earlier years, 19J0 to 1913, was less marked, if both hemispheres be considered together, and it was then due to smaller prominences at these latitudes.

(b) Tapering Forms.—These high narrow prominences may generally be described as columns, pyramids, or jets. They are about twice as frequent as the broad massive forms, and are so familiar to all observers that illustrations are

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* In tWs case, a prominence which remained visible for two or move days was counted as one **only,**

scarcely necessary. Columns may be seen on plates V[I, fig. 8 and IV, fig. 8, a pyramid on plate IX, fig. 2, and a jet on VIII, fig. 9. Forms such as that ofVlII, fig. 8 are also included. Straight vertical jets are not uncommon, but that shown on plate VIII, fig. 9, is an unusually striking instance, straight as a flagstaff and dra ped with a half-furled flag. It has never fallen to our lot at Kodaikanal to see a column of spiral structure such as have been figured by Young and some other observers.

High narrow prominences occur in all latitudes, but the greater number (nearly 70 per cent) belong to the high-latitude prominence zone between 40° and 55°. In the years 1905 to 1908, when prominences became frequent in polar latitudes, these forms were often seen there, at 70* and higher : on April 21, *1?* a jet 95" high fetood almost over the south pole, and in 1908 one 15o" [1] was at latitude 80°. But from 1909 onwards they scarcely ever appeared [1] latitude 55°. In the minimum years 1912 to 1§14 tapering prominences w only less frequent than in the years when all prominences were more abanu but it *in* noted that the columns which did appear were not so straight, and b> pyramids not so compact, as in maximum years, but often curved or bent o. smoky in appearance. Small jefcs of 30" or less often stood over sunspots throughout the period, but columns or pyramids or straight high jets such as that in fig. 9, plate VIII, never.

(c) Diffused Prominences.—These take many shapes, but they are not so compact and dense as the other two classes, but spreading and cloudy in appearance. Not that they are cloudy in the sense of being nebulous and devoid of structure, for these above all are usually most easily seen to be composed of delicate filaments throughout. Examples are seen in plate V, figs. 9, 10, II, in plate VI, and in plate II, figs. 5 and 6. Floating clouds almost always belong to this class, and also the tree form which may have a compact stem, but spreads widely at the top.

These diffused spreading prominences form much the commonest class, and it largely preponderates in every year, especially from 1907 onwards, with the exception of 1904!. In that year most prominences were drawn as more or less compact columns or pyramids, but this is evidently due to inexperience in observing and drawing: when this had been gained, and especially when good photographs were added, fine structure and faint extensions were recorded where they would not before have been seen. It was not found, however, that there is any essential difference between prominences seen in hydrogen and photographed in calcium, except that the photographs show many more fine filaments, and these often, join prominences which in the visual observations seemed distinct, or join to the chromosphere clouds which in visual observations seemed to float clear above it. These fine threads form one of the most constant and remarkable features of limb photographs: they stretch in every direction, and are vertical, horizontal, straight, or curved. See especially plate VIII, figs. 5 and 6, and plate VII, figs. 2 and 3, for filaments approximately horizontal ; plate VI, plate VIII, %• 7, and plate V, fig. 11, for filaments curving downwards ; and for prominxes obviously composed of filaments the broad masswe forma of pfcte VTT, fig 4 and plate VUI, fig. 4, and the diffused forms of plate VI and plate V} *bg.* 9.

Diffuse prominences rise higher than any other kind, or perhaps one ought rather to say that when prominences rise very high they almost always spread out, becoming more or less diffused and faint, as if a compact mass could not exist beyond any considerable height.

From 1905 to 1910 diffused prominences formed 45 per cent of the large prominences above one minute high in arc, and the years were all very similar in this respect But in the minimum years 1911 to 1913 the percentage rose to nearly 75, this type therefore taking the place to a great extent of more compact and massive prominences. In latitudes 40° to 55°, instead of pyramids, were groups of faint broken jets more or less united by long streamers, and in 1912 and 1913 the number of faint prominences is particularly noticeable. In 1914, after minimum was passed, we have seen that a large number of massive prominences appeared again, and the percentage of diffuse prominences fell to a little below 60.

The distribution in latitude of this class of prominence shows that they are found in almost equal abundance in both low-latitude and high-latitude prominence zones, for the number found below 30° is only slightly greater than the number between 30° and *60°*. During the years 1905 to 1908, when prominences advanced to the poles, a few of this class ranged to high latitudes, some reaching 85°, bufc these form a very small minority, and from 1909 onwards not more than- a dozen occurred higher than 55°. Some high diffuse prominences hover over sunspots, but these form part of another type, the main part of which is low. Otherwise this class is not associated with sunspots.

(d) Prominences in Bows.—This interesting type, remarkable rather for ©xtent than height, is a series of prominences close together, narrow at their bases but spreading*out and meeting one another at the tops, as if standing in a row and holding hands. Sometimes a series extends over thirty and even sixty degrees, with eight to ten prominences composing it, and frequently the series is longer than it appears, because it is extended in longitude, and successive portions appear on the limb for two or three days. When the prominences are of nearly equal height the series looks like a row of sheaves. It might be included among Diffused Prominences, since each member has the tree-like form which when occurring singly was counted in that class; or when the sheaves are very close together it might be considered as a Broad Massive Prominence; but the type has in it something so distinctive that it seems worthy to rank as a separate olass. An instance is shown among Mr. Evershed's drawings on plate XII, in a **group** seen on June 6,1891.

Rows of Sheaves are very stable, being frequently visible for two, three or iour days on one limb, and then reappearing on the other limb after about fourteen days. Sometimes they cross the disc more than once, and then, if the sheaves are close and bright, they may also be seen upon the disc in calcium disc-photographs as an absorption marking. One very characteristic row appeared first on the west limb on February 13, 14 and 15, 1909. The central part of this was evidently the highest, and also a little in advance of the rest, the line bending back eastwards on both sides ; for on the first day it extended only over 12° (from + 1° to -11°), and was only 30" high; next day it reached its full height, 75", and extended over 27° (from + 5° to - 22°); on the third day the central part was evidently beyond the limb, for it was only 60" high, but the whole line was visible for h6° (from + 18° to - 23°): On February 27 and 28 the row reappeared on th« oast limb, 80" high on the first day, and 70" on the second day in the central part, but only 20" and 30" high at the ends, and tlie extent in latitude was 82° (+ 3° to - 28° on the 27th, + 7° to ~ 25° on the 28th). Nothing similar was photographed on the day when it should have reappeared on the west limb, but on the east on March 26 some irregular sheaves appeared at + 9° to — 29°, the highest of which were 45".

In the years 1904-1910 the number of Rows of Sheaves varied from 11 to 22 per year, and the average number for these years was 16 : in the minimum years it was much less, being t> for 1911, and the same for 1912, only one in 1913, and this a small one with four prominences only, and three for]914. The distribution agrees in time therefore with that of sunspots, and the distribution in latitude agrees markedly also, with few exceptions, for only 12 out of the 128 tabulated had their centre more than 30° from the equator, only two more than 45°. Most of these high-latitude Sheaves occurred during the years whem prominences extended to the poles] especially in 1906, which was the year of greatest prominence extension northwards, and on May 26 of this year one was seen actually standing symmetrically over the north pole, It was a typical row of Sheaves united at their summits by filament* stretching out in both directions.

Yet, though these prominences occur almost wholly in sunspot zones, and are* most frequent during years of many sunspots, they invariably avoid sunspots,, sometimes crossing the limb just between two groups. For instance, a Row of Sheaves appeared on the east limb, from the equator to + 31°, on October 9, 1909,. and reached the west limb on October 23 (reappearing on the east limb on November 5, 6 and 7). A glance at our charts of October 16 and 17, when this prominence must have been crossing the central meridian, shows that it occupied a position just between two collections of sunspots groups, being two days behind a very active spot and three neighbouring groups, and four days in front of four other groups.

We conclude that the classification here attempted has some real significance^ since the distribution both in time and latitude of the four classes is not the same..

For firstly, though all are more abundant during* years of many sunspots than of few, the percentage of *(a)* and (<2), and to a lesser extent of *(b),* falls off during minimum years, (i) also approbating to the *(c)* type, while the percentage of (,) increases. That is to say, compact masses and defouto groups decrease, and columnar forms tend to spread and bend, while diffuse and faint promiuenees increase in proportion.

And secondly, *(a)* is found chiefly, and *(d)* almost exclusively, in latitudes between 0° and 30°, but *(b)* occurs principally between 30° and 60°, and especially between 40° and 55°, while *(c)*, which forms from 45 to 7^ per cent of the total number, is found with about equal frequency in both zones. That is, prominences of considerable extent in latitude, whether in a compact mass or in a united group, both largely composed of filaments lying north and south, are most abundant in the region of sunspots, and of low-latitude prominence zones ; and prominences of small extent in latitude such as columns, pyramids, and shafts, ocour much more frequently in the high-latitude zones; while diffuse spreading prominences are found almost equally abundantly in both zones. All four forma are occasionally found in polar latitudes during the years when prominences extend to the poles, but otherwise these large high prominences are seldom seen beyond 60° north or south.

We note also that prominences at exceptional heights, say above *4>'* of arc, are always diffuse, and gradually become invisible through faintness if they can be watched long enough. Also that large high prominences are not associated with sunspots, although they are most abundant at the same time that sunspots abound. Those which are most extended in latitude occur most frequently in sunspot latitudes, yet select longitudes free from spots j narrow forms are more abundant outside sunspot regions; diffuse forms occur in both regions, but also avoid spots, except in the few cases where they are part of a low-lying and very distinct type which will be described in the next section.

In order to discover whether among all classes of prominences, including those under 1' in height, the. tendency is for extended forms to appear in low latitudes and narrow forms in high latitudes, the prominences of one year were tabulated in zones, and the mean base was found for each zone. 1910 was selected, because in this year the low-latitude zones between 0° and 30° and the high-latitude zones between 40° and 60° were equally active (see diagram VI), that is to say, the total area in each was nearly the same. If the mean base of the prominences in one zone is greater than the mean base in the other, it is •clear that there is a greater proportion of long prominences in the former.

A very large number of prominences are mere jets with a base of only 1° or less, but these have no special significance for our purpose, and were disregarded, only those with a base of 2° and over being entered in the tabulation. The figures were taken from Kodaikanal Bulletins, which refer only to the length of base, not of the upper parts of prominences, and prominences in groups are counted separately unless in actual contact, otherwise the figures for mean extent would be greater. *We* find that there were 873 prominences with base of 2° and over in the low-latitude zones, and their mean base was 6° ; there were 621 in the high-latitude zones, and their mean base was 4^O>3.

This agrees with what we have found for the large high prominences considered separately, though the difference is not very large. It is much more striking when we consider only the very long prominences, those of 10° and more in latitude. In the low-latitude zones there were#159 of these ; 27 of them reached 20° and over, and the longest was tf 7°. In the high-latitude zones there were only 28, four of which reached 20° and over, and the longest was 25°.

2. *Prominences associated with Sunspots.*—When looking over prominence plates day by day, as the photographs are taken, one gradually becomes familiar with a type, usually much less striking in appearance than the large and lofty prominences we have been discussing ; and soon one becomes aware that whenever one of this type appears *on* the east limb, next day a sunspot will be there.

Examples are shown on plate IX, figs, i and 2, but the characteristic features of the type are too small and fine to show well except on the original negatives. It consists of jets, spikes, and streamers, radiating north and south from a centre, which is frequently marked by a very brilliant paint or low jet: this centre is always over a sunspot. Bright bead-like condensations are often strung in rows on the spikes, and long curving streamers have a terminal bead at the tip.

A preliminary discussion of this and allied types of prominences was published in April 1913,[1] Since, then all the sunspots of 1907 to 1914 have been tabulated, and the prominences near them examined. It was not considered advisable to include the three earlier years of our period, because the best observations and Instruments are necessary in distinguishing types of prominences which are low and of delicate structure, and this was found to be almost invariably the case with prominences situated above sunspots. The conclusion drawn from this investigation ia that not only is the type just described confined to the near neighbourhood of sunspots, but that it is the prevailing type which in these eight years was associated with them.

The investigation has confirmed our previous belief that gas is always rising in the centre of this type of prominence, and that this uprushing gas has a tendency to fall back upon the chromosphere at some distance from the sunspot, sometimes building up banks or columns there (see plate IX, figs. 3 and 4), sometimes apparently continuing to rise and fall like fountains in the form of arches (plate IX, figs. 5 to 8), so that a fully developed spot-prominence covers a large space. Sometimes also the streamers may reach a greater height than usual, rising to 100* or 150" of arc ; and on rare occasions *one* large thick jet among the small spikes rushes up violently and reaches an immense height, after which it fades away. The great outrush of January 28,1905, described among the Metallic Prominences, in which lines of nickel, chromium, iron, and other gases could be seen up to a height

* Monthly Notices of the Royal Astronomical Society, LXXIII, 422.

of 100", belonged to this type, for it was associated with, low bright jets standing directly over a sunspot; but the display was unsymmetrically developed, as m often the case, with no southern streamer to compare with the great northern one. The "tennis-racket," described among the rapidly rising prominences, is another instance of this : the numerous small streaks bending one way, while the great streak inclines another, can best be seen on figs. 3 and 4 of plate-IV". Usually, however, the whole structure is low, and it may be reduced to a single small but brilliant jet directly over the sunspot, so that we find typical spot-prominences to* be of three closely allied kinds, viz.: Single brilliant Jets ; " Rockets " that is jets and streamers shooting out from a central point; Arches.

h Jets and Rockets.—The small bright Jets which appear sometimes alone, sometimes as the centre of a "rocket" system, are often metallic. Out of 101 solitary jets, standing over sunspots, 54 were metallic; out of 160 " Rockats " 38 had a metallic jet at the cent-re. Unlike rockets, solitary brilliant jets aro often found away from sunspots, as well as over them, and even outside sunspot zones (as we saw when discussing metallic prominences); but when found standing directly over sunspots the connection cannot be doubted, and it looks as if they might often, be an early stage of rockets and arches, for the latter have occasionally developed where, an hour or two earlier, a single bright jet sfcood Moreover, the actual development almost from the beginning was traced on plates of February 23, 1909, when a small bright mass nearly doubled its height in an hour and a half (rising at the rate of 4'3 km. per second), and half an hour later had become the centre of streaks and bombs which seemed to have burst from it on all sides,—in fact a typical rocket prominence.-

Tie aW instances, as well as the general appearance of a f,,lly developed rocket prominence, seem to prove that this type abvays indicates an eruption of hydrogen, and sonaetimes also of the deeper-lying sodinm, magnesia, iron, at out

it is them accurately on a series of plates, and determinewhethertheyare ac.aUy in motion, and if so in what direction

in the morning and is generally ... Station deteriorates quickly cases, however, motion was detected and it was ... following ... motion into the centre we have never been ...

1909, January 9—A vervbrilliant ... at 8> 20- was perceptibty ... Photographed

1909, February 25—The streaks shown on plate IX, fig. 1, 60″ high, were represented by a y low triple jet two ho earlier, at 8^h 28^m.

1909, March" 27-A radial ... in rocket centre intenses, at ... the

1910, September 26—A brilliant double jet at the centre of a rocket prominence rose 12,000 km. between $8^h\ 20^m$ and $8^h\ 33^m$, that is, at a rate of 16 km. per second.

To these we may add the metallic prominence seen on the east limb in plate I (frontispiece), which rose at first at a rate of 8*2 km. per second, and later at 3/2 km. per second. It was exactly over a sunspot, and though • there are here no radiating streaks, the bombs often carried by streamers appear to be all crowded together in a mass, and may have scattered later, after the photographs had been taken.

No motion can be traced on our plates in the beautiful fountain jets, or in the great groups of prominences flanking them on either side, which stood above an immense sunspot on October 9, 1910 (see plate IX, fig. 9); but Mr. Slocam, who photographed them at Yerkes twelve hours earlier, saw " bright straight jets •coming directly out of the spot," and also an eruption at a distance of 60,000 km. from the spot, where gas was ascending at a rate of 40 km. per second. He also observed a streamer apparently flowing into the spot, and when the latter reappeared greatly diminished on the east limb on October 22, he saw a stream of gas which a high prominence was pouring down into the erlge of a group of flocculi, a few degrees to the south. From these observations and the general appearance of the prominence group, Mr. Slocum judged that they were all being attracted into the sunspot,[1] but we have never seen any evidence of this attraction of sunspots for promineaces. It seems however very possible that some of the gases which have rushed up out of a sunspot may afterwards flow back towards it, especially when the eruption has spent its force.

"What usually happens, however, seems to ba that prominences, instead of falling into the sunspot, are built up round it by gases coming out of the spot: hence the groups seen in fig. 9, plate XX, and the low banks which are very common in the neighbourhood of rockets. The clearest cases for this hypothesis are the following :—

On plate IX, fig. 3, a small brilliant mass is seen which was situated over a sunspot, and has streamers on both sides. To the right on the photograph is a group of 'Small prominences towards which some of the streamers extend, and an hour later this group had increased in height. Next day (see fig. 4) it had still further increased, and was connected with the point over the sunspot by a number •of fine thread-like streamers.

On plate IV, figs. 6, 7 an,d 8, the actual process of building-up may be traced, for at $8^h\ 42^m$ a small bright bomb is seen (above the right-hand arrow), at $11^h\ 19^{ro}$ it is larger and is falling towards the chromosphere, and at $1S^h\ 57^m$ •a complete column is in its place, still connected by streamers with the centre of the system (marked by the left-hand arrow). Tin's centre was at 2° south on the

[1] Asttophysioal Journal, XXXVI, 265, The Attraction of Sunspofcs for Prominences.

west limb, above the sunspot gxoup with large leader which bore the Greenwich numbers 7005 and 7006, mean latitude—2° and —3°.

Again, on Janaary 16, 1913, a column was photographed which grew higher at the rate of about 8} km/sec, while connected by streamers with the prommence centre.

On three other dates (in 1909 and 1910), streamers were found to be gradually curving downward at the end removed from the centre of a rocket prominence, and two of these were also growing longer, that is apparently travelling out from the centre. And bright beads were observed to be dropping off the tips of long streamers on March 6 and 7, 1912.

These observations, though not conclusive, strongly suggest that the banks and columns frequently seen on one or both sides of a rocket prominence consist of gases which originally rose out of a sunspot in the form of fine spikes and streamers.

When looking through some volumes of the publications of the Haynald Observatory, it was found that Fe'nyi bad devoted several pages of Vol. X to a discussion of rocket prominences, which be calls " Fleckenkronen," because they occur only above sunspots, and he considers that the sunspot is encircled by jets coming from a point about 10,000 km. below the spot. He thus explains the radiating and usually curved streamers on either side of the prommence centre, and thinks the short straight jet which apparently stands right over the centre is in reality a little behind or in front of it. A page of beautiful drawings illustrates some very characteristic rockets observed by him in 1891 and 1892, and on page 125 (Vol. *X),* another is shown together with its associated sanspofc and faculse. Fe'nyi says :—

"Of special interest are prominences consisting of]ong streaks and fine-"threads, most of which are placed obliquely, and all converging towards a " point which lies about ten thousand kilometers beneath the sunspot. These-"streaks are fugitive, often disappearing after a couple of minutes ; but almost "immediately others appear. These forms are entirely restricted to the ueighbour-" hood of sunspots, for they are frequently seen above spots, but never elsewhere, " so that whenever one is observed it is a sure sign that a spot is on the sun's limb* « This type of prominence obviously represents a circle of rays round a sunspot, "on each side of which we see the rays bending outwards, but the central rays " appear by perspective to stand upright and exactly over the spot. In appearance " it recalls the lines of force of a magnetic pole, and still more strikingly the polar "rays of the solar corona. The prominence rays, moreover, very often curve "downwards on both sides, just like the coronal rays above the sun's pole. It "looks as if we have indeed in sunspots that local magnetic pole which is suggested " by the discoveries of Hale." [1]

[1] Publication des Haynald-Observatorinms, X, 115. (Translated.)

With the whole of this description our observations are in agreement, only the specially brilliant little lump at the centre, often glowing with lower-lying gases than hydrogen and calcium, does not appear to us to be one of the radiating streaks seen in projection, but rather an eruption rising vertically out of the sunspot.

Arches.—Arching forms of prominences are fairly common, and are frequently mingled with rockets, but groups of interlacing arches, such as are shown in figs. 5 to 8, plate IX, are rare, and single horseshoe arches, as those in figs. 10 and 11 rarer still. The wonderful group of arches photographed on January 7,1910, began as three streaks with bright condensations attheir tips (see fig. 5, plate IX), like those often seen with streaks and streamers in rocket prominences, but these streaks showed themselves later as arches seen edgewise, their bright summits rising with diminishing velocity. Meanwhile, at 8^h 53^m some more streaks appeared beside these, and by 10^h 10^m a second group of arches is seen (fig. 7), touching the first, fully formed, interlacing, and beautifully beaded, wide open, so that we can look through them. As these rose to their full height in the space of two hours and five minutes, their average rate of ascent was 12 km/sec. The rate of ascent of the first group was as follows :—

Between	8^h 5^m and 8^h 53^m	...	3 km/sec
„	8^h 53*" and 10^h 10™	...	1·9 km/sec
„	10^h 31^m and H^h 6^m	...	the height remains the same
„	11^h 6^m and 12^h 44m	...	1«5 km/sec

At l'2^b 44^m the arches seemed to have floated free from their base, but part of the K line may have been thrown off the slit, through change of temperature in the epectroheliograph, combined with distortion of the K line due to motion. At 9^h 10^m it was noted that the C line was displaced to red at the top and to violet at the base of the arches, while eight minutes later it was displaced to red at the base for 2 angstroms, and to violet over the rest of the prominence. These arches appear to radiate from a point at 15° south on the west limb, which was the position of the large active sunspot 6793 (Greenwich number). On December 23, 1909, when this sunspot was crossing the east limb there had appeared at —15° east one faint arch.

Very similar groups of interlacing arches, but too delicate to reproduce, were photographed on dates which all fall in the year 1909 or the beginning of 1910, and all were above sunspots. The following is a list of the arches and their associated sunspots:—

Interlacing arches ptotograpnea liato		Associated stmapot		
		Greenwich number	Latitude	Typ«
1909, January 22	...	6606	+ 9° east	Yery large cluster
1909, March 28	...	6652	+ 10° east	Regular spot
1909, April 23	...	6663	-• 9° east	Small scattered spots
1910, January 7	...	6793	-• 15° "west	Very large regular spot
1910, April 11	...	6833	- 2° east	Two small spots

One of the arclies forming the group first on the above list was observed- to bo rising, and at the same time a bright low jet rushed up into its side. Although all these five groups were situated above sunspots, it will be noted that the spots were of different types; and they were also of different ages, three being new spots, one old and dying, and another middle-aged, that is a returned spot which afterwards appeared once again.

To these five should be added a group of arches of the same kind which was observed and drawn at Kodaikanal before the erection of the spectroheliograph, on November 27, 1904 : seven bright lines were recorded in its spectrum, and the C line was observed to be displaced to red. It appeared on the west limb, above sunspot 399 (Kodaikanal number).

Solitary Arches are shown in figs. 10, 11 and 12, plate IX. The first is the wonderful King or Horseshoe prominence, which was fully described and illustrated by six figures in Monthly Notices of the Royal Astronomical Society LXXIII, 429. It was extraordinarily bright and stable. It was already visible on "July 30, even through cloud on a flocculus plate, and had the same form ; 'but the observations of Riccò and Chevalier prove that it began as a curved jet, which rose higher as it developed- into a complete arch by continuing the curve on the northern side until it reached the chromosphere. It stood over a very large oval sunspot.

The similar though smaller bright horseshoe arch, shown on fig. 11, plate IX, accompanied on the east limb a small stream of sunspots ; and on October 23 and 27, 1909 two miniature horseshoe arches stood over sunspofcs, both on the east limb.

The solitary arch shown on fig. 12, plate IX, resembles much more the interlacing arches already described, for it is high and narrow, and rather fainfc : the narrowing at the base, and the bright condensation at the top are both characteristic features. This stood above a sunspot at its first crossing of the limb, on November 19, 1908; and on April 17,1909 a high faint arch, not photographed but observed visually, stood above it at its last crossing, when it appeared for the seventh time. At the intervening crossings it had been nearly always accompanied by " rockets," once by rockets with an arch, and once by a small brilliant jet.

On May 12, 1912, a faint arch, wide at the base, but with a bright top, 90" high, was photographed on the west limb, where the sunspot group 6982 (Greenwich number) was crossing for the last time.

In Young's book on " The Sun," page 209, is a figure of " jets of liquid fire, rising and falling in graceful parabolas," which closely resembles the groups of interlacing arches on our fig. 8, plate IX. It is dated October 5, 1871, and he gives a very similar drawing on page 203, undated, which, he includes among

" some of the more common and typical forms" of metallic prominences which accompany sunspots. Since this particular type seems to be very rare in the Kodaikanal records, and all the instances but one were photographed within sixteen months, it seemed possible that it becomes more frequent at certain times, and then ceases to appear during long periods. Search was therefore made among other records, viz., Kenley drawings from 1890 to 1906, Fényi's from 1888 to 1892 and also September and October 1886, and the Memorie della Societa degli Spetfcroscopisti Italiani from 1869 to 1908.

The following drawings of arches were found:—

On July 7, 1872, Secchi observed a wonderful group of prominences, from 3 p.m. onwards, one part of which resolved itself into very fine filaments which curved over, arch-like, at the tops. At 5^h 45^m p.m., this part had become a fountain,

" un magnifico getto come di fontana, simmetrico, verfcicale,"

with numerous vertical jets in the centre which descended on both sides; and by 6^{11} 17^{n}\ there were several complete arches.[1] At $6^h 37^m$ he saw shining threads detached from the chromosphere,

** fili lucidi sospesi in aria senza toccare la cromosfera/'

and these grew longer but also much fainter. At 5^h 45^m' when the appearance had been of a fountain, Seccbi saw the whole prominence in F as well as in 0, and at 6^h 0^{tn} the sodium lines were reversed at the top of some of the highest jets, which at this time reached 88" of arc. The 0 line was much distorted. These arches, when they were complete, and also when their bases disappeared and they became detached from the chromosphere, remind one very much of the Kodaikanal arches of January 7, 1910. They also stood over a sunspot, and they appeared nine months after Young's " parabolas."

The next instance we have found is five years later, when Ferrari, on November 7, 1877, at'the Oollegio Romano, observed from $9^{11}30^m$a.m. to 4^h15^mp.m. some wonderful changing prominences on the, east limb nearly on the equator. He gives beautiful detailed drawings, and those of 11^h 15^{s1} and IP 25^m, compared with those of l^h 35^{IH} and l^h 55^m, show how some brilliant jets curled over and formed arches. He describes the formation of a very thick arch : a brilliant jet resembled at l^h 35^m and 4^h p.m. « un blocco rientrante in se stesso di xnateria densissima e flnida come una colata di lava incandescente ",[a] but at 4^h 15^{U1}, when the sun was near setting, there was only a pointed flame, and this was growing faint. These arches, whose formation and dissolution were watched

* Memoiie della Sooieta degli Spetbroeoopiati Italiani, I, 73 and plate XI, figs. VI, VII, VIII.

* A. mans oi very thick but fluid matter, like incandescent lava, flowing back into itself.

from beginning to end at Rome, were also observed at Manilla, and they also occurred above a sunspot.[1]

Next year, on May 25, 1878, Tacchini, observing at Palermo, drew another curious set of arches suspended over the chromosphere, no bases being visible. These were above a fine sunspot.[2]

On October 1, 1880, the Bordi Solari of Tacchini and Millosevich, who observed at Rome, show interlacing arches nearly pne minute of arc in height, on the east limb at 6° to 12° south, and on the next day a rather similar prominence appears at 12° to 18° south. Sunspot 374 (Greenwich number) must have been crossing the east limb at this time.[8]

August 31, 1881.—West limb, 20° north. Interlacing incomplete arches, 50" and 60" high. No sunspot here.[4]

There is now another gap of five years, during which no arches are recorded in the drawings. Then we find the two following :—

March 9, 1886.—West limb, on the equator. A two-minute high narrow arch, filamentary, with the characteristic narrow base and brilliant summit which we have remarked at Kodaikanal, was seen at Rome, at 4^h 40".[1.5] A sunspot group (Greenwich number 1849) with mean latitude l°>5 south, crossed the west limb on this date.

July 30, 1887.—Arch within arch; and here also there appear to be some detached tops, close beside the complete arches, as well as some bright detached bases. West limb, 17° to 22° north. Height 80". Observed at Rome or Palermo.[0] There was no sunspot here.

Another gap of five years follows.

July 4,1892.—Again some detached arch-tops are represented, over two minutes high, this time above a high narrow arch and brilliant low jets. This group was observed by Fenyi, on the east limb at 11° north, exactly above a largo sunspot.

July 5, 1892.-Mingled with jets and streaks, a group of delicate arches—"feme zierliche Bogen"—120" high, were seen by Fe'nyi on the east limb at latitude 26° to 84° south. The great sunspot group, Greenwich number 2583, was —81° from the central meridian on July 7, so on the 5th it must have been very near the place where these arches appear, although Fe'nyi describes it on that day as well within the limb. It is remarkable that these two groups of arches were seen by Fe'nyi on two succeeding days, and that no other prominence of the kind is figured in all his drawings of the five years 1888 to 1892 inclusive- On

[1] Memorie della Society degli Spetfcroacopisti Italian!, VI, 82 and plate XCV.
[1] Ibid., VII, plate XCIX. * Ibid., XXXVI.
* Ibid, XXXVIL . Ibid., xvill, plate CXXVII. . rbi*., XIX, plate OXLII.

September 5 and 6, 1888, he records two arches over a sunspot, but the first was obviously formed of two meeting jets, and the second was a dense mass the middle part of which was raised up by an eruption immediately underneath it, while the two edges remained nearly attached to the chromosphere: neither therefore was a true arch.

On July 21,1892, at Kenley, a very fine horseshoe arch was observed by Evershod (see plate XII), much resembling the Kodaikanal horseshoe of July 31, 1908 (lig. 10, plate IX); but the southern side did not quite reach the chromosphere at the time of observation, $6^h\ 45^m$ a.m. A vertical jet curving over at the top is shown in the Roman Bordi Solari for this-day at the same latitude, but at Rome it is the northern part of the arch which is incomplete, in fact missing altogether. This was on the west limb at 30° south. No sunspot was seen here.

At Kenley, also, in the next year, 1893, there were seen two beautiful examples of grouped arches, on August 14 (see plate XII) and December 26. In both canes the arches are specially bright, and at one time they are detached, so that the appearance is of small fine hooks suspended above the chromosphere: it is possible that a drawing of September 26, 1895, represents the same stage of a series of disappearing arches. Those of August 14, seen at $7^{11}\ 55^m$ to $8^U\ 35^m$ a.m., appear on the Bordi Solari of Rome as nearly vertical jets at $9^h\ 20^m$; those of December 26, seen from $10^h\ 45^m$ to $l^h\ 55^m$, look somewhat like the bright tops of many arches close together, 75" high, as drawn at Rome at 11^h. Both these groups of arches were close to sunspots.

Here again we remark the rarity of arc lies, and their occurrence at dates close together, for during the seventeen years' observations at Kenley only three certainly belonging to this type were recorded, and during five years of the Kalocsa observations only two, and all these fell between July 1892 and December 1893. (No observations were secured at Kenley on the dates of Fe'nyi's arches.) The drawings on the Bordi Solari represent all prominences almost invariably as composed of fine lines, straight or curved, and it is hence more difficult to be sure of the type. However, no more typical arches are seen for nine years, when we reach the Kodaikanal group of November 1904 already referred to. Three years later a group remarkably similar to the " fountains " of our figs. 5 to 8, plato IX, was photographed at Yerkes Observatory on August 14, 1907, some arches being seen edgewise and some open, standing over sunspot 6236 (Greenwich number) on the east limb.[1] Then follows the Kodaikanal series of 1908, 1909 and 1910. Periodical records of prominences are not published at Mount Wilson, so we do not know whether this form has been photographed there,

[1] Aflteophysioal Journal, XXVIH, 255 and plate XVIII, fig. 1.

It appears, then, that although irregular and broken arching forms are common, regular arches, and especially the peculiar groups of line interlacing arches which much resemble one another, do not occur during periods of several years, and then a few are seen at dates not far apart; but as these dates group themselves round times of maximum, when all prominences are more abundant, this fact does not take us much further in trying to understand the nature of a very curious form of solar activity- All we can say is that this kind of prominence is almost always intimately connected with sunspots: out o£ the twenty-seven here enumerated, only three exceptions have been found, two in the Italian series, and one at Kenley. We cannot even guess why these arches are often brightest at the summit, nor what combination of forces can poRsibly produce a narrowing at the base.

Other Forms found near Sunspots.—The three types of sunspot-prominence discussed above are closely connected and often intermingled, small brilliant jots, arches, and streamers, all radiating from the same point, either simultaneously or in succession. Besides these, there are in the Kodaikanal records of 1907 to 1914 twenty-two forms found near sunspots which are somewhat singular. Nineteen of these were metallic or very brilliant prominences rather larger than the small Jets or points described above: three of the nineteen rose as high as 60" and one to 80", but usually they were only 30" or 40" with a base of about 3°, therefore not much larger than the Jets. One has a very unusual appearance for a spot-prominence, as it spreads out at the top in a sheaf; it appeared on January 29, 1908, the base extending from 9° to 12° north on the east limb, and a sunspot was due to cross this limb at 11° north on this date. As however before it reached tlie limb it had become, from a complex group, only a small spot, and it did not reappear, ifc is very possible that it had died out before the prominence appeared. Pour others of these metallic prominences were merely at the edge of the mean sunspot latitudes, so they are perhaps not really associated. For instance, one was at latitude 0° to 5° south, while a sunspot was crossing at mean latitude 7° south.

The three remaining peculiar forms were large prominences attached by fine threads to a point close above a sunspot. Two of these were figured in Monthly Notices of the Royal Astronomical Society LXXIII, 430, but it is not clear that they should be regarded as belonging to sunspots: if they are, it is a very unusual type. They were as follows : (1) « The Wing », see plate VIII, figure 7, above a very small spot only once seen near the west limb, but reappearing for two days on the east limb, still small. (2) « The Cockroach », see plate V, figure 5, apparently springing from a small bright mass above a large sunspot. (8) A bright somewhat massive prominence, height 50", base 4°, connected by filamentary streaks with a point on the east limb afterwards seen to be occupied intermittently by a sunspot.

Frequencies of Sunspot Prominences.—•Having determined the type of prominence which is associated with sunspots, the next step is to inquire how often it occurs, and whether it is more frequently found with one kind of sunspot than another, also if any such difference exists between the different sub-types of sunspot prominences. When, therefore, the sunspots of 1907 to 1914, and the prominences found near them, had been tabulated, the latter were divided into (1) Jets, (2) Rockets, (3) Arches, and (4) the Metallic, Brilliant, and Peculiar forms just mentioned. By Jets is meant a solitary bright little lump or very low streak; by Eockets, radiating streaks; by Arches a single perfect arch, or a group of arches, found alone : when jets or arches are mingled with radiating streaks and streamers, the whole is included under Eockets.

In order to secure uniformity and to avoid bias, it was made a rule to count all prominences as associated with sunspots when their centre fell within 3° of the sunspot's mean latitude (as calculated at Greenwich), and within one day of the passage of a sunspot across either limb, the date of passage being taken as seven days from the time when it crossed the central meridian. This is given in '* The Observatory," to the tenth part of a day, whether the spot actually crossed the central meridian, or was only due to cross it at such a time. Small sunspots cannot be seen near the limb, so it is not always certain whether they cross it: the rule was adopted that if they were charted at Kodaikanal when three days from the limb and on at least one other day also, they were assumed to have crossed the limb ; but spots which were first charted when as much as four days distant from the east limb were considered to be new formations, and spots which when last charted were four days distant from the west limb were assumed to have died out before reaching it. If they appeared within three days from either limb, but only for one day, it was considered that they were evanescent spots, such as often occur, and in that case they were omitted from the list.

The sunspots and associated prominences of 1904 to 1906 were not tabulated for the roason already given;, but in looking through them no exception has been noticed to the rule that large massive prominences do not occiir over sunspots and that the usual type consists of radiating streaks and Jets.

In all, 1088 sunspots were dealt with, but many of these crossed neither limb, and others crossed on days when the plates were too poor to decide whether fine diverging streaks were present which should be classified as "Rockets," or only small irregular prominences. The number of sunspot passages over a limb which were sufficiently well recorded for this investigation were 604. Ten were included from the year 1906, in order to complete the histories of Recurrent Spots. These, whose returns are all given in the volumes of Greenwich I'hoto-heliographic Results, were found to be specially prolific in sunspot prominences, and they are here tabulated separately.

Prominences accompanying recurrent sunspots at their passages over east and west limbs oj the sun

Years	Rockets	Jets alone	Arches alone	Metallic, brilliant, and peculiar prominences	Total snnspot prominences	Reourrent stmspofc passages
1907	31	34	..	3	68	100
1908	29	7	"1	2	39	79
1909	H3	11	3	5	52	100
1910	18	2	1	2	23	36
1911	5	3	"i	...	8	12
1912	4	•1	...	...	6	8
1913	..	..	...	...	..	...
1914	'3	*2	...	...	*5	10
Totals ...	123	60	6	12	201	345
Percentages ...	36	17	1-5	3-5	58	...

Prominences accompanying non-recurrent sunspots at their passages over east and west' limbs of the sun

Years	Bockets	Jets alone	Arches alone	Metallic, brilliant, and peculiar prominences	Total sun spot prominences	Non-recurrent sunspot passages
1907	4	14	..	1	19	47
1908	7	11	...	...	18	83
1909	9	5	2	4	20	43
1910	5	4	2	2	**13**	32
1911	6	4	...	1	11	23
1912	/*>	1	...	.	4	6
1913	3	...	...	1	4	6
1914	...	2	...	...	2	19
Totals ...	37	41	4	9	91	259
Percentages ...	.14	16	1-6	3·4	35	...

Summary of prominences accompanying sunspots, recurrent and non-recurrent

1907 to 1914	Rockets	Jets alone	Arches alone	Metallic, brilliant, and peculiar prominences	Total snnspot prominences	Sunspot passages
Total numbers ...	160	101	10	21	292	604
Total percentages	26	17	1-6	3-4	48	...

It appears from these tables that, Omitting all sunspot passages Across a limb wfcen prominence plates were missing or too poor for identifying prominence types, about half the sunspot passages were accompanied by typical sunspot prominences;, and about half of these were rockets, a somewhat lesser number single small brilliant jets, and a very small proportion arches, and metallic or brilliant prominences somewhat larger than the jets. (The peculiar forms were only three, and thorte doubtful, as we have remarked above.) There is however a difference' between recurrent and non-recurrent spots, for while the percentages of columns 3, 4, and 5 are almost precisely the same with both classes, rockets are found in as, many as 3G per cent with recurrent, but only 14 per cent of the non-recurrent, so it is this type of prominence which makes so great a difference in the total percentage o£ sunspot prominences which are associated with the two classes of sunspots. It will be noted also that more than half the number of Jets belonging to recurrent, sunspots occurred in the year 1907; but for this, the number of this type connected with recurrent sunspots would be very low compared with non-recurrent.. 1907 was a year of abnormally large numbers of metallic prominences, as may be seen by turning to the table of Metallic Prominences, and half of all the jets belonging to sunspots were recognized as metallic. (See page 92.)

Out of 604 well-recorded sunspot passages, 292 were marked by these prominences of distinct types, so closely connected that they may be regarded as one typo of suuspofc prominence. Of the remaining B12, in about half of the cases there was no prominence at all over the position of the sunspot, and in the other half thoro were small vague forms which occur commonly all over the limb, and most probably had no direct connection with the sunspots, i.e., whatever cause produced them in other positions produced them here also, irrespective of the presence of the sunspot. They were always small low prominences, irregular and faint, or in any case not specially bright.

Summing up, it may be said that sunspots fall into four nearly equal classes,. viz., those accompanied respectively by (1) Rockets, (2) Small bright Jets, a few bright prominences slightly larger than these, and a few Arches, (3) Small vague forms, (4) No prominences.

The higher percentage of Rockets with recurrent sunspots is probably connected with the fact that these are usually larger and more active than non-recurrent sunspots, Thus in the years 1907 to 1912, 55 per cent of the recurrent sunspots were more than 100 millionths of the sun's apparent disc, but only 13 per cent of the non-recurrent (the calculation is bdled on the Greenwich records of sunspot areas in which allowance has been made for foreshortening). That Rockets are particularly frequent with the larger sunspot groups is apparent from the following calculation; out of all sunspots recorded at Greenwich between 1907 and 3 912, only 24 per cent had an area greater than 100 millionths of the sun's disc ; but out of all sunspots which were accompanied by rocket prominences in the same period, 73 per cent were over 100 millionths. Moreover, the twenty-two specially fine displays of rockets, such as that shown on fig. 9, plate IX, are all associated with sanspots of areas from 200 up to 1865 millionths, with only four exceptions. Of these twenty-two, twenty were recurrent sanspots, and only two non-recurrent.

It was found also that a large number of the sunspots associated with rockets showed special activity by the occurrence of bright hydrogen reversals in their neighbourhood, observed when they were crossing the disc.

It seemed to be of importance to discover whether sunspot prominences are more frequent in the early or late stages of a sunspot history. The table below shows that both Rockets and solitary bright Jets are frequent at first crossings of the limb, that is when sunspots are young; that Rockets are much more frequent, but Jets rare, at intermediate stages, when they are at mid-development; and that both types are much less frequent at final crossings when sunspots are old. Arches, always rare, are associated indifferently with any kind or stage of sunspot.

At first crossing,	30	per cent of sunspots have		Rockets,	34	per cent	Jets.
At intermediate,	46	„	„	„	12	„	„
At last crossing,	17	„	„	»	13	„	„

Since large long-lived sunspots usually reach their maximum size and activity in the middle of their life-history, being small at the beginning, and quiet and regular in shape towards the end, the aboye results are what might be expected, and tend to confirm our belief that this kind of prominence is a direct manifestation of sunspot activity. Solitary jets obviously indicate less activity than the numerous jets and streaks which form a Rocket, and we find the former specially associated with young spots, the latter with spots in mid-career.

An attempt was also made to discover whether any particular type o£ sunspot was accompanied with special frequency by rockets and other spot-prominences. Dividing the sunspots associated with rockets into Father Oortie's five types, we find that 41 per cent were of types *IVa* and IY&, that is a regular spot with or without small companions, and 32 per cent were of type I, that is small single or scattered spots; and among recurrent spots considered alone, there were twice as many of the former as of the latter. These are, however, the commonest types, as recorded at Kodaikanal: pairs, irregular spots, and groups without well-defined chief spots, are rather rare. Jets are on the whole more frequently associated with small sunspots^han rockets are, although the proportion of large spots is still very high, the percentage being 60 instead of 73. There is a slightly larger number also of type 1,-39 per cent against 32 per cent,—**and** only 29 per oent of type **IVa** and *IVb* against 41 per cent. The Jets which were observed to be metallic (55 out of 101) accompanied any type of spot and any size, from 1714 to 10 millionths of the sun's disc.

Fe-nyi's drawings and suggestive articles in the Kalocsa Publications constitute a fund of information about prominences, and it has been possible to examine the series for the years 1888 to. February 1898 inclusive, to see what types of prominences he observed in connection with sunspots. These exquisite drawings show with perfect clearness to what type a prominence belongs, since not only fche form and height are indicated, but the cloudy or filamentary or spiky character are finely portrayed, and the system of marking positions of sanspots. beneath the prominences when the former are on the limb makes such an investigation easy.

It appears that of 163 sunspots whose position is thus marked on the prominence charts, 41 were accompanied by " Rockets, " five being fine typical displays.. This is between 25 and 26* per cent, or precisely the same proportion as is given by the Kodaikanal records for 1907 to 1914 (See page 102.) The streaks and jets composing these Rocket prominences of Fényi's sometimes rise to 70", 90/" 120", and in one case a cloud 125" hangs above a small rocket system; but usually they are small and low, as we also find at Kodaikanal.

Of the remaining sunspots recorded at Kalocsa during these five years, two (or 1*2 per cent) were associated with.interlacing arches, and 44 (or 27 per cent) with no prominences, of any kind. These percentages are practically the same as at Kodaikanal. Sixty-seven sunspots were marked by the presence of small prominences, none so much as one minute high, and most much lower: these-included small jets standing directly over the sunspot, or within 1° or 2° of it, and other small forms, some of which would doubtless have been included among bright spot-promin.en.ces, but without having negatives to examine it is impossible to decide which were bright enough to come in this category. The rest belonged to small vagao forms, which probably have no direct connection with the sunspots near which they happen to be, Finally, nine sunspots were associated with high prominences—broken jets and. clouds, between 65" and 120'!,.a curved column about 75" high, and three very brilliant eruptions reaching heights of 2, nearly 4, and 6 minutes respectively.

F6nyi's records therefore are in agreement with the Kodaikanal records, and we may summarize as follows what we have found concerning the connection between prominences and sunspots :—

(1), Large massive prominences are not found directly above sunspots.

(2) The prevailing type of prominence found above sunspots is the Rocket^ called by Fe"riyi " Fleckenkroue," which consists of jets and streamers radiating from the sunspot. It is not found except above sunspots.

(3) Rocket prominences are almost always low and small, but occasionally one streamer may be large, and rush up violently to a great height, quickly changing and fading away.

(4) Two other types, solitary small jets of marked brilliancy, often metallic, and arches, single or in groups, are closely related to Rockets, and often mingle with them.

(5) Occasionally brilliant or metallic prominences a little larger than mere jets occur over sunspots.

(6) Various small prominences occur over sunspots in about the same proportion as Rockets, but they assume no special form, are not specially bright, and occur frequently elsewhere. It is probable therefore that their association with sunspots is fortuitous.

(7) About the same proportion of sunspots as are associated with. Rockets have no prominences near them.

(8) Rocket prominences are most frequently found in connection with large active sunspots in the middle stages of their career. They are also frequent, and solitary brilliant Jets are most frequent, with young spots ; both types are much less frequent in the last stages, when sunspots usually become regular and quiet.

(9> 3STo case has been found in which prominences were falling into sunspots, but the reverse has several times been observed. With rockets, gas appears to be rising at the centre and shooting upwards and outwards ; but at some distance the motion becomes less, and the gas falls again, often piling up into low banks and columns on one or both sides.

From the foregoing observed facts we conclude that the force which acts on gases lying directly above sunspots is not usually so strong or so steady as that which supports floating clouds, or raises large masses to immense heights witli accelerating speed. Its nature seems to be more like that of an intermittent volcano, at times quiescent, at times driving up a narrow concentrated stream of incandescent gas, like lava welling up from great depths, and at times ejecting in quick succession and in all directions a number of fine streams and small masses, which disperse, or fall back upon the chromosphere at a distance of some thousands of kilometers, the force seldom sufficing to carrj them to any considerable height. In the first case we see no prominence, in the second a solitary brilliant jet or larger metallic prominence, in the third Rockets. And the same sunspot may be associated with either type or with none, at its successive crossings of the limb. In Arches, it appears as if the gas were continuously rising and falling in a constant stream, but the bright bead at the top, and the frequent narrowing at the base, are features difficult to account for.

Although the force thus seems^to be comparatively weak, and intermittent, it is suggested that it must be always operative in a certain degree, for this would explain why extensive or massive prominences cannot form directly over sunspots. And it must be deep-seated, for it often brings the lower-lying gases to the surface.

Since a low brilliant jet, often metallic, frequently marks the advent of a youthful sunspot, before it has become large and active enough to produce Rockets, is it not possible that the slight elevations of the chromosphere, scarcely worthy the name of metallic prominences, which appear apart from sunspots; outside aunspot regions, may indicate abortive attempts to form sunspots.?

V—PROMINENCES PROJECTED ON THE DISC.

In September 1909 a *very* large spot, numbered at Greenwich 6728, crossed the sun's disc. Its arrival on the east limb was marked by a very brilliant low jet on September 17; and when, always increasing in size, and accompanied by a troop of small sunspots, it swept out of sight across the west limb, on September 30, there was a display of " rockets", mingled with arches and very bright low jets.

Two days before this, when the spot was approaching the west limb on September 28, a great eruption was seen by Mr. Sitarama Ayyar directly over the umbra. Already at 8^h 23^m the *Ka* line was seen to be reversed, but at 10^h 30^m it was reversed so brilliantly that in spite of a poor sky the shape of the eruption could be plainly traced with a comparatively wide slit, and it was seen to bo changing rapidly. Displacements in the P line were observed which indicated motions of approach attaining at one time to 100 km./sec.;. the lines of sodium and magnesium were brightly reversed, and D_s was very dark over the whole eruption on one side of the spot. The spectroheliograms taken on this morning boro witness also to the great outburst: those of 7^h 55^m and 8^h 20^m showed the umbrao of tho groat composite spot quite clear and sharply defined, but on the plate of 10^{h} 89^m they could only be faintly traced, and there were instead several regions of intense brilliancy, the bright eruption covering practically the whole spob region, The Kodaikanal magnetograph recorded a magnetic storm on earth at this time,[1] and spectrum photographs of the spot show that a magnetic storm was taking place ID the sun also,[2] for although the first plate, taken at 10^h 1^m, shows nothing unuaual, two taken an hour later show the iron lines 3923 and 8930 distinctly doubled over the umbra of the spot,

This great-eruption was undoubtedly a very bright metallic prominence seen on the disc. Only seventeen times during our period (1904 to 1914) have metallic prominences been seen thus, although they have been recorded at the limb near sunspots 154 times. The following table shows the distribution in years of these eruptions which, showed bright lines of sodium, and sometimes magnesium and iron. Although the numbers are very small, the frequencies agree with those of

[1] Monthly Notices of the Eoyal Astronomical Society, LXX, 23, " *A.* Solar Outburst and a Magnetic Storm," by C, Michie Smith.

[2] Kodaikanal Observatory Bulletin XXII, " ^ote on the Maguetio Meld in the Sunspot of September 1909," by J. "Evorshed.

metallic prominences at the limb, showing the double maximum in 1905 and 1907*. with a dip in 1906, and a fall from 1908. This of course must follow from the; association with sunspots, which have the same curve as metallic prominences.

Yeara	Metallic Prominences seen on the disc, above sunspots	Years	Metallic Prominences seen on the diso, above sunspots
1904	0	1911	0
1905	7	1912	0
1906	2	1913	0
1907	4	1914	0
1908	3		
1909	1	Total ..	17
1910	0		

Although, it is very rare for a metallic prominence thus to betray its presence over a sunspot when on the disc, by brilliant reversals of metallic lines, hyrtrogen reversals are quite frequent. The total number of instances in which *Ha* has been seen bright on the disc throughout our period, is 1280, and the yearly distribution is shown below. Here also the fact that the reversals occur in the neighbourhood of sunspots necessitates a somewhat similar yearly distribution, but the numbers are smaller in 1907 and larger in 1909 than would be expected, and it is the same if mean daily numbers are taken. Considering the small numbers, however, and the possibility that more attention has been given at one time than another to this phenomenon, the resemblance is fairly close. The numbers are almost always greater east of the central meridian than west: this also was to be expected from the preponderating number of sunspots in the eastern hemisphere.

Ha Beversals observed on the disc

rears	Eastern Hemisphere	Western HemiHphere	Total	Percentage east
1904	109	100	209	52·15
1905	118	88	206	57-28
1906	98	82	180	54·44
1907	80	77	157	50-96
1908	65	75	140	46-43
1909	87	84	171	50-88
1910	37	27	64	57-80
1911	8	4	12	...
1912	1	6	7	...
1913	3	2	5	...
1914	64	65	129	49-61
Total ...	670	610	1280	...

Mean eastern percentage for the years 1904 to 1910 ... 52*85

The numbers for the years 1911, 1912 and 1913 are obviously too small to show any significant difference between east and west, but it is noteworthy that..

a change to a -western preponderance apparently bega.n in 1912, just as with, prominences at the limb.

The mean eastern percentage for the period down to 1910, when numbers were large, is 52"85, or nearly the same as that found for prominences at the liinb from 1904 to the beginning of 1912, 52'70. (See page 70.)

The assumption that these 1280 hydrogen eruptions are actually prominences of special brilliancy seen on the disc is confirmed by the fact previously noted that sunspots over which they occur are frequently associated with metallic prominences und "rocket" prominences when crossing the limb, while sunspots which appear on the disc unaccompanied by bright hydrogen reversals often cross the limb without prominences, or with small faint prominences only. The *Ka* reversals therefore give us an opportunity of observing prominences on the disc, and seeing whether their decline in numbers and activity takes place gradually as they cross from east to west, or whether the difference can be observed only when the opposite limbs are compared. And this should help us to decide whether prominences are really larger and more active on the advancing side of the sun, or only more distinctly visible, for some reason unknown.

The results of this enquiry are shown on diagram VIII, in which the middle rline represents the distribution in longitude of *Ra* reversals in the period 1904 to 1914. It is seen at once that the western part of the curve is lower than the eastern, yet there is no regular fall from east to west. There are minima at both limbs and at the centre, and the marked maximum between 45° and 60° on the east is matched by a lesser maximum at the corresponding point in the west. Superposed, therefore, upon the general lowering of numbers in the western hemisphere is a variation in longitude which is approximately similar in the two hemispheres. The minimum at each limb is probably due to foreshortening, which so much reduces visibility that many bright reversals here pass unrecorded, but dt is not easy to explain why numbers should fall off at the centre of the disc, where one would imagine they should be best seen.

One might suggest that the supposed earth-influence reaches its maximum extinguishing power here, when vertically above the prominences, and lessens somewhat as they travel westward, though never allowing them to regain their pristine activity and brilliance; but the explanation is more probably optical. The darkening* of D_3 in the neighbourhood of sunspots have a similar distribution in longitude, as remarked by the Director in his report to the International Union for Solar Research communicated to the Bonn Conference in 1913, and he suggests that a lesser depth of the absorbing helium gas is presented to us when we look vertically through it near the centre of the disc than when it lies 60° or 70° distant, hence it appears less dark and may become qurte invisible Iwhen near the centre. But this, he concludes, is an argument for extreme tenuity of the eras, because it is evident that we have to deal with partial absorption of D_3 light due to poverty of material at the centre of the disc, although the actual depth of helium gas can scarcely be less than 10,000 miles.[1]

Although hydrogen reversals are bright, not dark, the same reasoning applies to them ; and we conclude that they indicate the presence of extensive masses of hydrogen, brighter than the photospheric background, but exceedingly tenuous,, whose effective depth increases with distance from the centre of the disc, so that they are most distinctly seen at-about 55° on either side of the central meridian, but decrease in visibility from foreshortening when very near the limbs. As we believe that they are prominences, their tenuity is only what must fee expected, for everything points to small mass in the gaseous forms seen at the limb* which often rise fco great heights, move with very high velocities, and disappear suddenly.

The essential similarity between the curves for D_3 darkenings and Ha-reversals is apparent in diagram VIII, though it will be noted that the maxima in the upper curve (D_3 darkenings) are a little nearer the limbs, between 60° and 75°, instead of between 45° and 60°. The fall in the western hemisphere is not very obvious in the upper curve, but it is actually nearly the same in both cases, the eastern percentage of D_3 markings in the period 1904 to 1914 being 52*46. Here, also a change seems to have set in about the year .1912, for though only-three D_3 darkenings were observed in that year, and one in 1913, these were all' in the western, hemisphere, and in 1914 there was an equal number east and west,. just as with Hci reversals.

Reversals of hydrogen have often been photographed as well as observed visually at Kodaikanal since April 1911, when the new auto-collimating spectro-heliograph, constructed by the Director, was brought into regular use, and a long series of photographs of the sun's disc in *Ha* light were obtained. Several bright streaks aud patches can be seen on some hydrogen spectroheliograms of April and: May 1911, which are reproduced on plate X, the most remarkable being a large bright patch surrounded by radiating streaks, in figs. 1 and 2, Through this bright patch there runs a narrow black line, and a still more striking black line, in the form of a letter S, appears near the centre of the disc in fig. 3.

If the bright patches are prominences, what are these dark lines ?

They have long been familiar on calcium plates, for Hale and Ellerman drew attention in 1903 to "long black calcium, flocculi" on their photographs of the sun's disc taken in K_2 and K_3, but Prof, Michie Smith seems to have been the first to point out, when showing some slides of Kodaikanal photographs at a meeting of the Eoyal Astronomical Society in May 1907, that these narrow absorption markings were probably prominences, projected on the disc, since they led up to

[1] Transactions of the International Union for Co-operation ia Solar Research, Vol. IV, pp. *126,* 127.

prominences at the limb.[1] Some of these calcium absorption markings are shown on plate XI, and at first sight it seems incredible that the bright broad masses seen at the limb should assume such dark serpentine forms on the disc ; yet it is indubitable that while the transient eruptive prominence shown on the east limb on our frontispiece might have appeared on the disc as a bright reversal oyer a sunspot, the massive prominence on the west did actually appear on the disc as the long dark line shown on figs. 1 to 4, plate XI. Bright markings represent prominences of unusual brilliancy ; absorption markings represent prominences less bright; but that they appear dark on the disc by contrast only with the brighter background is obvious when one examines the many negatives which show a grey streak on the disc ending as a grey prominence at the limb, for the density of the silver deposit is exactly the same inside and outside the disc. And the length, is not so surprising when we remember the long groups of prominences which we have called "rows of sheaves," which sometimes extend over 60° of latitude, and when we reflect that the whole length of a prominence can never be seen at once unless it happens to lie exactly upon a meridian.

In 1908 M. Deslandres published a list of the most striking of these hydrogen and calcium absorption markings which he had observed at Meudon in 1894 to 1899 and 1903 to 1906, with the small spectroheliograph of that observatory; and he gave them the name of Filaments, by which they have since been generally known. Later, with a spectroheliograph of much higher dispersion, he found that when K_3 was perfectly isolated, so as to give a pure image of the highest layer of the sun's atmosphere, the filaments were very distinct, and that together with a number of finer lines (to which he gave the name of Alignments) they form a network of wide meshes all over the sun's disc. Of these he has made a special study, and his results were published in the Annales de TObservatoire d'Astronomie Physique de Paris, Yol. IV, with numerous beautiful illustrations: further observations and discussions have been added from time to time in the " Comptes Rendus " of the Académie des Sciences.

M. Deslandres says that every prominence is situated at the end of a filament or alignment, excepting only eruptive prominences near sunspots; nevertheless he does not consider that filaments are prominences, but only closely allied with them, and he states that in his photographs the prominences are not exactly in line with filaments where they reach the limb, but always slightly to one side, or rarely on both sides. One hesitates to disagree with so great an authority on these phenomena, but we can only state that all our experience at Kodaikanai goes to prove the essential identity of the filaments and the prominences which have been photographed here, and American astronomers seem to have reached the same conclusion

[1] The Observatory, XXX, 236.

with regard to their own observations.[1] Unfortunately it is impossible to reproduce photographs which will show prominences as they appear at the limb on calcium disc plates, but two typical instances out of many may be described.

(a) On April 9, 1910, a rather small and narrow prominence, photographed at latitude 50° south on the east limb, was seen to be continued on the disc as a filament. It remained visible for six days, and meanwhile the filament, which at first was only a short streak, gradually lengthened westwards, so that it seemed quite obvious that a very long narrow marking was being gradually brought into sight by the sun's rotation, and that the persistent prominence at the limb represented a new part of the streak each day.

(b) On April *22*, 1907, a " row of sheaves" appeared on the east limb, extending over 23° of latitude, but it must actually have been 34° long, and have slanted from south-west to north-east in latitude 9° to 43° north, for it was seen for four successive days, during which the southern part disappeared, and a more northerly part came into view, which gradually became higher than the southern end. These are the measures of its positions on the four days;—

April	22	+ 9° to + 32°	East limb.
„	23	+ 11° to + 34°	„
„	24	+ 19° to + 43°	„
„	25	+ 35° to + 43°	„

On the 25th and 26th a narrow dark calcium marking was photographed on the disc, which touched the prominence at its northern end (now the only part visible), and slanted thence in a south-west direction, so that its southern end lay well within the disc. This southern end was measured : its latitude was 9° north, and its distance from the east limb on the 25th was the distance to which rotation of the disc would bring it in three days ; on the 26th it was one day's journey further advanced. This filament, therefore, while touching the north end of the prominence, lay with its southern extremity exactly where the southern extremity of the prominence should have been on these dates. And that the prominence was likely to have survived for five days is most probable, for this is a very stable type, and it had already been seen on the west limb, from April 7 to 10 in the same latitude, 10° to 40°, and showing in the same way first the southern and afterwards the northern end.

But the finest instance of a prominence appearing alternately on limb and disc is the famous prominence of February, March and April 1910. It aroused attention in three continents, for it was photographed on the limb in America,[2] on

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* " Mr. C. Mchie Smith has cited evidence that the dark calcium floocuK are prominences Been in projection on the disc. Observations by Evershed, by Bass, and by Hale and EUerman, are in accord. I have accumulated !?j!rt nC6fr0mtlie Enmford 8PeoLrolieHoSraras t0 oonBm this." Mr. Philip Fox in AiteophyBlcal Jonnal,

* By Slocum at Terkes Observatory. Aatrophysical Journal, XXXIT, 125, plate XII.

the disc in France,[1] and on both in Kodaikanal. A full account of our observations will be found in the Astrophysical Journal.[2] The main facts of its life-history aro briefly these.

On February 5, 1910, a prominence appeared on the west limb, not quite a minute of arc in height, but extending over 16°, and this reappeared six times, alternately east and west, never reaching a greater height than 100*, but varying somewhat in form and extent. Sometimes it took the appearance of a "row of sheaves," but usually it was so close and compact that it belonged rather to the typo of Broad Massive prominences : it was remarked that the extent was always greater on the east than on the west limb. (It is curious how haunting is the eastern preponderance when once it has been pointed out.) It was also traced on the disc as a dark calcium marking during its three transits. Plate "VIII, fig. 1 shows the prominence on the west limb on March 4, fig. 2 on the east limb on March 17, plate I on the west limb on April 28 ; and plafce XI shows it on the disc at its successive transits. On February 28 it is nearing the west limb, is not very long, and lies chiefly in the southern hemisphere (like the prominence on February 5 and February 19); on March 23 and 25, when it was crossing the disc for the second time, it is a great bow-shaped streak, the centre of the bow lying on the equator (the prominence at this return had stretched from +15° to — 20°, and the equatorial portion had appeared first); in April the prominence on both limbs, and the marking on the disc, had lost the northern extension, and only the southern arm of the bow is seen on the photograph of April 18, near the eastern limb.

The great bow is very suggestive of a wave surging over the photosphere, with a greater speed at its centre, which is on the equator, than in higher latitudes, and accurate measures were made of its motion. From the intervals between the successive appearances of the prominence at the east and west limbs, it was founcl that the region emitting the prominence gas was rotating with the same angular speed as the photosphere at the equator, as determined from sunspots. But measurements of the daily motion of the filament across the disc showed that the gas itself was apparently rotating near the equator with an angular speed which in February was 5 per cent, and in March 11 per cent, greater than the photosphere at the equator. (The high-latitude portions of the filament were unfortunately too indistinct for exact measurement.)

It is true that if the absorbing gas was at a considerable height above the photosphere, but rotating in the same period, its apparent movement across the disc would necessarily be faster than that of the photosphere. Its effective height, however, is not likely to have been more than 30", and the increased speed

[1] By Deelftndres at Meudon. Annales de l'Observatoire d'Aafaronoinie Physique de Paris, Vol. IV, plate 42.

* JUteophyBioal Journal, XXXIII, 1. "W the Angular Speed of Rotation of a Long-enduring Prominence," by J. Bvershed. Plates I to IV.

due to this height would not exceed 3 per cent. It would aeem, therefore, that a certain dennite region in the sun was emitting gas for three months, and that the gas emitted drifted westward as the region moved across the disc.

The changes in form of the prominence when on the limb, and the changes of intensity when on the disc, amounting at times to complete disappearance and reappearance, show that the emission of gas was intermittent; but we speak of it as the same prominence, through all its changes, from February 5 to April 28, just as a wave, though changing constantly both in form and composition, remains the same wave.

Comparing hydrogen with calcium spectroheliograms (see plates X and XI), it is apparent that filaments show much more distinctly against the nearly uniform background of the former. Not only are the long snake4ike absorption markings clear, but a number of smaller patchy markings are conspicuous which scarcely show on the mottled calcium plates. If the figures in plate X are examined, it will be seen that besides the long sinuous lines on figs. 1, 2 and 8, to which attention has already been called, and a smaller one in the southeastern quadrant of figs. 1 and 2, there are many smajl patches. These patches tend to group themselves in rows, as may clearly be seen near the south-east limb in fig. 2, from the south-east limb to centre of disc on fig. 3, and in both hemispheres on fig, *4}* the northern, group being unusually black and large, and united by fainter lines. It will be remarked that all these are in about the same latitude of *50°* north or south, while the long lines are in equatorial regions ; and this is a general rule. The small patches are Deslandres' " polar filaments," which he sees united by very faint " alignments, " and compares with a necklace of beads. Sometimes they follow one another in such long rows that they must completely encircle the pole.

A third kind of absorption marking which is seen on plate X, figs. 1 and 2, is a group of very small fine streaks radiating from a eunspot disturbance, and these often show a spiral curvature, as pointed out by Prof. Hale. The sunspofc in the southern hemisphere can here be plainly seen : it is a round spot, and is surrounded by dark spirally curved streaks and very pmall bright patches. *No* sunspot is visible in the northern hemisphere, but the large bright patch and dark line which we have already noted mark the position of a spot which had crossed the east limb on April 1; it broke up, and died out on April 10, but the region was evidently still active, and here also is a group of fine radiating streaks, both dark and light. They are faintly seen on fig. 1, when the disturbance was on the central meridian, but those round the southern spot are clearest on fig. 2, and fig. 3 shows a curved dark streak at the edge of a sunspot disturbance near the east limb. On the original negatives these are all very distinct. Large active sunspots seldom appear on hydrogen plates without these radiating lines, and it is possible that they represent a bird's eye view of rocket prominences A typical rocket prominence, with bright metallic centre, accompanied the northern sunspot (Greenwich, number 6938) when it crossed the east limb on April 1.

Long dark lines like that which runs through the bright patch are not infrequently observed crossing flocculi, but generally, as in this case, no sunspot is visible.

lla absorption markings were photographed at Kodaikanal from April 1911 to the end of 1913 ; in 1914, as their number had greatly diminished, and the grating was required for other important researches, their observation was temporarily discontinued, and no more plates were taken until January 1,1915. During the three years in which they were photographed, curves of their distribution in latitude were prepared for each half-year, in the same way as for prominences, aud published in the Kodaikanal bulletins. On diagram XI they are drawn for the whole years, in the same way as the prominence curves in diagrams III to YI, and it is evident that the resemblance is very close. The distribution is the same, with two chief zones of activity in each hemisphere, one in sunspot regions, and one at about 50°. The fall at minimum is, however, even more marked, and it will be remembered that we found compact massive prominences become much less frequent in minimum years, while faint diffused prominences are relatively more abundant. It is most probable that faint and diffused prominences do not show themselves on the disc in our plates.

Southern predominance is also very strongly marked here, much more so than on the prominence curves, which seems to indicate that prominences were not only more abundant in the south, and more active (as shown by the southern preponderance of metallic prominences), but also more compact and dense.

At first, during the period April to June 1911, hydrogen absorption markings predominated on the eastern side of the sun, the percentage being 52'0 for numbers, and 53*5 for areas, or practically the same as for prominences, bright hydrogen reversals, and D_3 darkenings; but during the second half of 1911 the west predominated ; and for the rest of the period (i.e. to 1913 December) predominance fluctuated between east and west in such a way that when numbers are reckoned for the whole period they are almost exactly equal, eastern percentage being 49*8, while areas show a slight western preponderance, eastern percentage being 48*0. This is, however, the period during which prominences also showed a change to western preponderance.

Nevertheless, the curve of longitude distribution for hydrogen absorption markings would closely resemble the curves of the other disc markings observed through earlier years (see diagram IX, and compare with diagram VIII), but for the presence of a pronounced and disconcerting hump at 70° to 80° west of the central meridian ; for here also there are minima at the limbs and the centre, and maxima between, although these maxima lie somewhat nearer the centre than in the other curves, viz., at 30° to 40° west, and 80° -to 50° east; and until the curve begins to rise again towards the western hump, the eastern and western parts are symmetrical, and the western lower than the eastern. It is possible that this hump was only a temporary feature with no special significance, for it is almost entirely due to a great development of markings at this longitude in 1911, which was not sustained during the two following years; and as the number of hydrogen markings fell off greatly during 1912 and 1913, and the areas still more, the curve chiefly represents the period April to December 1911.

The curve of diagram IX has been constructed from lengths, not numbers, in order to give due weight to the long markings: they were measured by treating each sinuous line as if it were straight, and counting the number of degrees of longitude between the two extremities, without paying attention to any twists or bends, a somewhat rough method, but convenient for the purpose, and accurate enough, as is proved by the fact that it yields the same eastern percentage for the whole period as the areas, viz., 48*0.

It must be remarked that during minimum years high-latitude filaments (like high-latitude prominences) are much more abundant than low-latitude filaments,, and high-latitude filaments are usually short and roundish: their shape, therefore,, may make them more easily visible near the centre of the disc, and thus partly neutralize the fact that their greater effective depth makes them more conspicuous near the limbs, and therefore the position of greatest visibility for hydrogen filaments, at least during years of minimum, may be normally between 30° and 50° from the central meridian, while bright hydrogen reversals have their position of greatest visibility at 45° to 60°, and D_3 darkenings at 60° to 75°. On the other hand, further observations may perhaps show that there are two eastern and two western maxima in longitude for hydrogen filaments, at about 40° and about 75°, corresponding with the high-latitude "beads" and low-latitude " snakes," while bright reversals and D_3 darkenings, which have only been observed near sunspots, in sunspot latitudes, have only one eastern and one western maximum. Only a prolonged series of observations of all the disc markings can show whether their apparent small differences in longitude distribution are real or not: the outstanding fact at present is their essential likeness.

The yearly numbers of hydrogen absorption markings, and the total yearly lengths, are given below, divided into east and west; and it will be observed that lengths fall off towards the year of minimum, 1913, much more rapidly than numbers, exactly as prominence areas fall off more rapidly than prominence numbers'.

Year	Numbers		Lengths in degrees of longitude	
	East	West	East	West
1911 April to end ...	249	273	2152	2371
1912 ...	H 4	115	726	570
1913 ...	72	81	326	523
Totals ...	435	469	3*204	3464

Dr. Royds has investigated the connection between Hα absorption markings and prominences, and his results are as follows ;—

Although many prominences which appear at the limb do not show on the disc—sometimes, no doubt, because they are transient phenomena—, yet whenever, a dark marking reaches the limb a prominence almost invariably appears. Even when the dark marking cannot be traced right up to the limb, an associated prominence can often be observed, especially in the belt near 50°, where the dark markings are of longest duration. The prominence is generally more extensive than the dark marking, but some distinctive part of it usually coincides in position. It is possible that the greater width of the prominence is owing to the fact that sometimes its upper diffused portion only is visible, the main stem being cither in front of the limb or behind it.

Deslandres finds line-of-sight motions in his filaments which show that the gas is in general ascending.[1] Systematic observations have been made at ELodaikanal to investigate this question, but so far, in a large majority of cases, no measurable displacement has been observed, either when the filament is near the limb or near the centre of the disc. Dr. Royds has found some displacements in filaments which were in the neighbourhood of sunspots.

Filaments whioh appear on our calcium plates have been investigated by Mr. Sitarama Ayyar, from 1907 April to 1911 March, that is, during the period when the best; calcium plates were being obtained and the markings were frequent. From 1911 to 1914 not many were seen. The photographs were taken in H in 1907, and afterwards in K. K_3 cannot be isolated from K_a, for the spectroheliograph has a low dispersion, and separates H and K by only 5 mm.

Mr. Sitarama Ayyar finds that the filaments differ much in intensity, and he selected for study and tabulation only the longer ones, and those which were easily distinguishable. In a few cases the ends were ill-defined and merged into faint shadings ; this indistinct portion was not included. The results of his investigation may be summarized as follows :—

I. *Distribution and Frequency of Long Filaments.*—For the whole years included in tho period, the numbers of long filaments, compared with prominence numbers and areas, are given below.

Years		Number of filaments	Number of prominenoes	Mean daily areas of prominences
1908	...	131	6253	5-39
1903	...	152	6472	4?U
1910	...	194	6779	4-10

The increase from 3 908 to 1910 in the number of prominences at the limb, although areas were decreasing, has already been remarked, and is shown on diagram I, curve No. 3. Filaments, that is prominences on the disc, when reckoned in numbers, naturally i n c r e ^ e j W b ^ :he ratio is much higher. The probability

[1] Aunales de VObservatoire d'Astronomie Physique de Paris, IV, 115.

• xi x A i 1. i • ,•,, ^..nT^inPTipft numbers is accounted for by the increase is that the whole increase in prominence nuiuuuia xo • ^ ,. n ,, £ n • ;i oc TOO a Tinll nresentlv see—it is chiefly small promi- of small prominences, and—as we snail presetwy DD J T . nences which are represented on the disc by long calcium filaments. It is possible that the increase in numbers of both small prominences and long filaments is partly due to continual improvement in the quality of the photographs, by means of improvements in the spectroheliograph and its handling; but Deslandres has also remarked that there was a great development of filaments *m* 1910, just when sunspots were diminishing in numbers.

The curves of distribution in latitude for the Long Filaments in these three years agree well with the prominence curves (compare diagram X with diagram VI), except that the high-latitude zone is poorly represented. High-latitude filaments, which are conspicuous on hydrogen plates, are usually short, and do not show well on calcium plates ; long filaments, showing clearly on calcium plates, with which we are alone concerned here, very seldom go beyond ±35°, although occasionally their extremities have been traced as far as 70°. Thus there is only an indication of the zone between 50° and 60° in the northern hemisphere in the year 1909, but in the southern hemisphere it beoomes of some importance in 1910, when it was the highest zone in the prominence curves. The low-latitude-zone has about the same position in both sets of curves, and in both is more developed in the southern than in the northern hemisphere. Long Filaments therefore were much more numerous in the south than the north, during these years, although prominences, many of which were in high latitudes, occurred in almost equal numbers in the two hemispheres.

Years	Filament lumbers		Prominenoo Numbers		
	North	South	North	South	
1908	52	89	2920	3295	The prominences on
1909	75	89	3206	3233	the equator are
1910	62	138	3388	3338	omitted.

(Filaments which extend across the equator are counted as belonging to both hemispheres.)

Apart from the fact that high-latitude prominences are very seldom seen on the disc as long filaments, the very small numbers of the latter as compared with prominences indicate that only a certain kind of prominence can appear in this form on our plates.

The eastern preponderance which we have found everywhere during these years does not fail to put in an appearance here; in fact, it is greater with long filaments than with anything else, for the percentage east in the period January 1907 to June 1911 is 61-9 when numbers are compared, and 65-tS when lengths are compared, by adding the total numbers of degrees covered by these filaments in each hemisphere. They are therefore not only more numerous but longer in the eastern hemisphere than in the western.

The lower curve in diagram VIII shows the distribution of long filaments across the sun's disc. The fall towards the west is clearly indicated, and in addition to this there are minima at the centre and at both limbs, similar to those in all the other longitude curves in diagrams VIII and IX. These minima are doubtless all due to the same causes, and we have suggested above that visibility near the limba is lessened because of foreshortening, while visibility near the centre is lessened because of lesser effective depth in the absorbing or emitting gas. In this connection it is interesting to recall the observation of M. Deslandres, that filaments appear broader when at some distance from the centre than when near it*

The calcium filament curve is the most regular of all these longitude curves, probably because based upon larger numbers. The number of filaments represented is only 577, but their total length is 14,404 degrees, or double thab of the hydrogen filaments of diagram IX, measured in the same way. That is, each filament is treated as a straight line, and the distance between its extremities estimated in degrees oE longitude: if all the windings were taken into account, the length would often be considerably greater.

Ifor filaments are often of enormous length, at times reaching to over a quarter of the sun's circumference. They are sometimes visible for many days in succession, as is shown by the following table:—

44t	filaments were seen on	2 days	1	filament was seen on	7 days
.20	,,	3 ,,	2	filaments were seen on	8 ,,
14	,,	4 ,,	1	filament was seen on	9 ,,
6	,,	5 ,,	1	,,	11 ,,
[illegible]	,,	6 ,,	1	,,	[illegible] ,,

2. *Direction of the Long Filaments.*—It is not common for filaments to lie parallel with either the sun's equator or axis: they more usually slant, and Deslandres noted that the high-latitude extremity of a filament is usually *to* the east. This struck Mr. Sitarama Ayyar independently as the most interesting feature of his long filaments ; but he found that it applied only to the eastern! hemisphere. Omitting 72 filaments which lie parallel with the equator or axis, we have a total of 5H4: of these there are 34)1 in the eastern hemisphere, and only 32, or 10 per cent, have eastern ends in a lower latitude than the western ends ; but out of 193 in the western hemisphere 86, or 45 per cent, have their eastern ends, in low latitudes. It happens that this calculation was at first made separately for the two periods 1907 April to 1909 March, and 1909 April to 1911 March : the results were practically the same for both periods. The great bow-shaped filament of March 1910 is a striking instance of this rule, the middle of the filament lying on the equator, and the two arms, both, north and south, bending eastward. See fig. 2, plate XI.

The explanation of this slant in the eastern hemisphere is probably the difference of rotation between higk and low latitudes, for it js known that rotation is slower "in high latitudes, and this would cause the high latitude part of a filament to lag behind the part nearer the equator ; but why this should not act equally in the western hemisphere it is not easy to explain. Possibly most of the filaments are extinguished while crossing from east to west, so that a large proportion of those in the western hemisphere are new formations, and then they might not yet liave acquired the slant which would preseiifcly result from the difference in speed of rotation. Assuming that the difference is the same as that which lias been found for sunspots, a filamint which at its first appearance lay perpendicular to the equator in latitude 20° to a0°, and at a distance of two days' journey from the west limb, would have acquired a slant of 32° sixteen days later, when it would be well within *the east limb, and clearly visible there. Or if it lay four days' journey within the west limb, and stretched from latitude 20° to 45°, it would have a, slant of 35° when four days within the east limb. This accords very well with the average slant of'filaments in the eastern hemisphere. The hypothesis rests upon unproved assumptions, but at least it does not appear to be oontradioted by any known facts. It should not, however, be forgotten, that Adams has found at the hydrogen level of the chromosphere only a slight difference in rotation speed in high and low latitudes.

Mr. Sitarama Ayyar has also investigated the positions of long filaments with regard to floceuli. He finds that 41 per cent of 606 filaments are connected with flocculi; a very small number have flocculi at both ends, and a larger number run through the midst of flocculi; but by far the greatest number have a flocculus at one end only. And of these, 167 in number, all but 18 have the free end in higher latitudes than the flocculus end.

When it is remembered, however, that sunspots and flocculi in these years were in low latitudes (mean sunspot latitude fell from 12°'l to 6°5 between 1907 and 1911), it seems inevitable that with most of these* long filaments the end that was near flocculi should be in lower latitudes than the other end; also that in a period when both filaments and flocculi were abundant a large proportion should lie close together. In fact, as 59 per cent contrived to avoid flocculi, although frequenting the same latitudes, the conclusion seems to be that there is on the whole a tendency among long filaments to avoid sunspots, just as we found with the long prominences (extended masses and groups).

Relations of long Filaments with Flocculi

April 1907 *to March* 1911

Number of Filaments with a flocculus at both ends	10	
» », running through flocculi ...	74	
» » with a flocculus at one end (always the low-latitude end except in 18 cases)	167	
Total number connected with flocculi		251
Total number not connected with flocculi		[illegible]
Grand Total ...		606

3. *Prominences connected with Long Filaments.—One* hundred **and seventy-** three of the long filaments examined by Mr. Sitarama Ayyar reach the limb, and of these 103 end in prominences visible on the calcium plates. As Dr. Eoyds found with tho Ha filaments, the prominence is often broader than the filament, but in most cases where this happens that part of the prominence which is in continuation of the filament is clearly distinguishable. The following characteristics were noted :—

Filament-prominences, though not so bright as prominences standing directly over flocculi at the sun's limb, are distinctly brighter than the average. (They would not otherwise be visible at all on the flocculus plates. But their brightness is probably caused by density, rather than high temperature, or they would appear bright, not dark, when on the disc.)

They are of moderate height. Of the 103,19 were 20" or less, 72 were from 20" to 40", 8 from 45" to 60", and only 4 were over tO". The greatest height reached was 130".

They are quiescent. In only *two,* or perhaps three, cases, was the prominence eruptive. Even, then it is possible that a superimposed prominence,, and not the filament-prominence, was eruptive.[1]

They are never metallic.

It is clear that our investigation of prominences projected on the disc can only be preliminary, because the period in some cases has been very short (less than three years for Ha- filaments, and four years for calcium filaments). Nevertheless- some definite conclusions can be drawn which, seem to be worth putting" on record L

(1} Brilliant eruptive prominences near sunspots are often seen upon the disc as Ha reversals, and on very rare occasions metallic lines have also been observed. In all, 12S0 Ha reversals were seen between 1904 and 1914. Of these, 688 were- recorded between 1907 and 1914, which is not a much greater number than the 604 typical spot-prominences recorded at the limb in those years, As a spot prominence has only a chance of being seen while the sunspot is crossing the limb, bat a reversal may be seen on any day while the sunspot is on the visible disc, one would expect the proportion of reversals to be greater than this; but it is only the brightest spot-proratinences which can be thus seen on the disc.

(2) Disturbances round sunspots are also photographed on hydrogen spectro-heliograms, as both emission and absorption markings, in the form of patches, and fine radiating streaks, often spirally curved. The latter may be "rocket"' prominences seen on the disc.

(8) A certain number of quiescent stable prominences show themselves on the disc as absorption markings of hydrogen and calcium. These consist chiefly of snake-like streaks, which are well seen on the calcium plates, but better on the hydrogen, and patches which tend to follow one another in a row like a necklace of beads, and these can scarcelybe distinguished on c j ^ ^ J ^ e s > owill g to tlie*

[1] Filaments have since bean recorded which were evidently associated with large eruptive prominences.

variegated background. . Snakes are almost restricted to low latitudes, seldom going beyond 35° north or south; beads belong chiefly to a latitude of about 50°. This accords with what we found among the prominences at the limb, for long prominences covering many degrees of latitude are most frequent in low latitudes, and prominences restricted to a few degrees chiefly occur in high latitudes, where they often appear to be extended in longitude, since they remain at the same position on the limb for several days in succession. It is chiefly prominences below 60" in height which become conspicuous on the disc as absorption markings.

(4) Several facts point to the conclusion that it is the specially dense prominences which appear as filaments on the disc. They usually appear compact when photographed on the limb, and they are bright enough to show themselves oatside the disc on flocculus plates, but this cannot indicate high temperature or they would appear as bright reversals and not as absorption markings on the disc. The small width of filaments, often less than that of the prominences of which they form a continuation, suggests that they represent only the dense core of the prominences, the diffused upper and surrounding portions remaining invisible. The distribution in latitude of long and short filaments is similar to that of long and short prominences of the compact dense kinds, and not to that of diffuse and faint prominences which occur with equal frequency in high and low latitudes. Also, filaments almost disappear at the minimum of sunspot frequency, when prominences, though still fairly frequent, are mostly faint and diffuse.

(5) filaments, like metallic prominences, and prominences with line displacements, show an even higher eastern percentage than the generality of prominences : and this seems to indicate that prominences are not only more numerous and more active, but more dense in the eastern hemisphere. All these phenomena began to change their eastern excess in the year 1911 or 1912.

(6) Filaments were much more abundant in the southern hemisphere than the northern, during the years 1907 to 1913.

(7) Darkenings of the D_3 line seen on the disc probably represeDt prominences also. lor they indicate the presence of unusually dense helium gas as filaments indicate relatively dense hydrogen and calcium ; and these three gases which are to* chief constituents of prominences at the limb, probably exist Wether in filaments on the disc. If D_3 darkenings could be photographed, they would probably be found to coincide with hydrogen and calcium filaments.

(8) When we trace prominences across the disc as bright Ea reversals as calcium and hydrogen filaments, and as D_3 darkening*, it appears that there Is a gradual fall m numbers from east to west until the year 1911 or 1912- W ™ addition to this there is a minimum at the centre and'another at ea h Lb and there ,s a maxmaum on either side of the central meridian. The posxTions of these maxnna seem to be slightly different for each kind of disc marking H reversals, D_3 darkemngs, and long calcium filaments, which are all lowitLde

markings, they fall somewhere between 45° and 75°; for hydrogen filaments, which include both low-latitude and high-latitude markings, of differing form, there are possibly two maxima in each hemisphere, one at 30° to 50°, and the other at 70° to 80°, but since the latter appeared, only in the year 1911 and not later, it is probably only a temporary feature, with no real significance. It is suggested that the minimum at the limbs is due to lessened visibility owing to foreshortening, and the minimum at the centre to &, less effective depth of gas to produce radiation or absorption; and from this it is argued that the amount of gas concerned in producing all these phenomena must be exceedingly small. If so, and if filaments represent the densest of the pi"ominences, the generality of prominences must be exceedingly tenuous.

VI.—CONCLUSION" AND SUMMARY.

Sixty thousand Kodaikanal prominences, and eleven thousand from Kenley, and other thousands from[1] Borne, Sicily, Kalocsa, yet we cannot take one prominence and say : This caused it, thus and thus it began$_3$ and developed, and ended. II we could do this, perhaps we could say what the sun is, and the universe of stars, and incidentally what is the destiny of this beautiful planet on which we live. But scientific work demands great patience. Only rarely comes a flash of insight, and for this there has always been long and toilsome preparation, and the new vision prepares the way for further gradual advance into the unknown. The discovery of Janssen and Lockyer made it possible to see prominences daily; Hale's invention of the spectroheliograph made it. possible to photograph them daily; and the plotting and observing which has now been carried on by different workers for more than forty years has taught us some facts about the forms, the movements, and the distribution of prominences, facts which suggest lines of farther research, and promise further discoveries to explorers.

The chief facts so far established, and the problems suggested by them, may now be very briefly stated.

First, there are four belts round the sun, two in the north, and two in the south, which are specially prolific in prominences ; and the high-latitude belts have a> different life-history from the low-latitude belts, and tend to produce prominences of, different form.

The low-latitude belts or zones are in the same latitudes as sunspots, and have the same history, for they increase and diminish in activity simultaneously with sunspots, disappearing in years of minimum, and they seem to draw in gradually towards the equator, like the sunspot zones. Only a small proportion of the prominences in these zones, however, are directly associated with spots, and these are nearly always small and low, of the " rocket " type, though occasionally one of the streamers composing this type may rise to a great height. " Rockets " most frequently appear over large active middle-aged sunspots; they are also associated, but single low jets of unusual brilliancy are still more frequently associated, with young active spots; small and old spots cross the limb unaccompanied. The rare Arch form belongs also *to* this zone, and accompanies sunspots; and almost all metallic prominences of measurable height, or showing any considerable number of spectrum lines, are more or less closely connected with spots and faculse.

But all the larger prominences, of which there are many in this low-latitude zone, are not directly connected with sunspots. Massive forms, and long groups, occur in regions free from ppots, and when dense enough they appear on the disc as dark " filaments, " very narrow, and often very long. They do not look so narrow on the limb because there one sees a quantity of diffuse gas surrounding the denser core; and their length is seldom appreciated because the whole prominence does not lie on one meridian, but slants east and west, so that successive portions come into view on successive days. This type is long-lived, and sometimes crosses a limb more than once.

In the high-latitude zones, these long prominences do not often appear, nor of course the rockets, or arches, or metallic jets, which are specially associated with sunspots, although very low metallic prominences showing lines of magnesium, and sodium, and the enhanced lines of iron, are sometimes seen.' The form characteristic of this zone is a pyramid or column, which is often seen for many successive days at the same latitude, and these sometimes appear on the disc as roundish patches following one another in a row.

This high-latitude zone, although it also decreases somewhat in activity at sunspot minimum, does not disappear then, nor does it ever travel towards the equator; on the contrary, its movement is towards the pole, wbich it reaches about the time of sunspot maximum, and it dies out there. After sunspot maximum, it forms again in latitude ± 50°, and it reaches its greatest activity between sunspot minimum and maximum.

When prominences reach the poles, magnetic storms on earth reach their maximum frequency; hut this is also the time of sunspot maximum, and on the whole the relation of magnetic.storms seems to be closer with sunspots than with prominences. It may be, however, that one of the necessary conditions for a. sunspot to have power to cause a magnetic storm on earth is the presence above it of an eruptive prominence.

When prominences extend to the poles., and are also abundant all round the-disc, as at sunspot maximum, the corona is of the " dahlia" type, that is to say, > there are streamers all round the disc, even at the poles; but when prominences, cease at their usual limit of about 60° north and south of the equator, coronal' streamers also cease at about the same latitude, and the poles are marked only by short straight rays.

Secondly, we have the puzzling fact of the eastern preponderance. Since 1880, prominences have been on the whole more numerous on the eastern than on tho western side of the sun, and although there are some fluctuations, the fuller the observations the more constant the eastern excess appears to be. Moreover, prominences are not only more numerous, but, according to Kodaikanal records, they are more active, and denser, on the east. It is not only at the limb that the difference is observed, for prominences, when photographed on the disc as bright emission and dark absorption markings, are fewer and smaller over the entire western quadrant, as compared with the eastern. The decrease is not regular, however, from east to west, for it is complicated by what appears to be an optical effect, due to foreshortening near the limbs, and lessened effective density at the centre.

The only difference between the east and west sides of the sun is that one is advancing towards us, the other receding from us. But an investigation at Kodaikanal seems to negative the suggestion that prominences may be brighter, and therefore apparently more numerous, on the advancing side, and there seems no possible reason why they should be more active, or more dense. On the advancing limb they are just arriving on the earthward side of the sun, on the receding limb they, leave it; and this suggests a possible Earth-influence, which is supported by the further fact, that line-of-sight movements in prominences are more frequently away from Earth than towards it, on both limbs, as if the gases were being repelled from Earth. Towards the end of our period, about the year 1912, a change set in, and prominences both at the limb and on the disc, and also the direction of line-of-sight movements, began to show an eastern and westwn equality, or even a western preponderance. One of the interesting questions for the future is whether this is only a fluctuation, or an enduring change.

Of a different nature is the contrast between north and south on the sun. During the last three sunspot cycles, sunspots have been on the whole more abundant in the southern "hemisphere, but the northern has reached each phase a little earlier, and therefore when on the up grade of each cycle it has at first been more prolific than 'the south, which later overtook and surpassed it. The same has been the case with, prominences since 1890, and during the last cycle we find that the greater activity of the south is manifested not only by the greater areas of prominences, but by metallic prominences being more numerous, and those with many spectrum lines extending to much higher latitudes in the south, also by the much greater number of filaments, both on calcium and hydrogen plates; that is to say, prominences were not only larger but more active and more dense in the south.

It will be important to note, during the coming cycle, whether this difference between the two solar hemispheres persists, and if so, to consider what can be its cause.

Another research, which has only just been begun, is that of the rotation speed of prominences. That they rotate faster than the chromosphere is indicated by measurements of their spectra, and also by the behaviour of the long-lived prominence of 1910. The fuzzy appearance at the upper limit of the lines in many prominence spectra, suggesting turbulent motion at the summit, has also to'be explained; and the eastward slant of the high-latitude extremities of long filaments seems to indicate a lower speed of rotation in high latitudes than in low, at the level of prominences, similar to that found at sunspofc level.

Lastly, the individual motions of quickly moving prominences invite study, especially as a means of investigating the forces at work in the sun, and this study is already beginning to yield suggestive results. The prevailing type of sunspot-prominence, the " rocket ", is evidence of an intermittent explosive force in sunspots, acting upwards and outwards, but only neutralizing gravity to a limited extent, since the gas ejected seems always to have a tendency to fall down again upon the sun's surface at a little distance from the sunspot. In the large masses, on the contrary, which are sometimes suspended above the chromosphere, or rise rapidly above it, often with accelerating speed, we recognize a powerful force which continues to act for hours, and neutralizes gravity completely, for it is rare to see one of these masses descend : they usually fade away when their greatest height is reached. It will be extremely interesting to discover whether the same speed is always reached at the same height: there is some indication that this is the case. It is desirable to know also what is the limiting height beyond which prominences always become invisible.

This rapid motion, and rapid fading, and the fact that a difference in depth of a few thousand miles apparently affects the visibility of a prominence on the disc, favour the presumption that however voluminous a prominence may be, it is always exceedingly tenuous. And if this is so, it follows tJ^at the atoms are so far apart that their free path is infinite, and the mass of gas cannot have any temperature in the ordinary sense. Its luminosity is due to the internal energy of the atoms, perhaps derived mainly from absorption of the intense solar radiation.

The changes of individual prominences in density and luminosity, and the differences between prominences in these respects, but above all a knowledge of their average density, and the cause of their luminosity, are amongst the most, interesting and important problems which await solution.

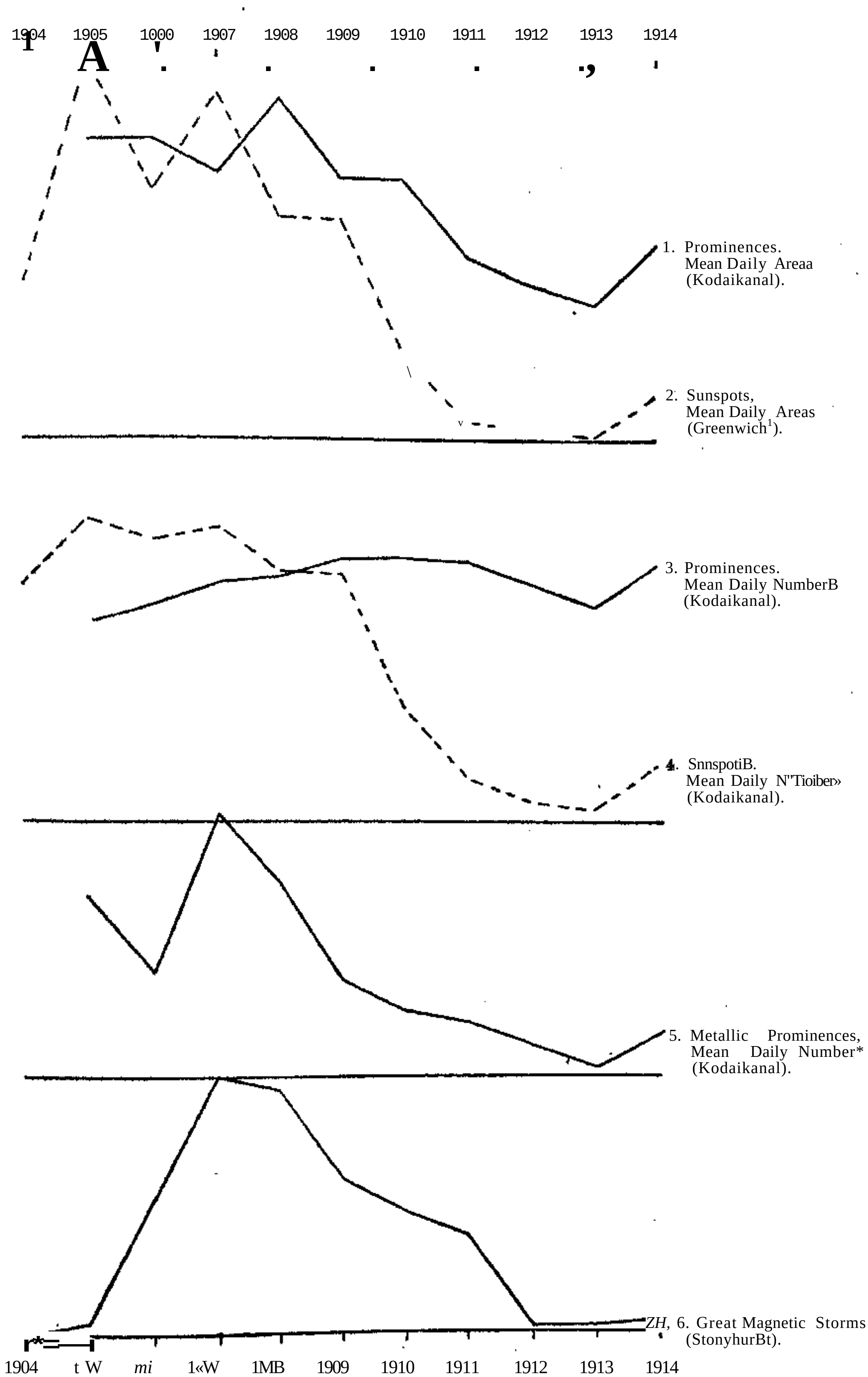

DIAGRAM I.

Prominences, Sunapots, and Mitgnetic Storms during the years 1904 to 1914.

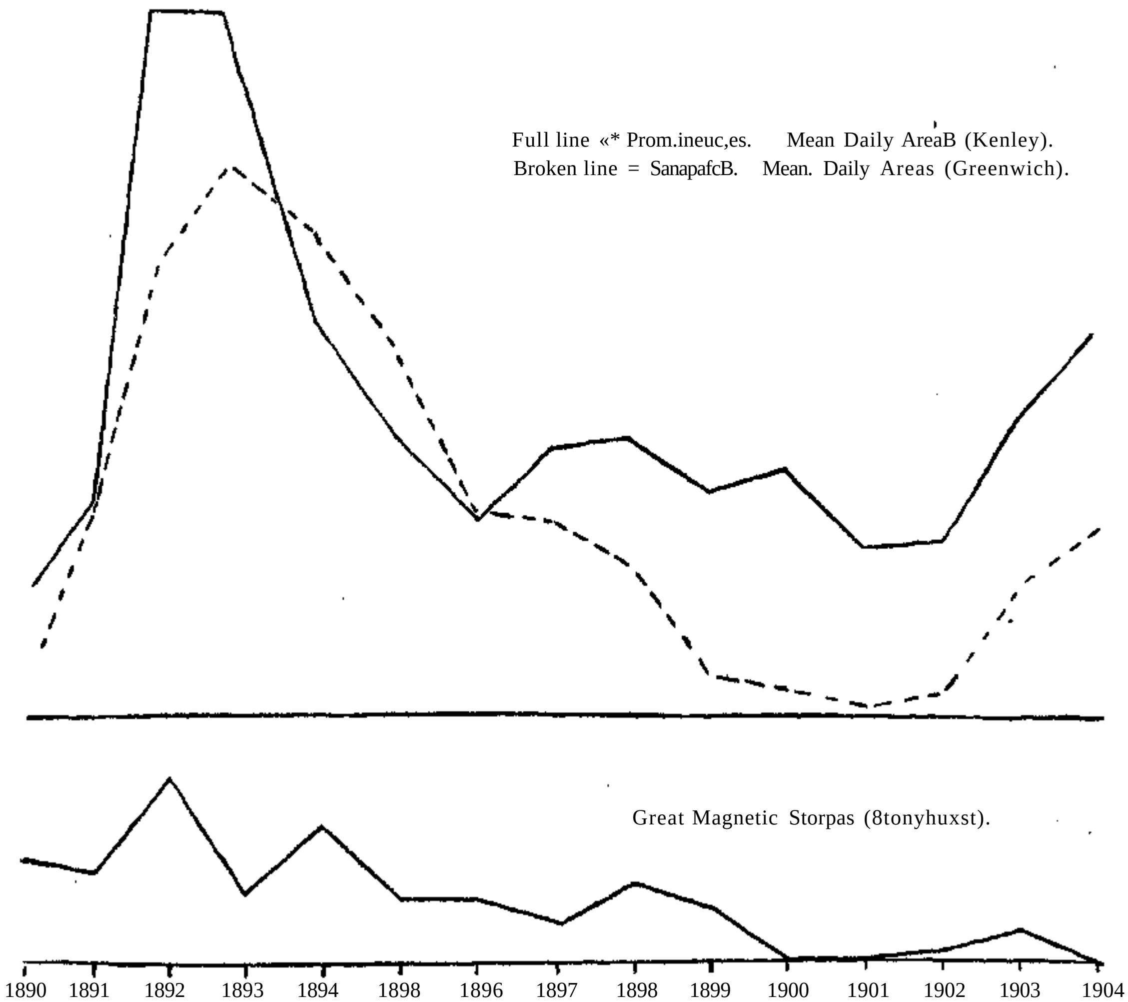

DIAGRAM II.

Prominences, Sunspots, and Magnetic Storms during the years 1890 to 1904.

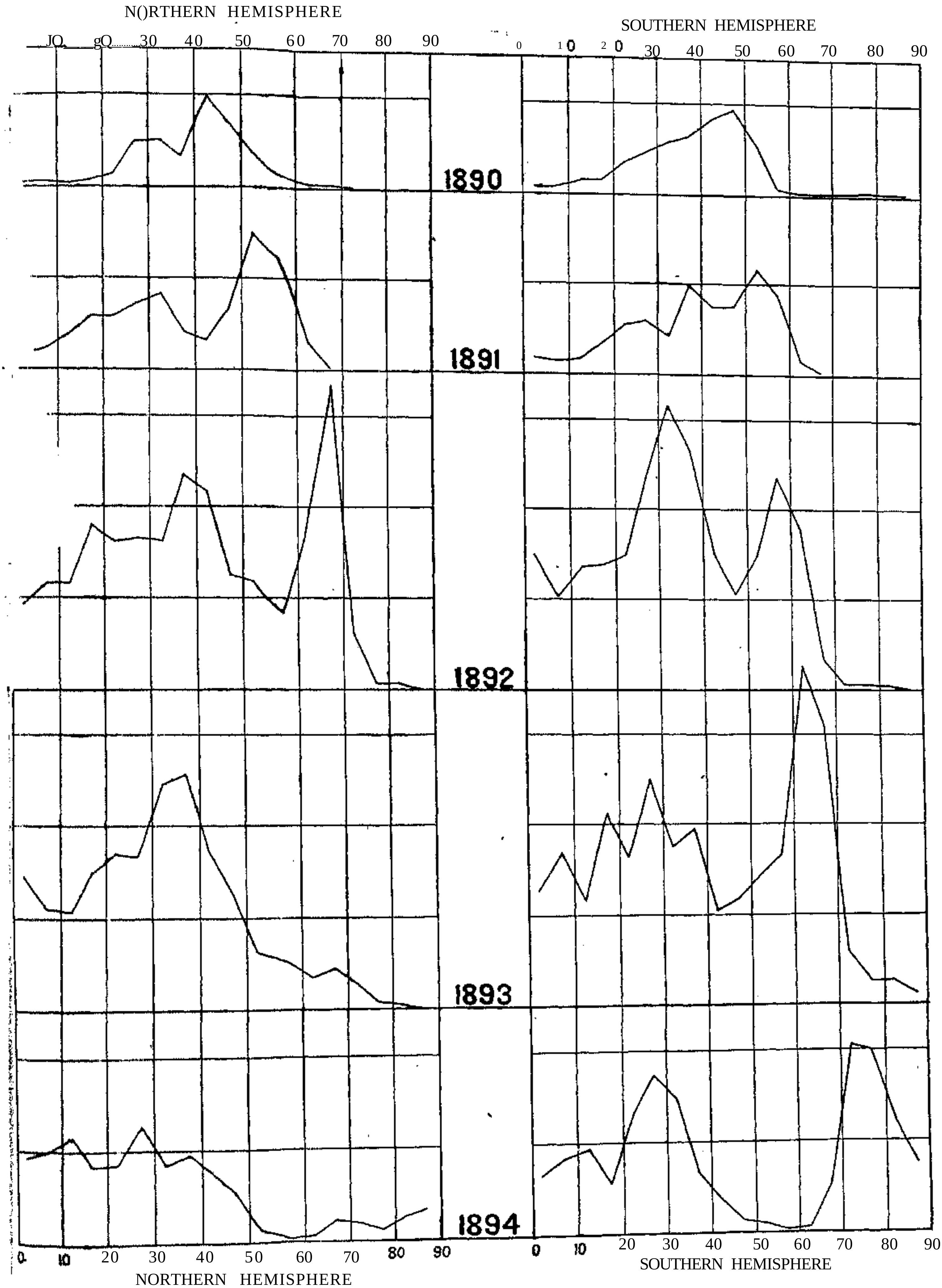
NORTHERN HEMISPHERE
SOUTHERN HEMISPHERE
10 20 30 40 50 60 70 80 90
0 10 20 30 40 50 60 70 80 90
1890
1891
1892
1893
1894
0 10 20 30 40 50 60 70 80 90
0 10 20 30 40 50 60 70 80 90
NORTHERN HEMISPHERE
SOUTHERN HEMISPHERE

DIAGRAM III.

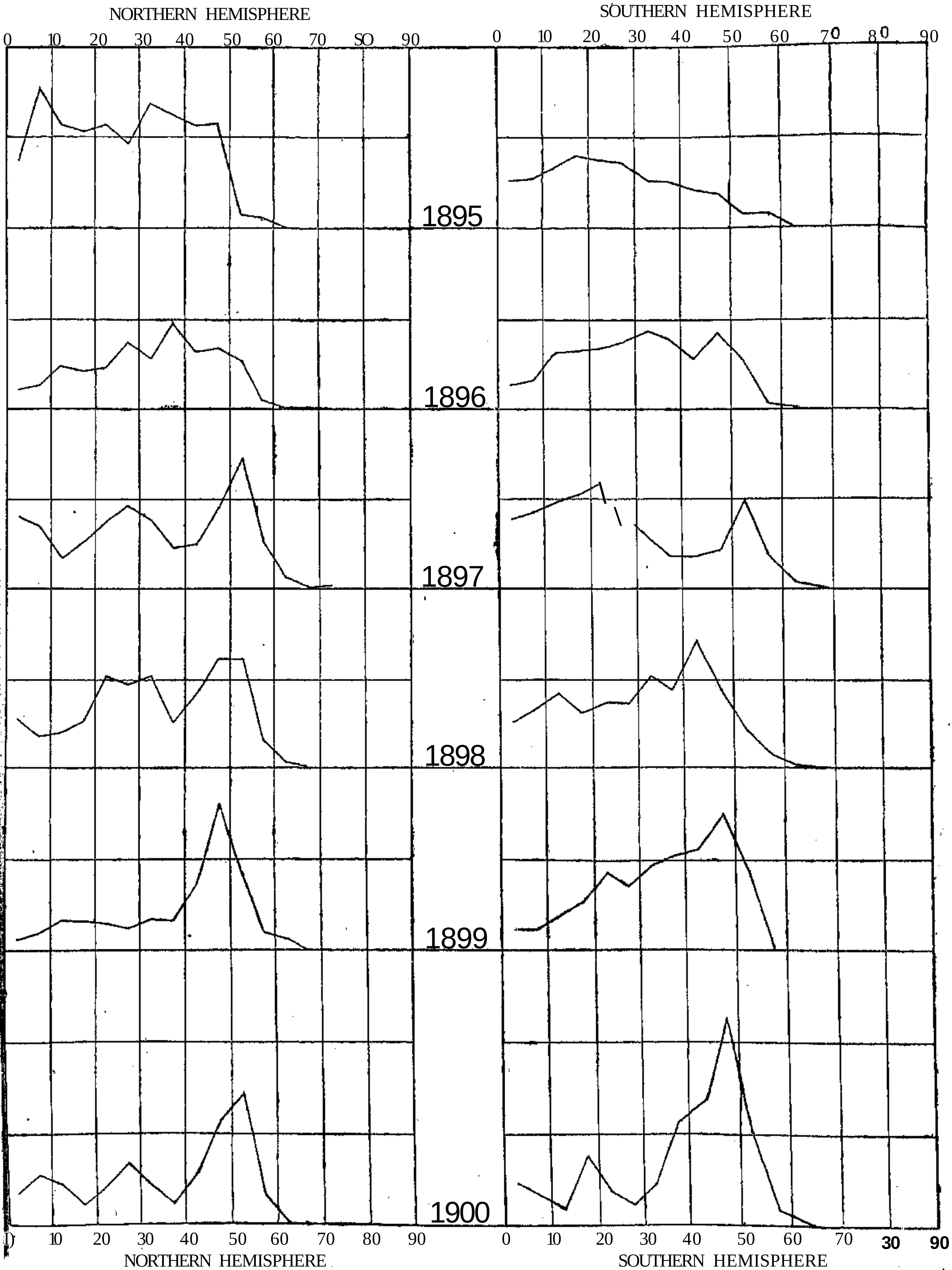

DIAGRAM IV.

Distribution of Prominences in Latitude for the years 1895 to 1900 (Kenley Observations).

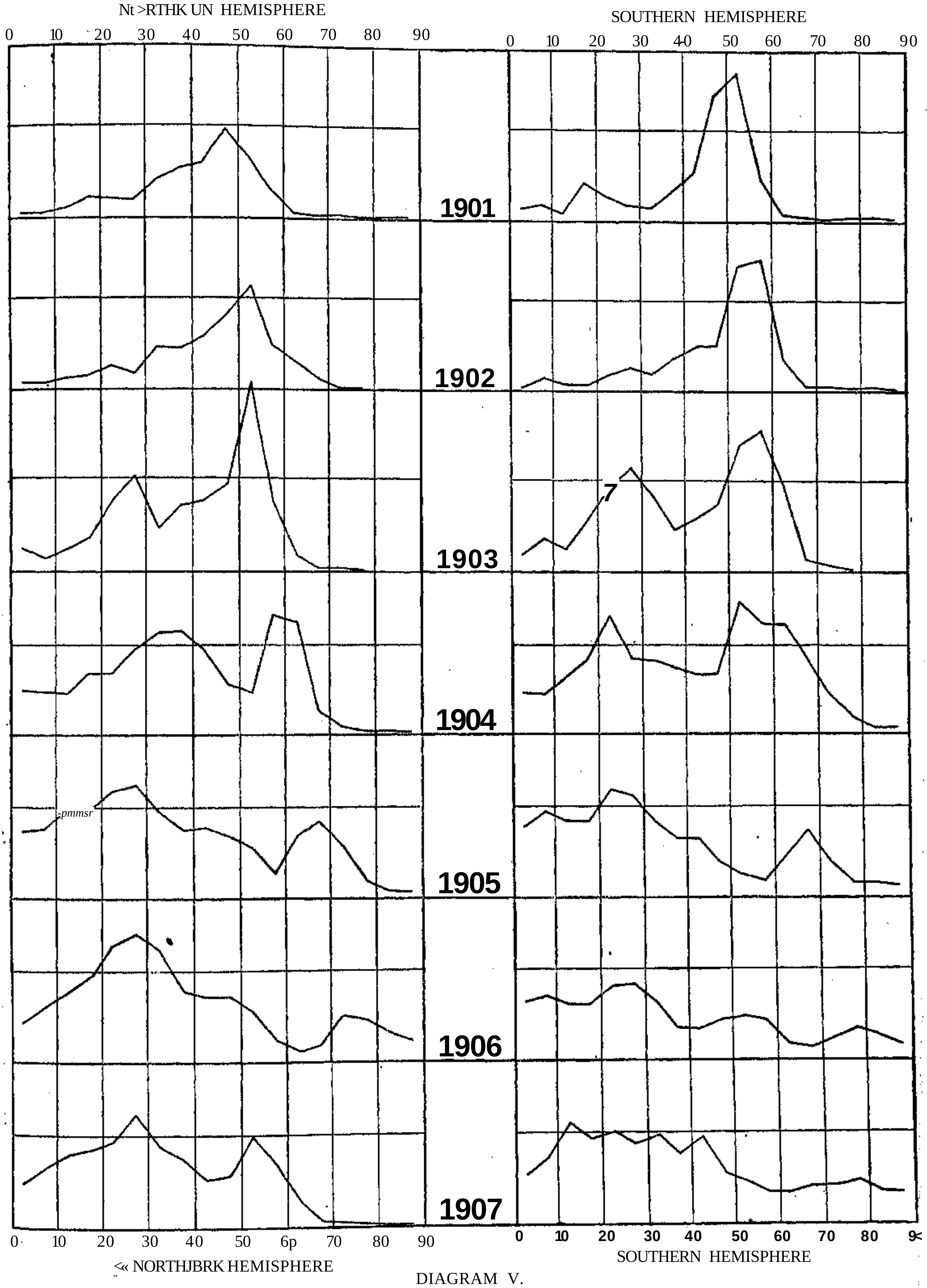

DIAGRAM V.

DiBtribution of Prominences in Latitude for the years 1901 to 1904 (Kenley Obsns.) and 1905 to 1907 (Kodaikanal Observation

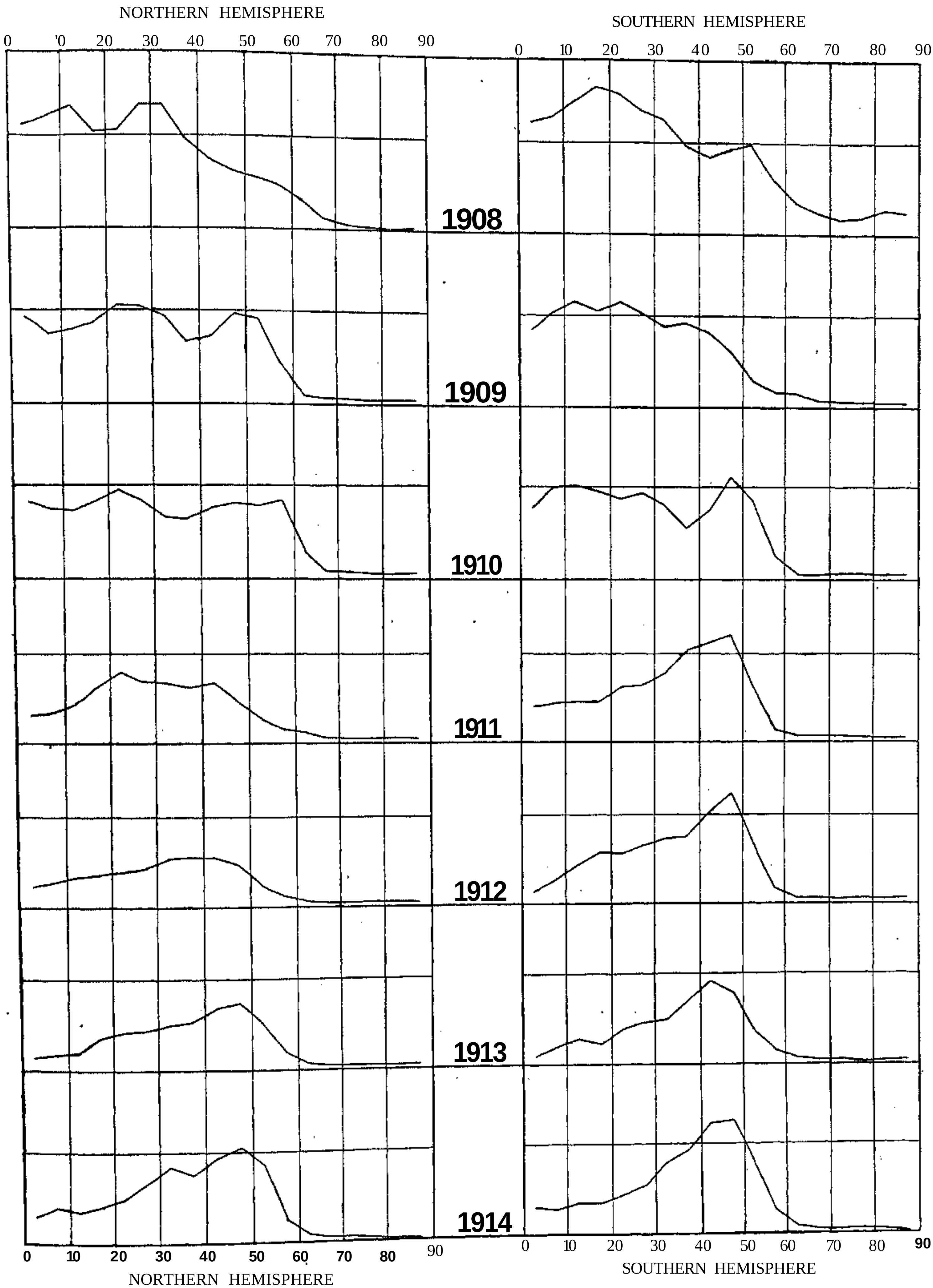

DIAGRAM VI.

Distribution of Prominences in Latitude for the years 1908 to 1914 (Kodaikanal Observations).

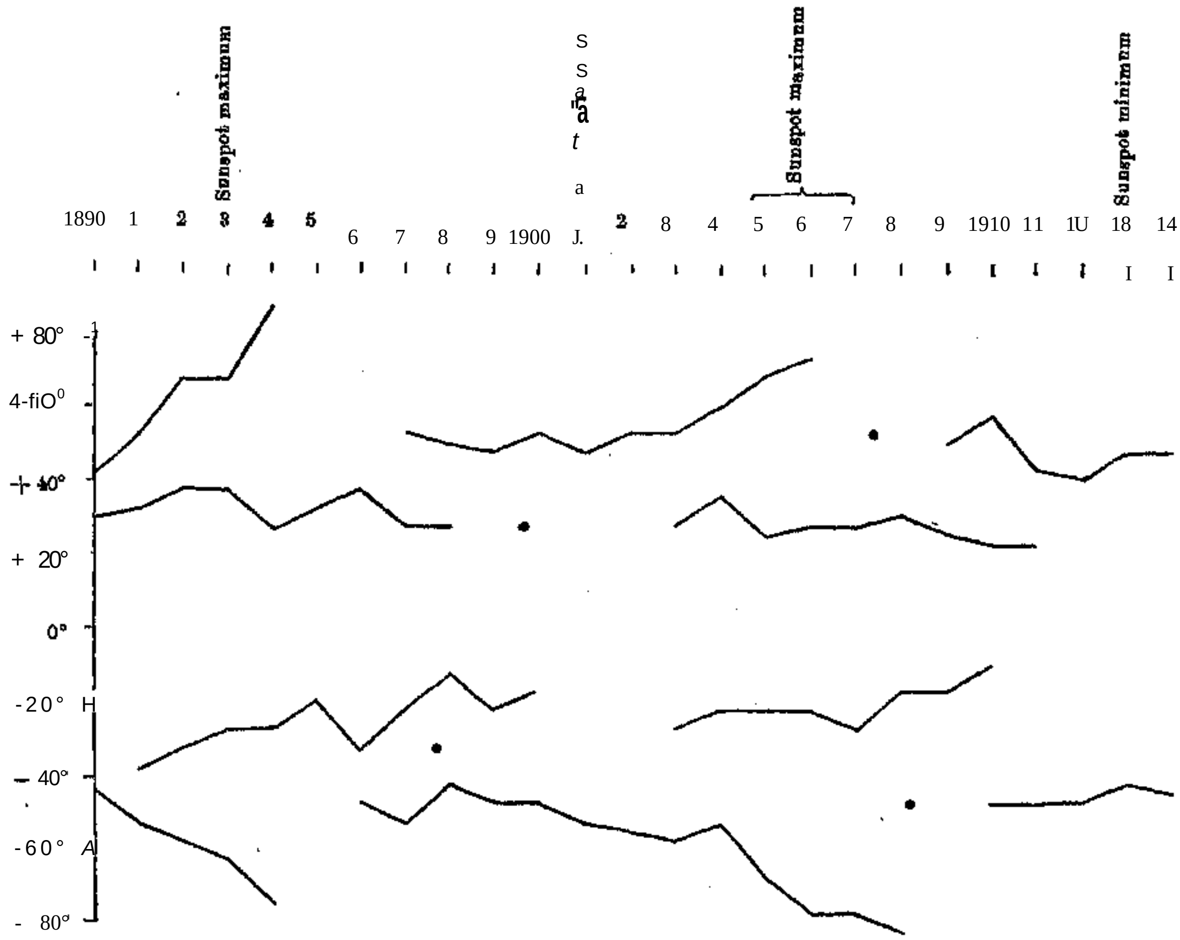

DIAGRAM VII.

Variation in Latitude of the four chief zones of Prominence Activity during the years 1890 to 1914.

(Kenley Observations 1890 to 1904 ; Kodaikanal Observations 1905 to 1914.)

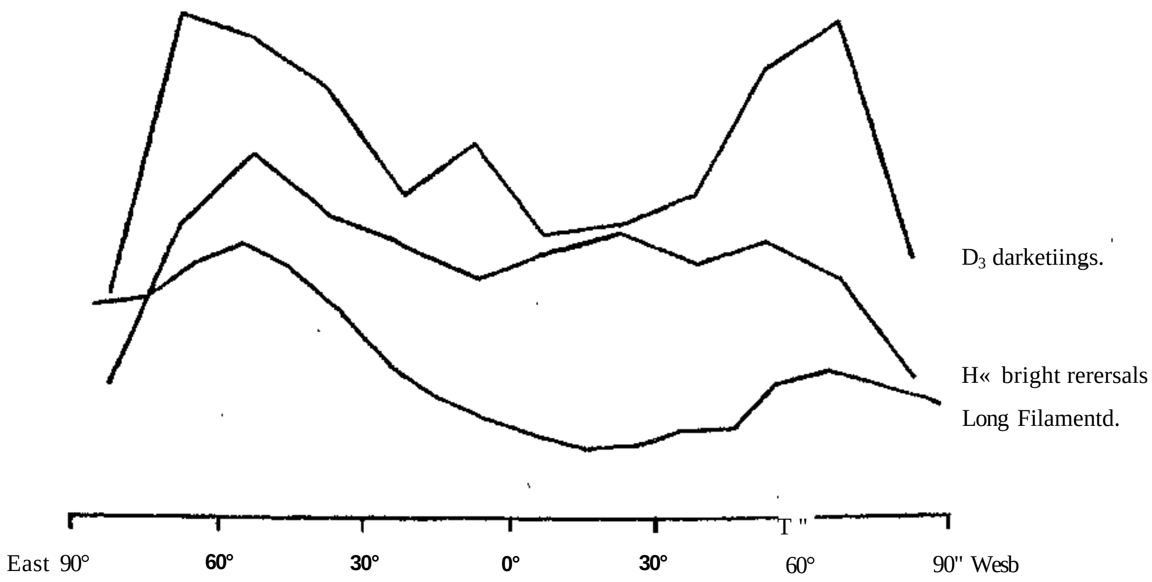

DIAGRAM VIII.

Distribution in Longitude of: Dise Markings.

Upper curve : 40>7 D darkonings observed in the years 1904 to 1914.
Middle curve : 1280 bright hydrogen reversals observed in 1904 to 1914.
Lower curve : 577 filaments photographed, in calcium light between April 1907 and March 1911.

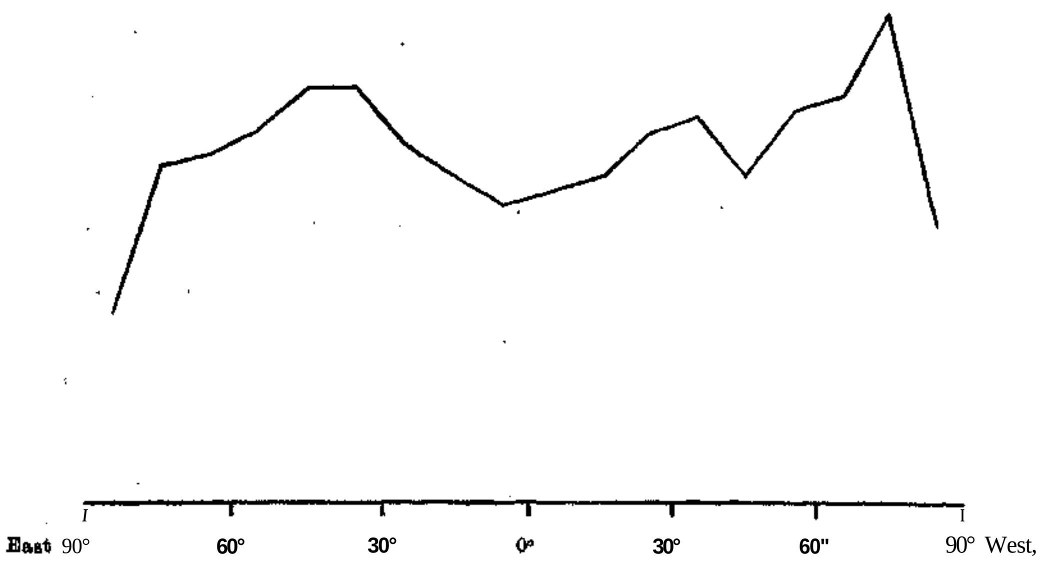

DIAGRAM IX.

Distribution in Longitude of Hydrogen Absorption Markings on the Disc during the period April 1911 to end of 1913.

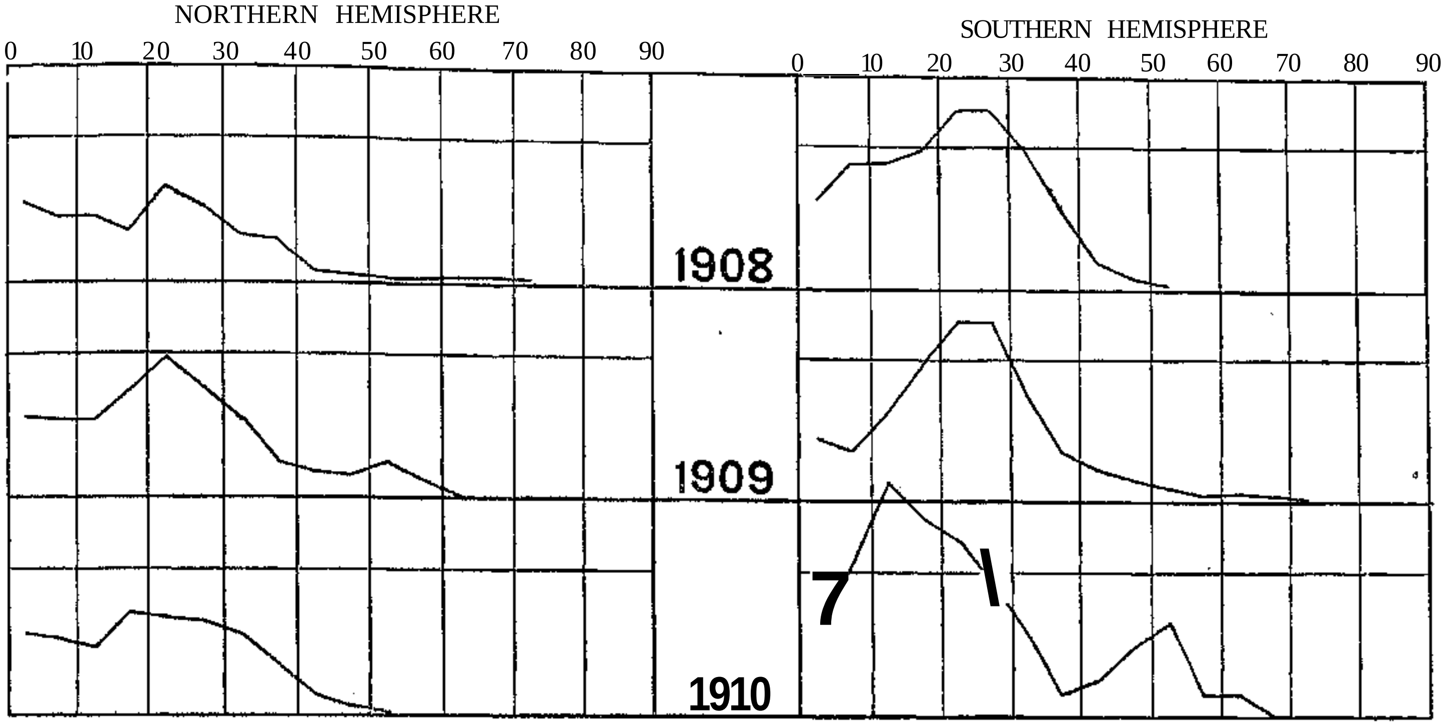

DIAGRAM X.

IHslriimtion in Latitude of Long Filaments photographed in calcinm light at Kodaikanal during the years 1908 to 1910.

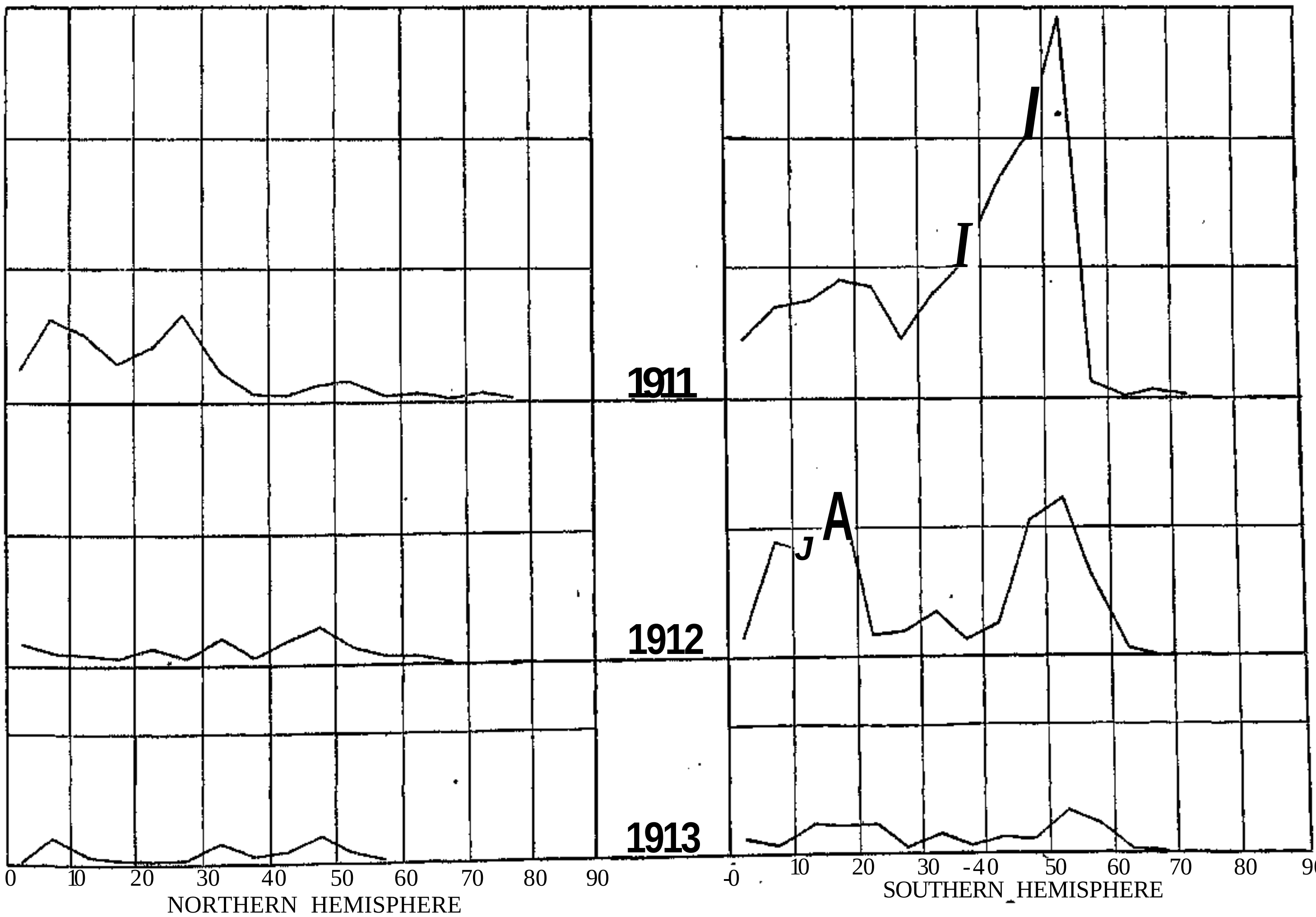

DIAGRAM XI.

Distribution in Latitude of Hydrogen Absorption Markings photographed at Kodaikanal during the years 1911 to 1913.

Fig. 1. 9^hl 38m.

Fig. 4. 16h. 5m.

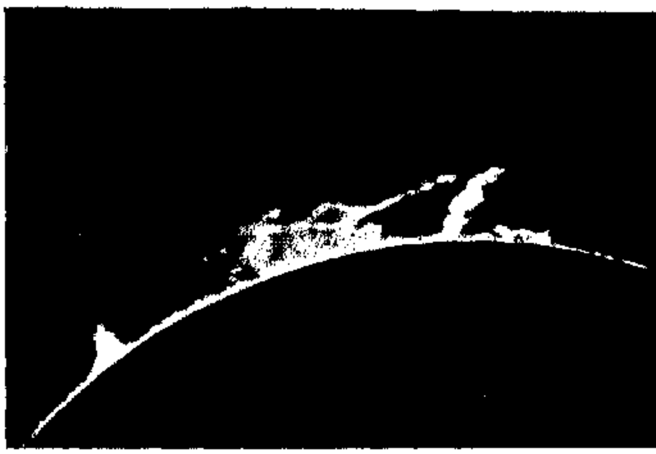

Fig. 2. 11h- 13m"

Fig. 5. 17h- 11m.

Fig. 3. 14h- 36m«

Fig- 6- 17h" 32m"

A VERY LARGE PROMINENCE

Photographed February 18th 1908.

This pn>iimi<>M<-(> „,«*. with accelerating velocity, finally reaching a height of 9' 45', or 400,000 km. above the Sun's surface. Its latitude was 17° to 63° south on the east limb.

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Fig. I.
May 23, 1915.
8h. 34m.

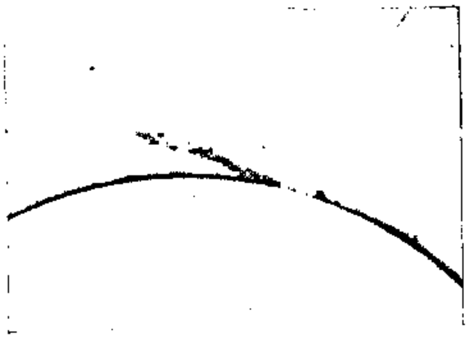

Fig. 4.
April 2, 1
8h. 41m

Fig. 2.
May 23, 1915,
8h. 48m.

Fig. 5
April 2,
9h. 26

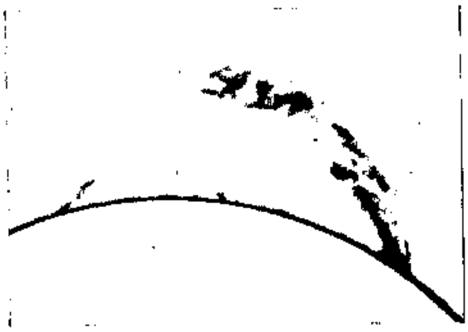

Fig.
April 2,
10h. 12

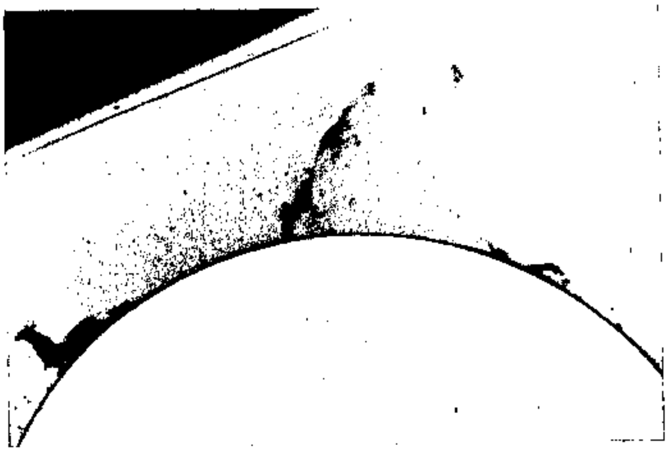

Fig. 3.
May 23, 1915.
9h. 22m.

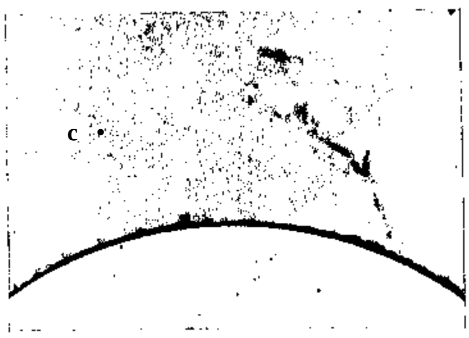

Fig.
April 2,
10h. 3

Latitude + 3° to + 40° West

Latitude - 12° to - 34" East.

TWO ERUPTIVE PROMINENCES.

These were not associated with sunspots. In each case one end of the prominence appears to be driven upward with groat velocity. This type is extremely brilliant in the early stages, but rapidly fades.

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Fig. 1. 8^{h}- O^{m}''

Fig. 2. 8^{hl} $1O^{m}$-

Fig. 3. 8^{h}''' 48^{m}-

Fig. 4. 9^{h}''' 13^{m}'

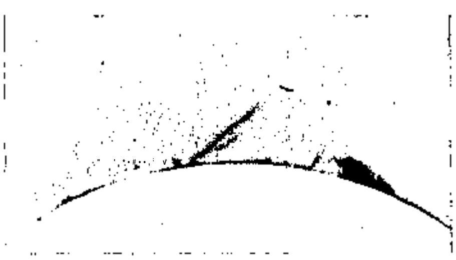

Fig. 5. $1O^{h}$- 5^{m}-

March 1st, 1910. Latitude - 7° W.

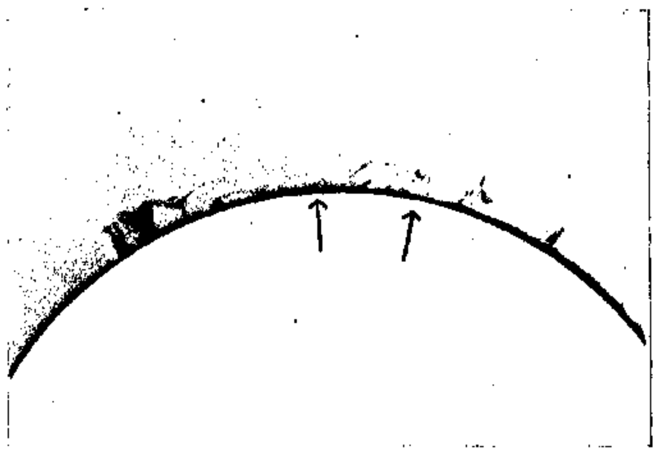

Fig. 6. 8^{hl} 42^{m}>

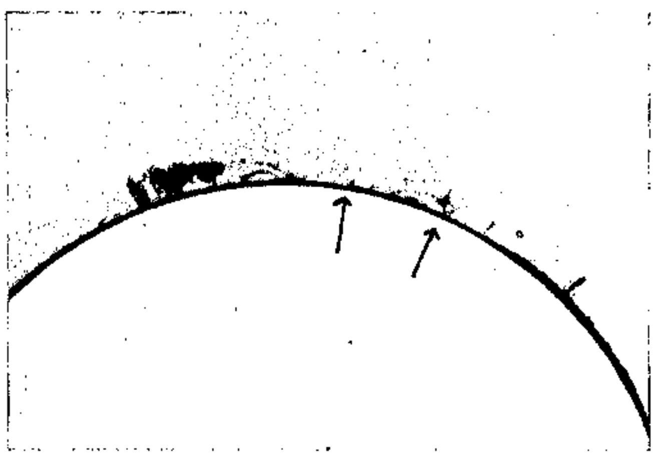

Fig. 7. 11^{h}- 19^{m}-

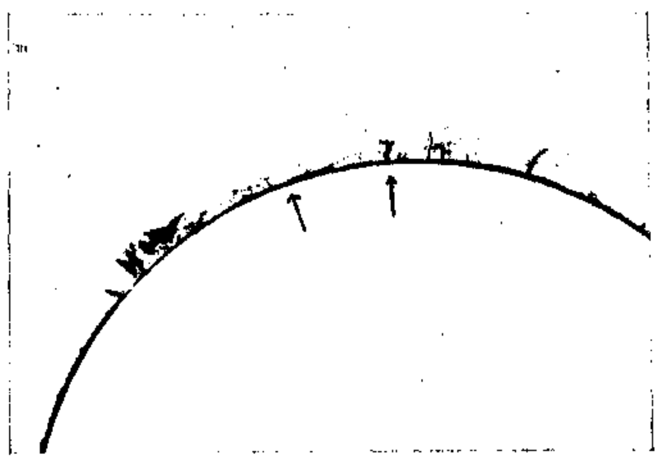

Fig. 8. 13^{hl} 57^{m}'

December 24th, 1912. Latitude-2° W.

TWO PROMINENCES OF "ROCKET" TYPE

ASSOCIATED WITH SUNSPOTS.

Fig. 1. Jet rising out of a flocculus. Pigs. 2—5. Development of the jet, which is one, of a charactoriHtic radiating group, but rises to an unusual height with gi*cat rapidity. It does not swing out towards a vertical position, like those on Plate III.

Figs. 6—B. A small bright mass, apparently ejected from the centre of radiating streamers and spikes, grown larger while falling towards the chromosphere, and finally becomes a column. Its position and the position of thu centre are indicated by arrows. The southern prominences also were possibly built up thus.

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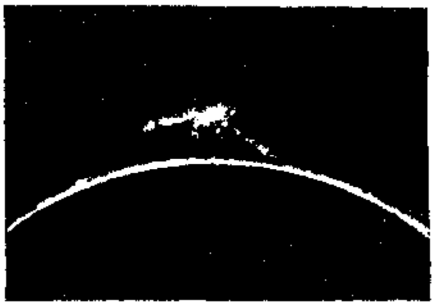


Fig. 1. Aug. 31, 1912. 9^{h}-45^{m}- Lat -2.5° East.

Fig, 2. Oct. 12,1908. 10^{h} 11^{m}- Lat-78° East.

Fig. 3. Oct. 17, 1907.
8^{h}- 31^{m}- _47" E.

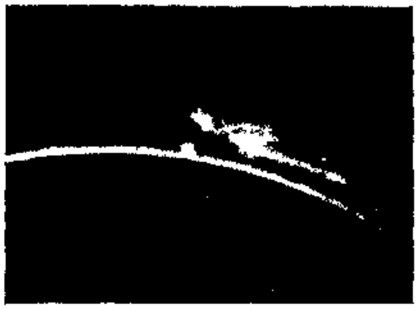


Fig. 4. Nov. 23, 1908.
8h. 51m. _0° to _20° E.

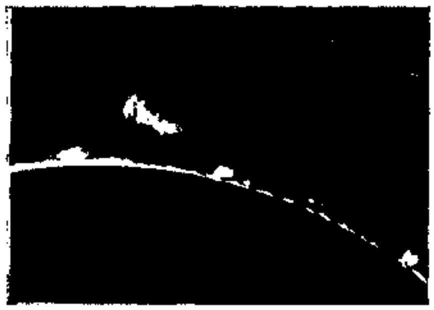


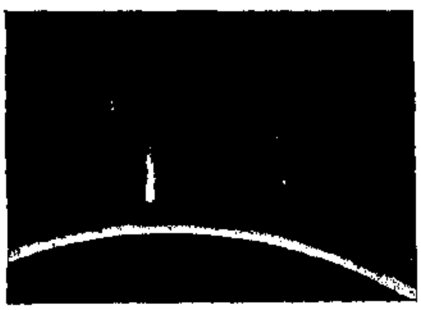
Fig. 5. Dec. 6, 1909.
9h. 16m. -9° West.

Fig. 6. Mar. 25, 1909.
8h. 31m. _28°W.

Fig. 7. Mar. 25, 1909. 9^{h} 42^{m}

Fig. 8 Mar. 25, 1909. 11^{h} 51^{m}

Fig. 9. Sep. 23,1909.
8h. 32m. -18° W.



Fig, 10. Sep. 23,1909, 9^{h} 37^{m}-

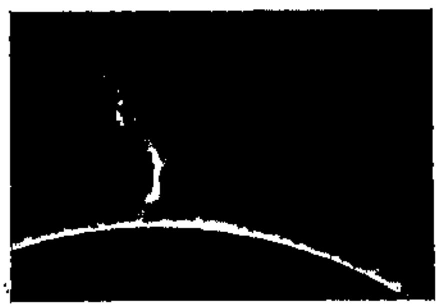


Fig. 11. Sep. 23,1909, 9^{h}- 42^{m}

DETACHED PROMINENCES.

Fig. 1. Rising cloud. Fig. 2. Rising cloud, which two hours earlier was connected with the chromosphere. Fig. 5. Stationary cloud, joined by filaments to the chromosphere. Figs. 6—8- Descending cloud. Figs. 9—11. Prominence at first detached, afterwards joined to the the chromosphere.

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Fig. I.
8h. 8m.

Fig. 2.
9h. 30m.

Fig. 3.
10h. 42m.

Fig. 4.
11h. 48m.

A PROMINENCE SHOWING REMARKABLE CHANGES.

Jan. 12, 1909. Latitude +40° to +15° East.

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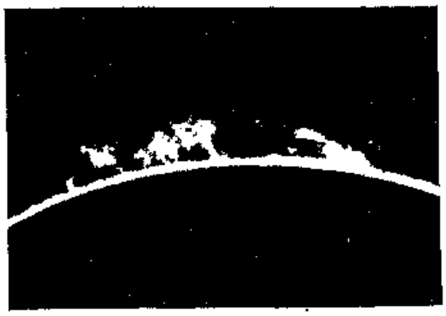

Fig. I.
Aug. 13, 1908.
8h. 39m.
Lat -48° E.

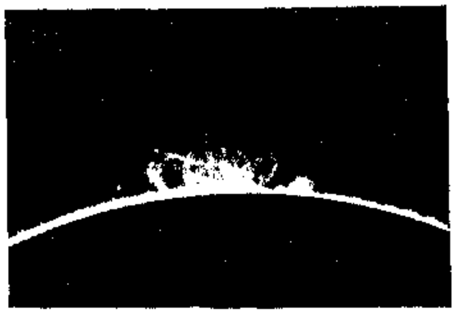

Fig. 4.
Dec 14, 1908.
8h. 58m.
Lat. +30° E.

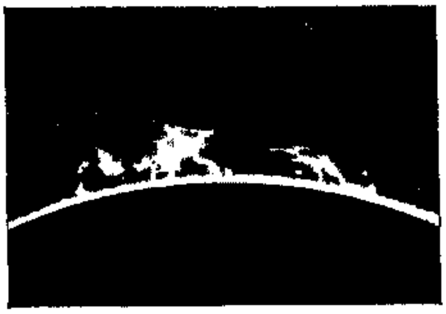

Fig. 2.
Aug. 13, 1908.
9h. 2m.

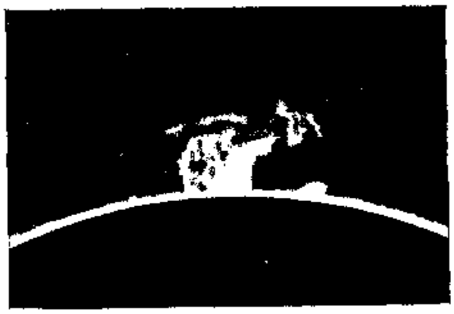

Fig. 5.
Dec. 14,1908.
11h- 45m

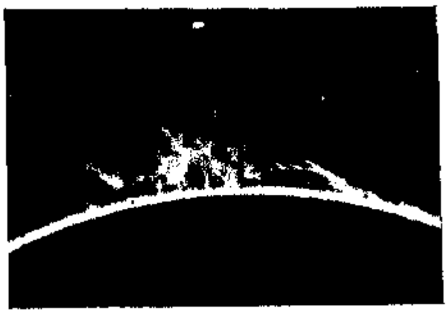

Fig. 3.
Aug. 13, 1908.
9h. 34m.

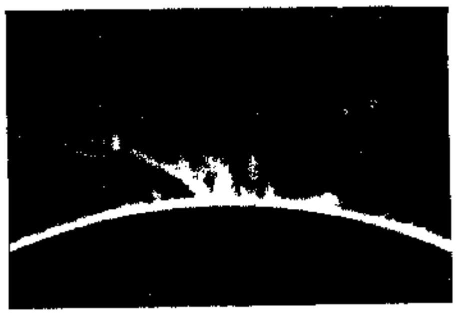

Fig. 6.
Dec. 14,1908.
13h 45

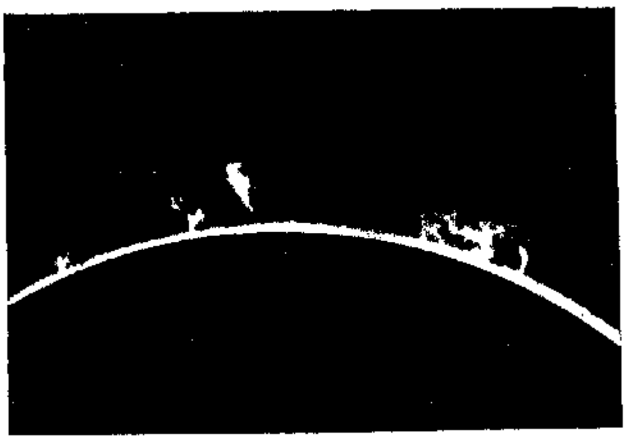

Fig. 7. Nov. 9,1911. 7h- 58m

Fig. 8. Nov. 9, 1911. 10h 12m-

Latitudes +17° and -7° West.

THREE PROMINENCES WHICH SHOWED STRIKING CHANGES IN THE COURSE OF A FEW HOURS.

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Fig. 1. Mar. 4, 1910. -13" West.

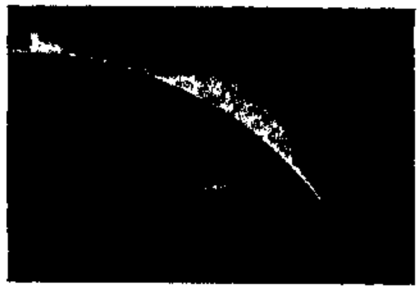

Fig. 2, Mar. 17, 1910. -2° East.

Fig. 3. Nov. 19,1908. -25° East.

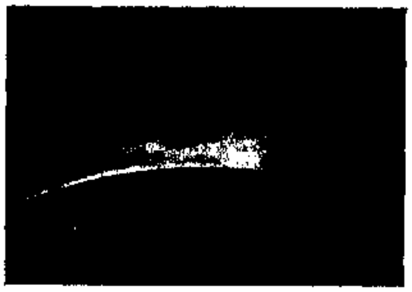

Fig. 4. Mar. 17, 1909. -f 14° East.

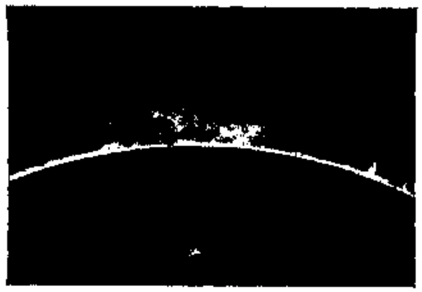

Fig. 5. Mar, 16,1909. +11° East

Fig. 6. Oct. 27, 1908. -13° East.

Fig. 7. Sep. 22,1909. +10° to-10° West.

Fig. 8. Jan. 15, 1909. -f-33"West.

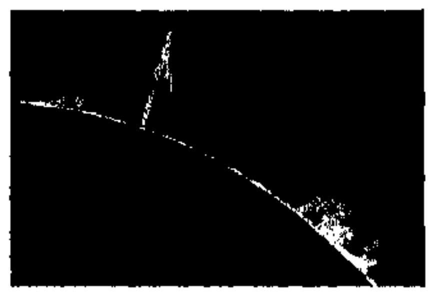

Fig. 9. April 21,1909. +20° West.

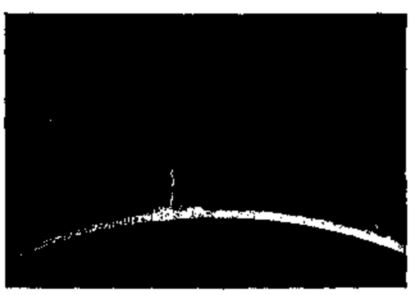

Fig. 10. Nov.30,1909. +11° East.

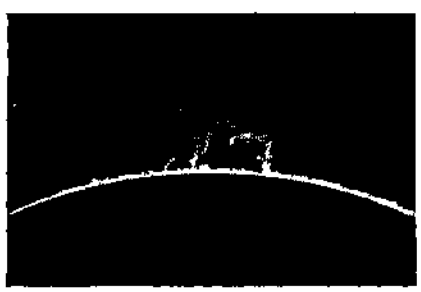

Fig. 11. Mar. 24, 1909. -25° West.

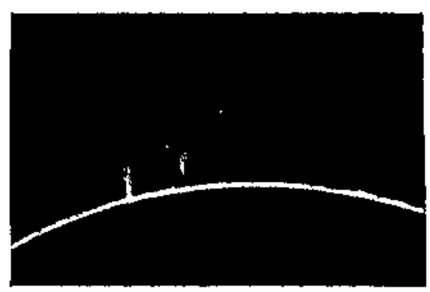

Fig. 12. May 2,1907. -15° East.

PROMINENCES OF VARIOUS FORMS,

Figs. 1 and 2. A very stable prominence which was photographed alternately on limb and disc for three months. Fig. 3. An unusually bright prominence. Figs. 4, 5, 6. Broad massive forms, composed chiefly of horizontal filaments. Fig. 7. Prominence with sharply defined boundary on northern side. Figs. 8, 9. High narrow forms. Fig. 10. Eruptive prominence over a sunspot. Fig. II. Broad prominence sxipported on slender coltmms. Fig. 12. Diffuse prominence of unusual form.

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Fig. 1. Feb. 25, 1909.
10h. 34m. _j_6n E>

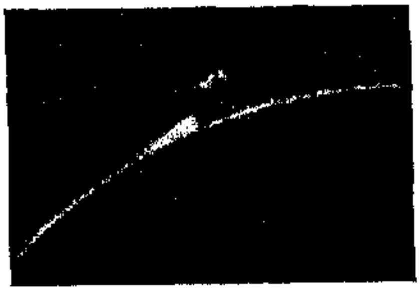

Fig. 5. Jan. 7, 1910.
8h. 5m. _15o w.

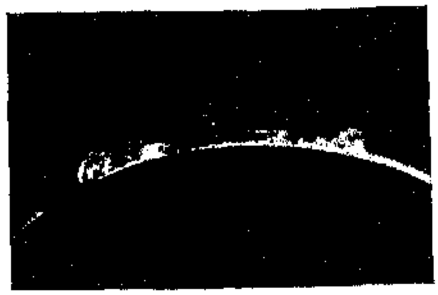

Fig. 9. Oct. 9, 1910.
gh. 56m. _12° w#

Fig. 2. Dec. 22, 1909.
gh. 20m. _|_io°E.

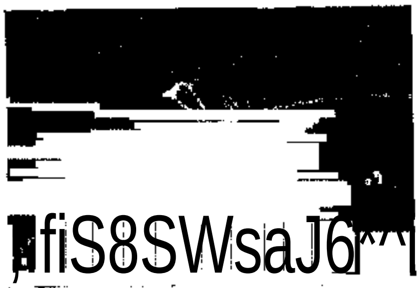

Fig. 6. Jan. 7, 1910.
8h. 53m. —IRO W.

Fig. 10. July 31, 1908.
8h-47m. +11° E.

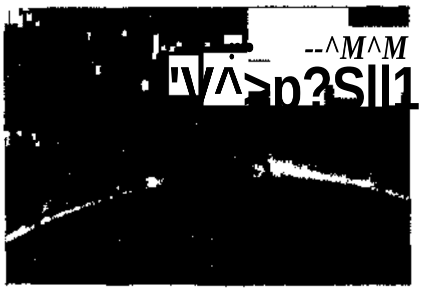

Fig. 3. Jan. 9, 1909.
8h. 20m- -}-9°W.

Fig. 7. Jan. 7, 1910.
10h. 10m. _15^w_

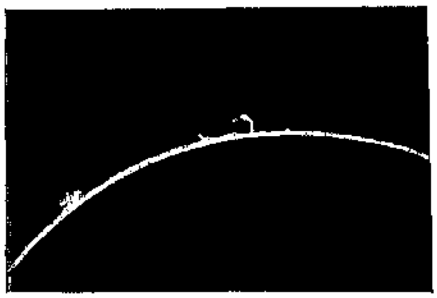

Fig. 11. Jan. 18, 1910.
11h'42m> +10° E.

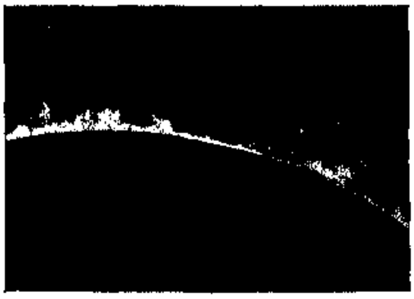

Fig. 4. Jan. 10, 1909.
8h. 32m. +9° W.

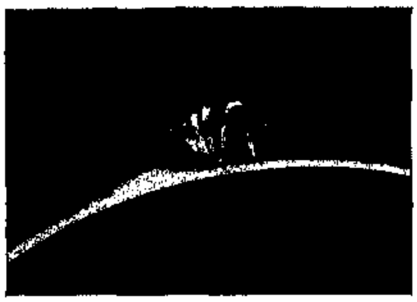

Fig. 8. Jan. 7,1910.
Uh, 6m. _15o w<

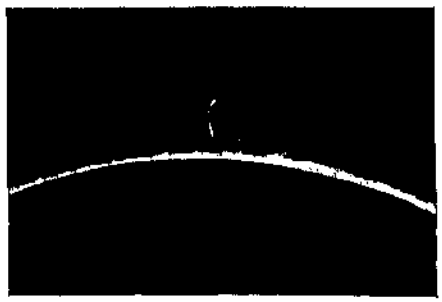

Fig. 12. Nov. 19, 1908.
8h. 25m, +13° W.

TYPICAL PROMINENCES ASSOCIATED WITH SUNSPOTS.

Figs. 1, 2, 3, 4, 9. "Eocket" Prominences: jets and streamers radiating from a centre.
Figs. 5—8. A group of Arches rising and developing.
Figs. 10 and 11. "Ring" or "Horse-shoe" Prominences.
Fig. 12. A single Arch, with characteristic bright condensation at the summit.

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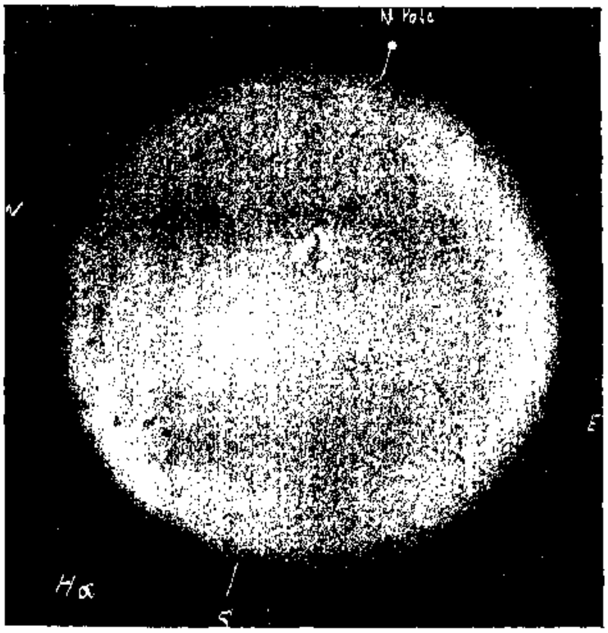

Fig. 1. April 8,1911.

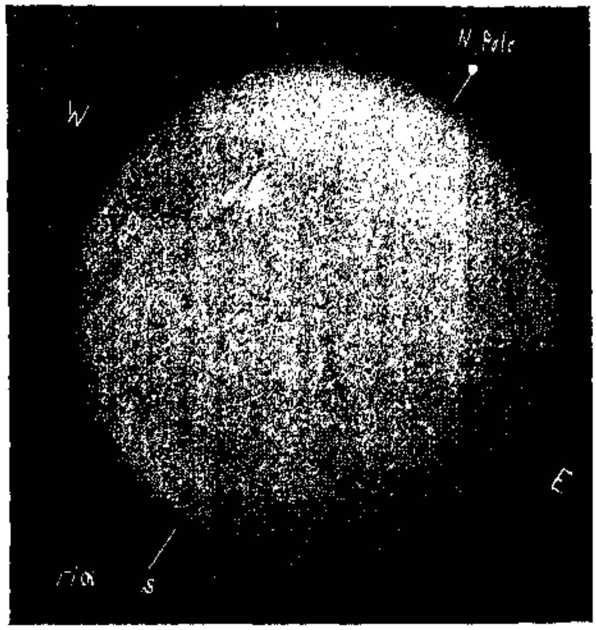

Fig. 2. April 10, 1911.

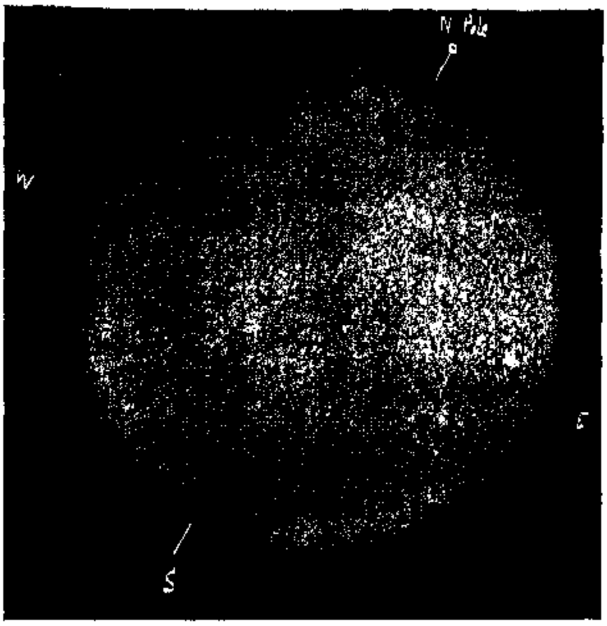

Fig. 3. May 27, 1911,

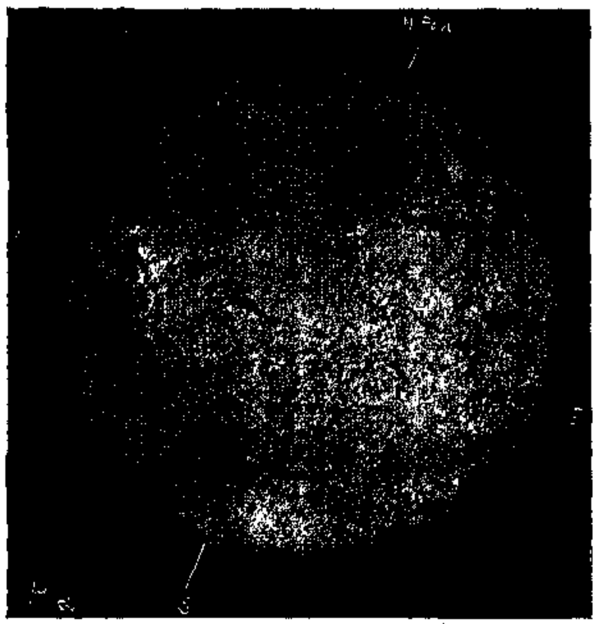

Fig. 4. May 2,1911.

PROMINENCES ON THE DISC, APPEARING AS HYDROGEN EMISSION AND ABSORPTION MARKINGS.

The long narrow dark lines on figs. 1, 2, and 3, are prominences similar in character to thowe photographed on the calcium disc plates; but in hydrogen photographs, owing to the more uniform background, short patchy prominences are also visible. These dark patches occur chiefly in latitudes of about $\pm 50°$, and tend to lie in rows approximately parallel to the equator, while the "long Filaments" occur chiefly in low latitudes, and are usually highly inclined to the equator.

The bright patches are usually in the neighbourhood of stmspots, and indicate highly heated eruptions.

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Plate XI.

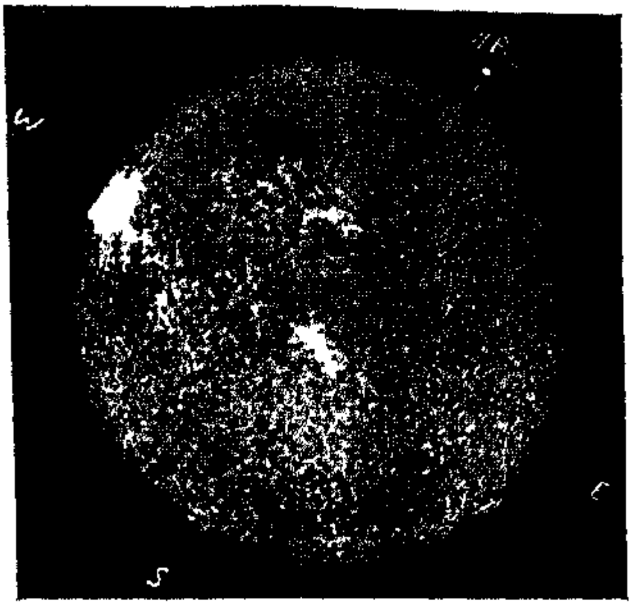

Fig. 1. Feb. 28, 1910. 8h 31m

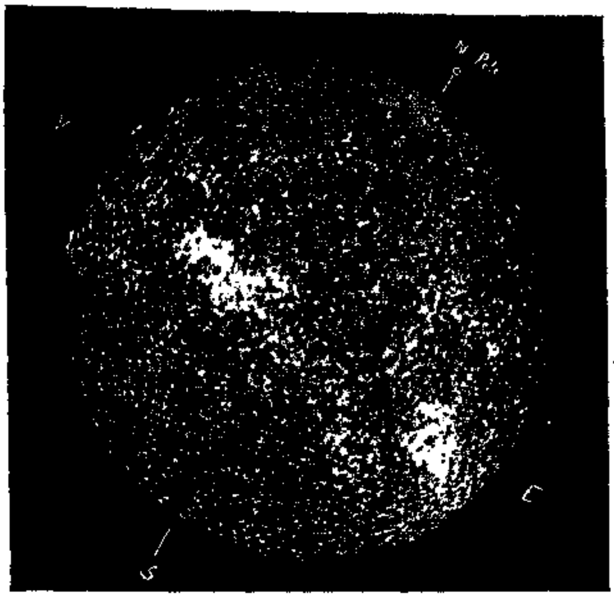

Fig. 2. March 23, 1910. 8h 1m

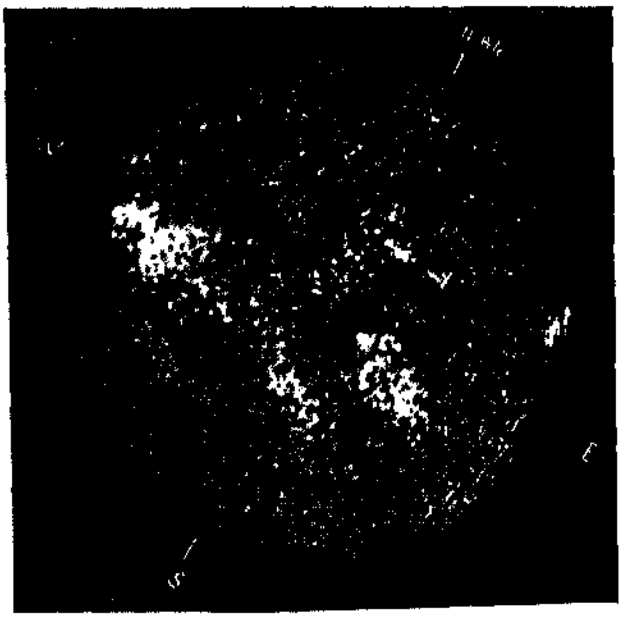

Fig. 3. March 25, 1910. 8h 11m

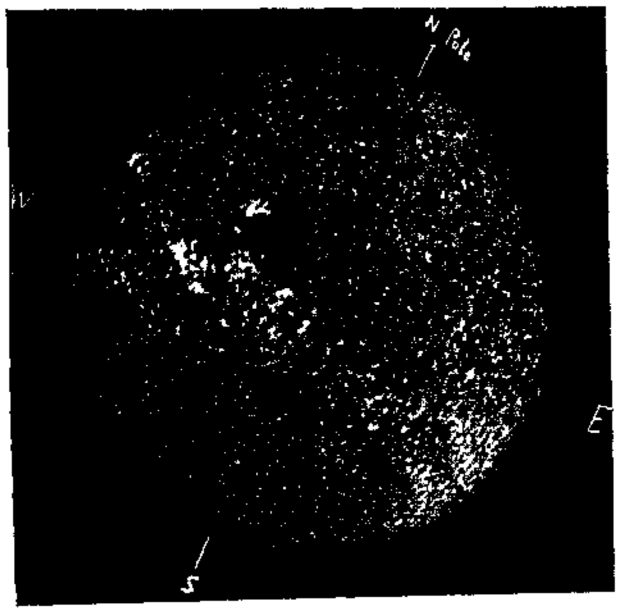

Fig. 4 April 18, 1910. 9h 14m

PROMINENCES ON THE DISC, APPEARING AS CALCIUM ABSORPTION MARKINGS.

The sinuous dark line seen in low latitudes on the western hemisphere in fig. 1, in the eastern hemisphere in figs. 2 ... centre of the disc in fig. 3, represent successive appearances of a long-lived prominence which was p... nes on west and east limb alternately, and also during its three transits across the disc. ... in high south latitude in fig. 4.

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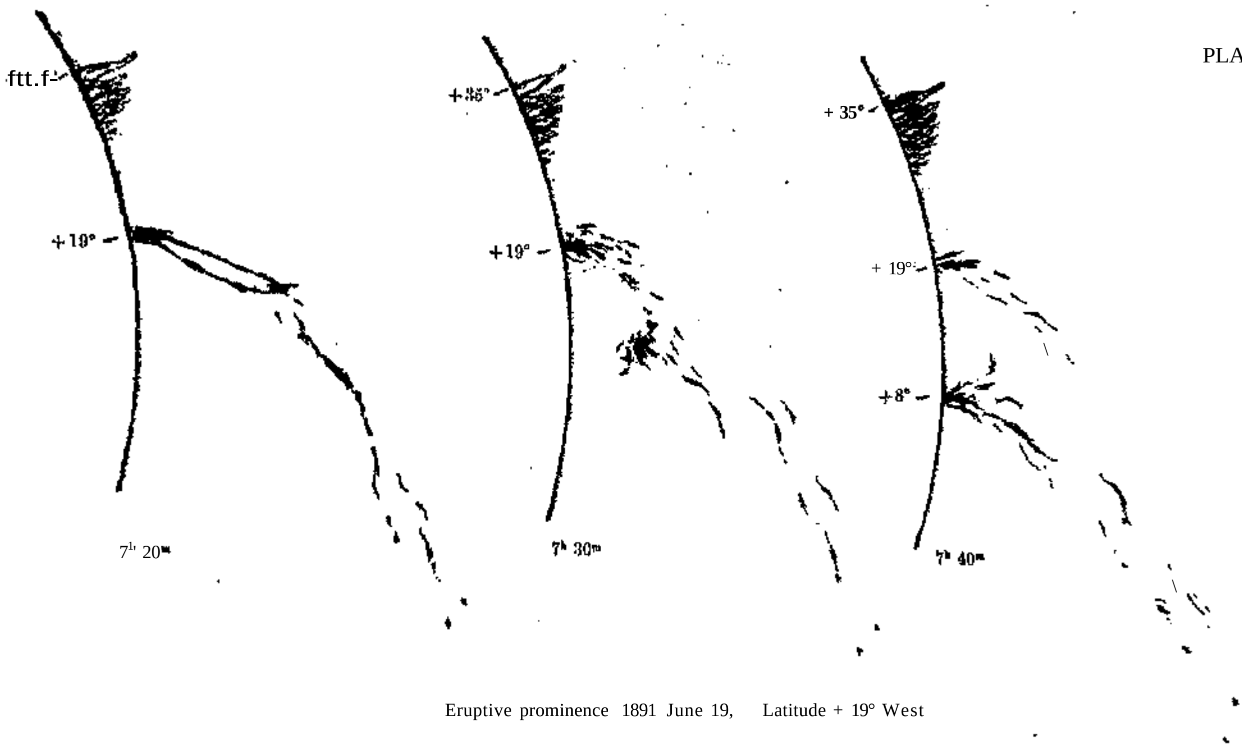
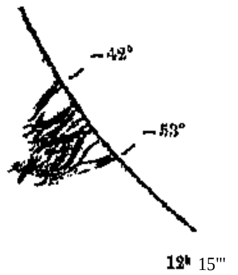
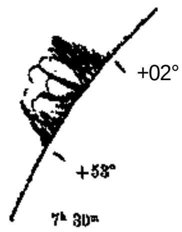


Eruptive prominence 1891 June 19, Latitude + 19° West

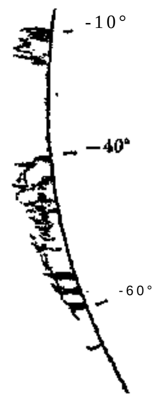


18!) I Fobraary 15. Latitude - 47° East.

1891 August 29. Latitude - 42° W.



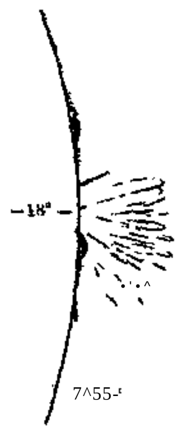
1891 October 8. Latitude + 57° E.



1H01 June 6. 3U 0m p.m.
S.E. limb.

1892 April 7. Latitude + 36°
N. East limb.

1892 July 21. Latitude - 30°
S.W. limb.



1893 August 14. Latitude - 18"
W. limb, Over Sunspot.

WOMB TYPICAL PROMINENCES DRAWN BY J. EVEESHED AT KENLEY

IN THE YEARS 1891, 1892, AND 1893.