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TWO LONGITUDINAL ZONES OF APPARENT INHIBITION OF SUNSPOTS ON THE SOLAR DISC

BY

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Abstract.—Observations of sunspots made at Kodaikanal during the years 1909 to 1929 have been utilized to study the occurrence of spots in different longitudes over the sun It is found that there is a zone of apparent inhibition between longitudes 30° and 50° on either side of the central meridian Spots of short duration tend to avoid the zones, while the long-lived ones show a diminution in areas when passing through them

Although observations of sunspots at Kodaikanal began in the year 1903, a new system of registering the observations was introduced in 1909, giving the serial number of each sunspot, or group of spots as the case may be, its heliographic latitude and longitude, the dates from and to which it was visible on the sun and the longitude, east or west of the sun's central meridian, where it was when first observed At the end of 1929 there was a mass of material accumulated during 21 years and available in a convenient form The nature of the distribution of sunspots in latitude was well-known, but no examination of their distribution in longitude had been made by anyone. Although, under ordinary circumstances, no peculiarity could be expected to exist in such distribution, as spots have an equal chance to occur in all longitudes on a rotating globe like the sun, it appeared desirable that the matter should be placed beyond doubt by venturing an actual investigation. Accordingly the Kodaikanal data were made use of for the purpose and the results are set forth in this paper.

Distribution of 1-day Spots.

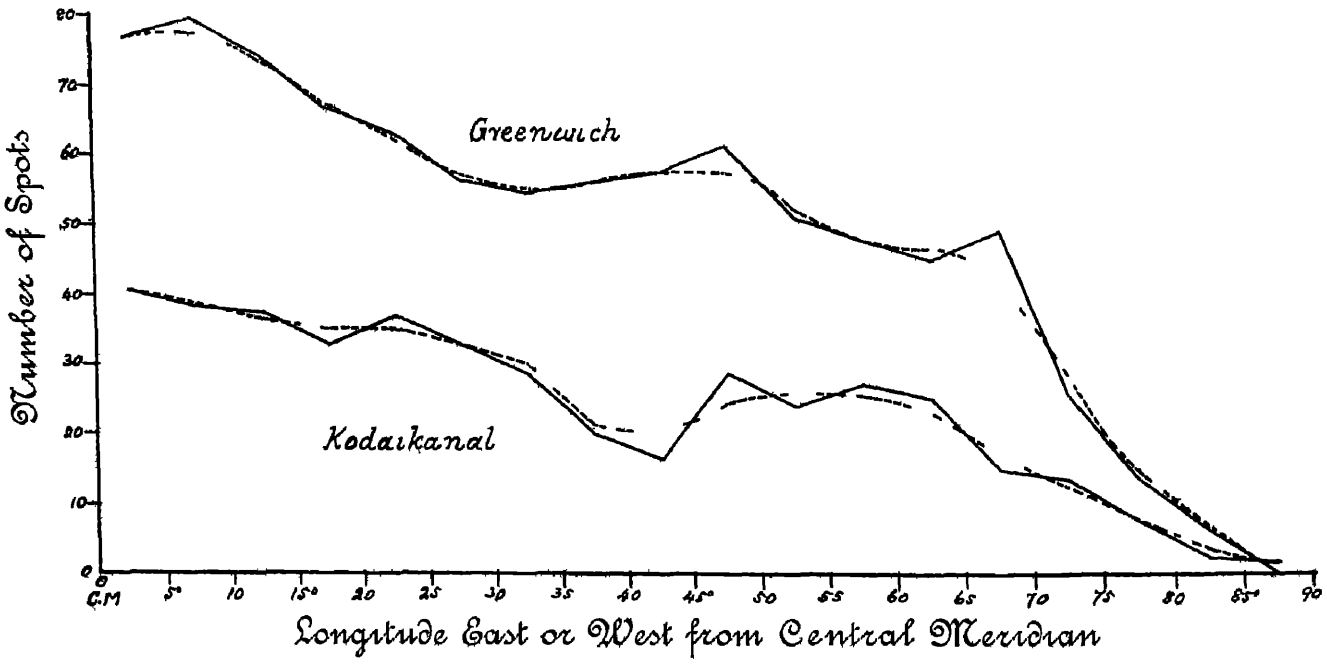
2. The investigation began first with spots of the shortest duration, namely those which were seen on single days only and disappeared before the next day's observation. The second and third columns in the Kodaikanal spot register are headed "Latitude N." and "Latitude S" and the last column "Longitude from Central Meridian when First Seen" The positions of 1-day spots as defined by the register were plotted on squared paper in their proper longitudes and latitudes east and west of a central vertical line representing the central meridian and north and south of a central horizontal line representing the equator, of the sun. There were 857 spots of this class. As the plotting progressed, a remarkable and hitherto unsuspected feature began to manifest itself on the chart. The spots showed a distinct tendency to fall in three separate regions and tended to avoid two longitudinal zones, one on either side of and some distance away from the central meridian The chart finally showed three concentrations of spot positions, one at the middle of the disc and one at either end, with an attenuation in the region between 30° and 50° of longitude east and west of the central meridian. The number of spots falling inside each zone of 5° of longitude were then totalled up and a curve drawn to represent the arrangement of these totals in the different zones. It was found that the curve rose to a maximum in the region of the central meridian, fell off from 30° reaching a minimum in the zone 35° to 40° in the eastern hemisphere and 40° to 45° in the western hemisphere, and then rose to a secondary maximum near 60° and fell off again.

3 At the suggestion of Dr Royds, the Director, the data published in the "Greenwich Photoheliographic Results" were also examined for a similar effect for all the past years as far back as the data would carry us. There was material available for 39 years from 1874 to 1912 and there were 1,767 spots seen only on one day. The data regarding the spots are arranged in the form of "Ledgers", which give information regarding each

individual group for each day of observation, the latitudes and longitudes being given to a tenth of a degree From the ledgers the positions of 1-day spots were plotted in the same way as was done for the Kodaikanal data, and a curve drawn to represent the totals in each zone of 5° as before The same phenomenon, as was revealed by the Kodaikanal material, was seen in this case also There was, however, a slight difference in that the two zones of minimum concentration were located about 5° nearer the central meridian All the same, there was no longer any doubt as to the reality of the existence of the two zones of inhibition and three distinct regions of activity on the solar surface As far as 1 day spots are concerned the central region on the solar disc appears to be the most active and the two regions on either side, beyond the gaps of inhibition, comparatively weaker

4 The numbers east and west of the central meridian are combined and means derived The upper curve in diagram 1 shows the means so derived for the Greenwich data and the lower curve shows the same for Kodaikanal The broken lines are the smoothed curves for the two classes of data They show to better advantage the existence of the zones of comparatively smaller activity between 30° and 50° of longitude in both the eastern and western hemispheres

Diagram 1 —Distribution of 1-day Spots in Longitude
(Mean of East and West)



Distribution of 2-day Spots

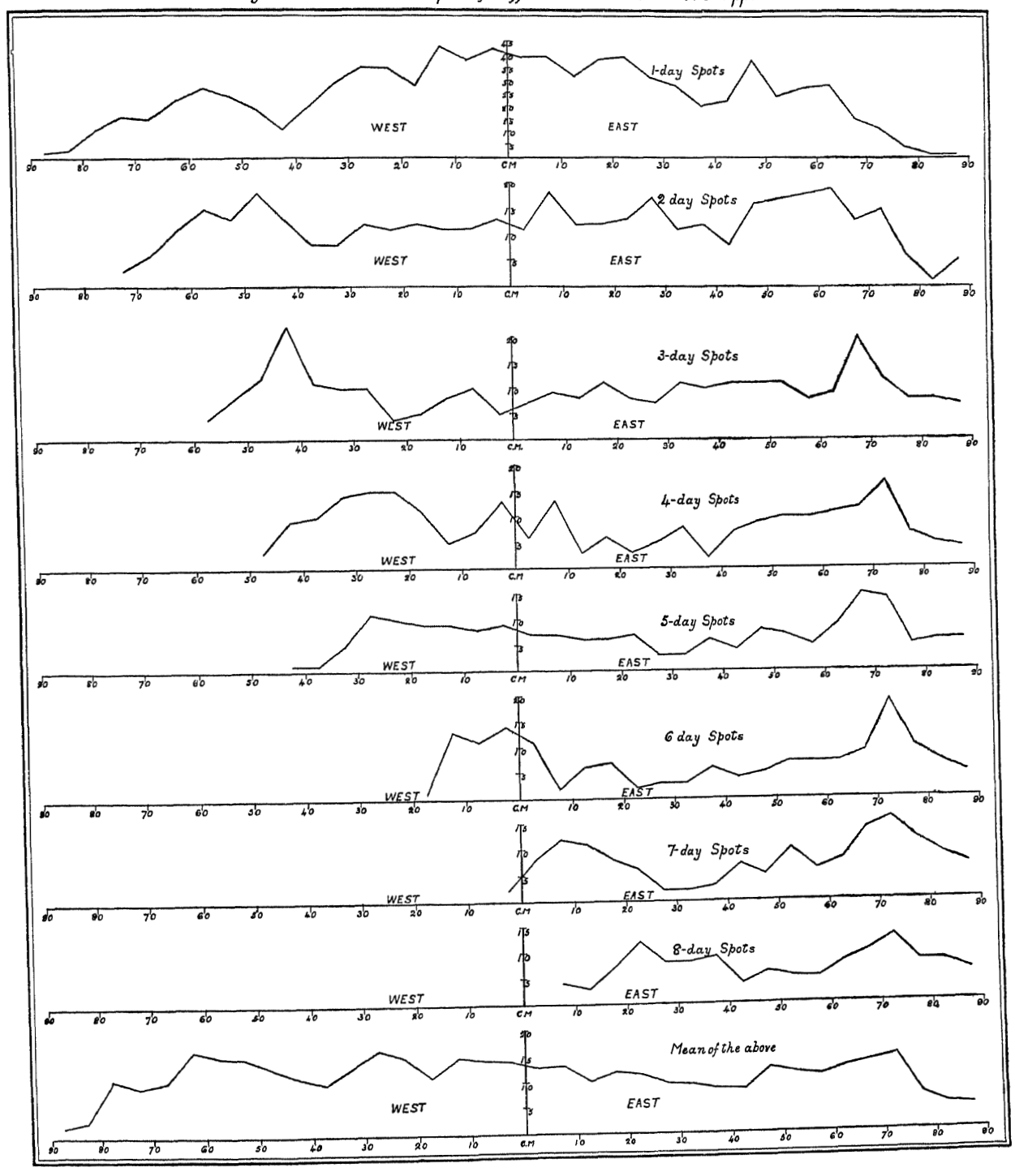
5 The interesting results obtained in the case of 1-day spots naturally led to the question whether the same kind of inhibition could also be observed in the case of spots of greater duration The case of 2 day spots was therefore taken up Spots of greater and greater duration naturally made the problem less and less simple, and from the data furnished by the Kodaikanal register, only the first appearances of each class of spots could be studied. As the sun's disc is daily examined for spots, any new spots observed on a particular day must have come into being some time between that day's and the previous day's observations Of course, the spots that are first seen on the east limb of the sun may all, or most of them, come round from the other side of the sun. Barring these, all other spots must have had their origin somewhere near and to the east of the longitudes at which they were first noticed An examination of these longitudes, therefore, should give us an indication as to the places of origin of the spots On plotting the first appearances (i e , the longitudes when first seen) of 2 day spots, 389 in number, in the same way as the 1-day spots were treated, it was found that the number of first appearances was a minimum in the zones of inhibition revealed by the 1-day spots, but the central concentration became less conspicuous than the two lateral ones

Other Classes of Spots

6. The same examination was extended to spots of greater duration, but it appeared unnecessary to plot the first appearances in their actual positions in latitude and longitude, as in the previous cases So columns were opened representing each 5° zone of longitude and the first appearances of each class from 3-day spots to 8-day spots were separately entered in the respective zones in which they fell according to the longitude given by the register The total numbers of each class of spots were, 270, 240, 187, 159, 148 and 124 respectively. The number of each class in individual zones were then totalled up The distribution of each class is represented by a curve in diagram 2, along with the curves for 1-day and 2-day spots.

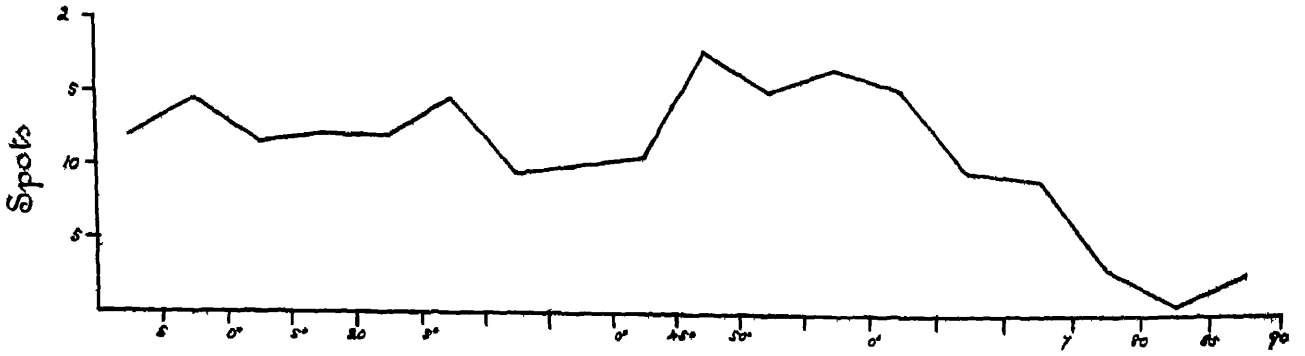
Diagram 2.

Longitudes in which Sun-spots of Different Durations First Appear

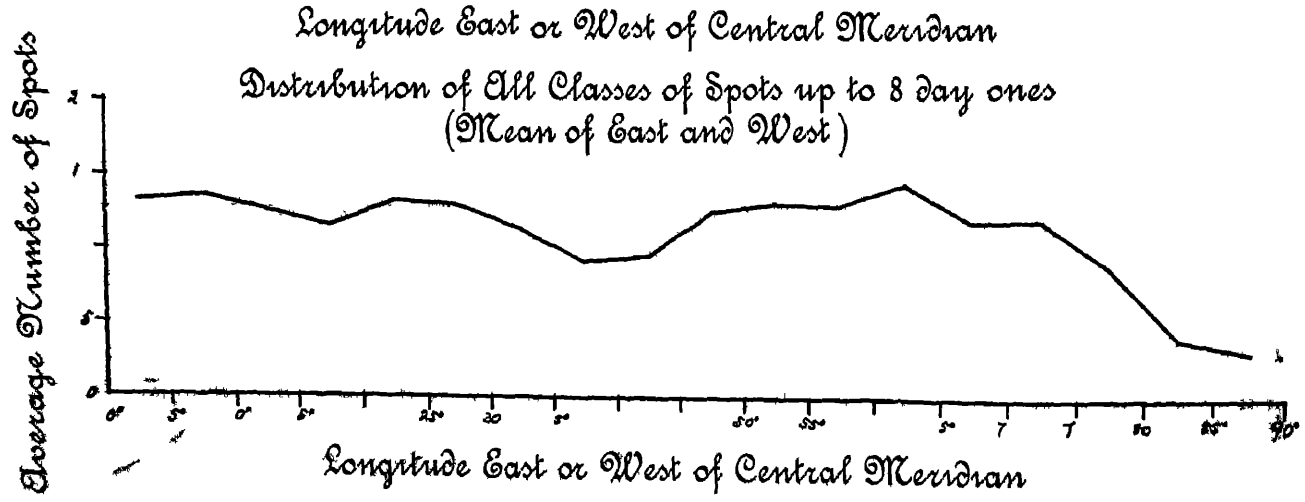


The picture presented by the curves is very interesting Excepting in the case of 1 day spots the central con centration occupies a subordinate position and the two lateral concentrations become the stronger Besides while the peak on the east is more or less permanent in position that on the west shifts more and more eastwards according to the duration of the spot so much so that the western peak in the curve of 4 day spots is found over the region of inhibition in the west and the western peak in the curve of 8 day spots lies over the inhib t on zone in the east This no doubt militates against the idea of two permanent zones of comparative inactivity on the solar surface but we have to remember that these spots represented by the peaks in the west are those of which we had two three four five etc observations ac ording to the class to which they belonged and that the last observations of them were near the west limb of the sun Hence we cannot say whether they die out at the limb or disappear from view on the invisible hemisphere They must therefore be considered as spots having a duration longer than two days three days or four days etc as the case may be The peaks have therefore to be regarded as spurious to some extent as the number of real 2 day 3 day 4 day etc spots must be much smaller there But in spite of the exceptional behaviour of the 4 day and 8 day spots the totals as well as the means of all the columns unmistakably record a fall in the regions where the two zones are expected to be as can be seen from the cur e at the bottom of diagram 2 The means for east and west for 2 day spots and for the average of all the classes up to the 8 day ones are shown by the two curves in diagram 3 The troughs in the two curves at the seat of the zones is quite evident

Diagram 3 —Distribution of 2-day Spots in Longitude
(Mean of East and West)



Distribution of All Classes of Spots up to 8 day ones
(Mean of East and West)



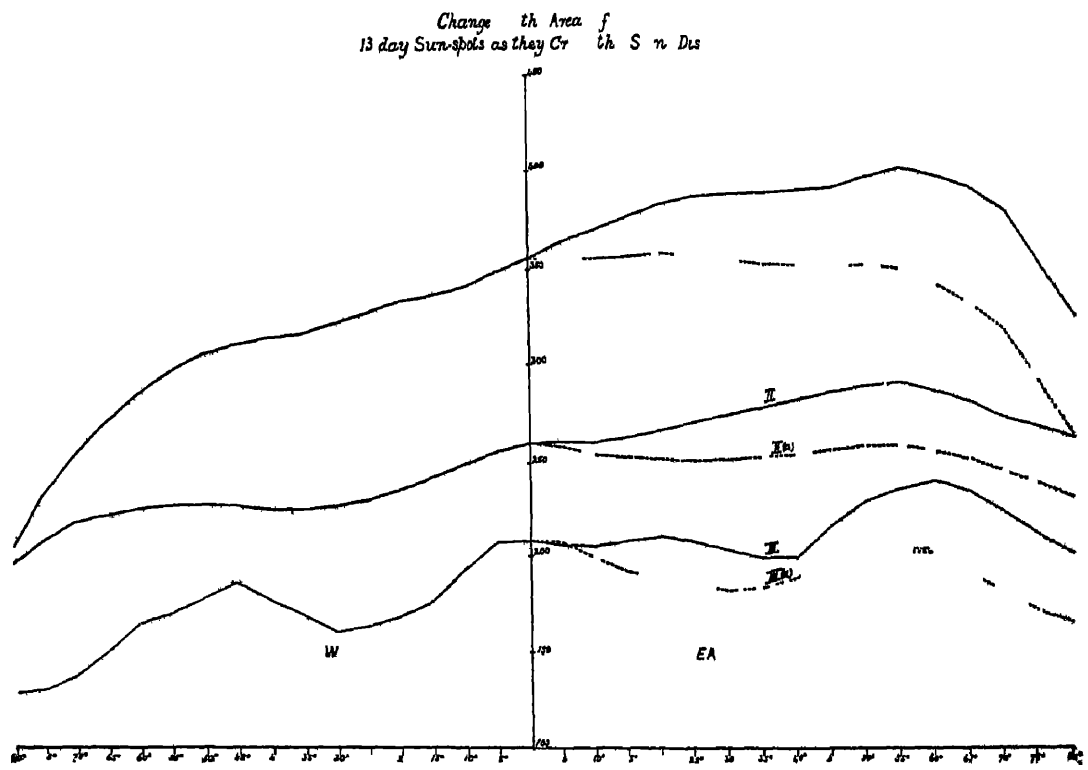
Areas of Sunspots

It remains only to see whether and, if so in what way these zones affect the long lived spots which start outside the zones and cross over to the west in their transit across the sun s disc Of course, the only way in which we can test this is to watch their behaviour from day to day or through successive stages in their journey on the solar disc. We can, for example investigate if their areas undergo any change when they cross the zones, but the problem is not one of simplicity Spots of less duration than thirteen days, start in all longitudes within their possible limits and are observed on successive days wherever they happen to be

at the time of observation The trouble in reducing their areas to any fixed standard positions is enormous. The simplest case and at the same time one that would offer a crucial test appeared to be that of 13- or 14-day spots which start from the eastern end of the disc and travel to the western end, passing through both the zones of inhibition on their way Here too there were some difficulties For instance, the successive observations of two 13-day spot groups Nos 954 and 987, as given in the Greenwich Photoheliographic Results, were at longitudes $-75°.6$, $-65°.5$, $-59°.9$, $-36°.4$, $-22°.1$, $-8°.6$, $+4°.0$, $+12°.7$, $+26°.1$, $+43°.8$, $+52°.7$, $+70°.8$, $+79°.6$, and $-80°.1$, $-65°.0$, $-37°.2$, $-25°.2$, $-12°.2$, $+1°.3$, $+10°.4$, $+29°.4$, $+40°.5$, $+54°.3$, $+68°.7$, $+80°.4$, respectively, east being reckoned negative and west positive It is evident that the comparison of the areas of a large number of spots observed at such varied longitudes cannot be undertaken before they are determined for all groups for some stated longitudes The following method was adopted for this purpose On a large sheet of squared paper every 5° of longitude was marked along the abscissa up to 80° on either side of a central vertical line representing the central meridian of the sun, the ordinates being made to represent the areas of spots From the Greenwich Photoheliographic Results the areas for each 13- or 14-day spot-group at the longitudes of observation were taken and plotted on the squared paper and the points were joined by straight lines From the curves so obtained the values of the areas at 80°, 75°, 70°, 65°, etc., on the east and west up to the central meridian were read off and entered in tabular form In this way were reduced all the 13- and 14-day spots given in the Greenwich Photoheliographic Results for the years 1874 to 1885, excepting a very few which displayed most extravagant changes or whose areas could not be confined within the limits of the squared paper. There were 113 spot-groups studied in this way. It is true that, strictly considered, the areas so derived for the adopted standard longitudes are not quite accurate, for during the interval between any two observations the areas might have undergone irregular changes, whereas the method of reduction adopted assumes that the change during the interval has been uniform It is believed, however, that the error due to this assumption will not be large. It may be mentioned that the same assumption has been made in order to fill wider gaps in the Greenwich Photohelio Results, when there were no photographs available for certain days The data obtained by the method described above give the areas of spot-groups for every 5° of longitude from 80° east to 80° west Curve I in diagram 4 represents the mean of the areas of 113 groups, and I (*a*) by the side of it the mean of east and west combined Although the curve shows a general deterioration in areas, as groups transit the sun's disc, there are perceptible dents in it on either side of the central meridian at the stages where the zones of inhibition are situated In the course of plotting and tabulation it was noticed that the majority of spot-groups underwent many kinds of vicissitudes during their life on the visible disc, such as blazing up in area, acquiring or dropping out companions, splitting up into smaller spots or joining with others to form a compact one The areas were reduced regardless of these changes, so that if the influence of the zones could be detected even under the most adverse conditions, the existence of the zones could be established beyond any doubt During the final stages of reduction, all spots which were described as "Regular" in the Greenwich ledger and which did not exhibit any pronounced changes were noted. There were 33 spot-groups so marked, and these were totalled and averaged separately This is represented by curve II in diagram 4 Curve II (*a*) by its side shows the mean for east and west It is clearly seen that when the changes due to extraneous causes are removed, the influence of the zones is seen to better advantage, but even in the cases described as "Regular" the conditions were not ideal There are indeed very few spots which are quiescent and show absolutely no changes. If we were to confine ourselves to such ideally quiescent groups only, the material for discussion will be very meagre, but it is likely that an assemblage of data given by a large number of such groups would bring out the existence of the two zones most clearly, as can be seen from curve III in diagram 4 It is the curve of the area of a single spot-group, No 765, which is described in the Greenwich ledger as "A Regular Spot with a Small Companion" As all changes seen during the life-history of every group are briefly noted at the head of the table pertaining to each, the absence of any mention of changes shows that the group selected was a quiescent one which simply transited the sun's disc, undergoing only the general deterioration which, as already noticed, affects all spots This group may therefore be taken as free from outside influences and may be expected to behave in an almost ideal fashion when

passing throu_h the zones of inhibition and that is what it has done as its curve and the mean curve III (*a*) clearly show

Diagram 4



Conclusions

1 There are two zones on the sun's disc between 30 and 50 of solar longitude east and west which exercise an apparent inhibitory influence on sunspots

2. The short-lived spots tend to avoid the two zones and the areas of long lived ones are reduced to some extent while passing through them.

3 In the case of spot-groups passing the sun s disc from end to end a general deterioration in areas is noticed This requires explanat on

4 It is significant that the two zones of inhibition occupy a permanent place with respect to the sun s central meridian whose position on the sun is, as is obvious relative to the earth The origin and the physical nature of the two zones have naturally to be explained with due regard to this fact

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