The changes which have now been particularised are important when we consider that they apply to less than half a degree in right ascension, and one degree in declination; but there are two causes of uncertainty to be taken into account before we can give full acceptance to the objective reality of these changes.

1st. Photographic magnitudes of stars do not all agree with those which have been determined by eye observations, and this fact may account for some of the differences in the magnitudes.

2nd. There may be errors in the charting by eye observations, notwithstanding the greatest care and skill on the part of the observer, but any uncertainties that may appertain to them, as well as to the subject matters of this communication, can now be removed by those who possess the necessary optical power; for the exact nature of the changes to be determined has been pointed out by photography, and the essential data furnished for the purpose. That the stars, Nos. 3, 4, 8, 12, 33, and 83, which have been referred to as shown on D'Arrest's chart, and not shown on the photograph, are absent on the latter on account of some physical change having taken place in the stars, receives confirmation by the fact that the photograph shows more than 400 stars on a sky space where D'Arrest has charted only 212 stars.

I am indebted to Dr. Pechüle, of Copenhagen, for a copy of D'Arrest's chart and catalogue, and he informs me that he has for some years kept a watch upon the region of the *Nova*.

Note on the Sun-spots of 1889. By E. W. Maunder.

Though the Sun-spots of 1889 were few in number and generally small in area they presented some characteristics of especial interest; for the past year saw the close of one cycle of solar activity and the commencement of a new one, and the peculiar features of a transition period were well illustrated by the spot-groups which came under observation.

General Features of the Sun-spot Record of 1889.

From every point of view 1889 was a less fertile year than those which preceded it. Without going back to 1884 or 1885—years of great activity—it may be useful to compare it with 1886 and the two succeeding years, for in 1886 there was a lull of so pronounced a character in the late autumn as to lead one experienced solar observer to regard it as probably the true minimum. The following table shows how 1889 compares with the years preceding it as to days without spots, number of spot-groups observed, and mean daily spotted area:—

Year.	Days of Observation.	Days without Spots.	No of Spot-groups.	Mean Daily Spotted Area.
1886	363	61	128	381
1887	361	106	79	179
1888	358	155	54	89
1889	359	209	32	77

The areas in the above and in the following tables are expressed in millionths of the Sun's visible hemisphere.

There can be no doubt, therefore, that the minimum did not fall before 1889.

Duration of Spot-groups.

A marked feature of the spot-groups of 1888 had been the tendency of the disturbances to be intermittent. Amongst the fifty-four spot-groups of that year there was not a single case of a group being seen through the whole of three semi-rotations, nor even through the whole of two; though in one instance a group was seen during part of three successive rotations, and in another case a group was seen during part of two successive rotations. These were the only two examples of a group returning to the east limb after its disappearance at the west limb. But whilst the continuous life-history of a group tended to be short, there were several cases—nine in all—in which a district was the seat of an intermittent action, an interval of rest prevailing between the different outbreaks. The following table shows the localities in which this intermittent action was observed:—

No. of Group.	First Seen.	Last Seen.	Hel. Long.	Hel. Lat	Mean Area.
2075	Nov. 11	Nov. 22	15°6	− 4°0	193
2077	Dec. 9	Dec. 9	19·7	− 3·7	9
2043	March 31	March 31	142·2	− 1·0	7
2050	April 25	April 29	144·8	− 1·5	15
2064	Aug. 12	Aug. 22	143·5	− 2·6	29
2030	Jan. 12	Jan. 16	148·6	−13·3	24
2049	April 24	April 29	153·4	−13·3	47
2055	June 19	June 19	163·4	−12·7	11
2070	Sept. 6	Sept. 16	163·8	−14·9	57
2072	Oct. 3	Oct. 3	166·8	−14·5	22
2076	Nov. 27	Dec. 9	163·3	−11·8	217

Group 2064 was not seen on August 17, nor on August 19 and 20.

2048	April 21	April 27	184·3	− 2·8	36
2069	Sept. 6	Sept. 10	185·8	− 0·3	16

Group 2069 was not seen on September 9.

No. of Group.	First Seen.	Last Seen.	Hel. Long.	Hel. Lat.	Mean Area.
2047	April 18	April 18	243°·5	− 6°·7	15
2051	April 28	April 28	247·4	− 7·5	5
2054	June 15	June 19	257·8	− 10·0	30
2059	July 10	July 17	266·2	− 10·1	65
Group 2059 was not seen on July 12.					
2052	May 11	May 23	273·5	− 7·8	443
2058	July 6	July 7	272·6	− 6·9	10
2063	Aug. 8	Aug. 10	274·5	− 8·1	28
2066	Aug. 28	Sept. 9	276·7	− 6·1	248
2035	Feb. 18	Feb. 29	297·3	− 4·7	220
2042	March 25	March 25	299·0	− 4·6	3
2053	June 9	June 16	301·9	− 4·6	52
2062	Aug. 1	Aug. 2	304·9	− 5·8	17
2068	Aug. 31	Aug. 31	301·7	− 3·3	10

A tenth group, group 2060, was lost for a single day (July 18). Longitude 150°·3, latitude +6°·0.

In marked contrast to this tendency to intermittent action shown by the spot-groups of 1888 we find in 1889 only four examples, two of them but very slightly marked, in which spots broke out a second time in a district after an intervening period of rest. But whilst the examples of this intermittent action were fewer and less distinct than in 1888, there was an increased tendency to more persistent displays.

The following table shows the duration of the different groups during the last four years. It will be seen that with a total of thirty-two groups as against fifty-four in 1888, the number of groups seen in a second or third rotation was twice as large in 1889 as in the preceding year:—

Duration of Group.	Number of Groups. 1886.	1887.	1888.	1889.
1 day	20	11	12	4
2 days	17	9	9	6
3 „	17	9	5	3
4 „	7	9	2	0
5 „	6	7	4	1
6 „	6	5	1	2
7 „	4	3	2	2
8 „	6	2	3	0
9 „	1	2	1	1
10 „	1	5	0	1
11 „	5	2	4	1
12 „	8	3	3	0

Duration of Group.	Number of Groups. 1886.	1887.	1888.	1889.
13 days	1	2	3	1
14 „	0	1	0	0
2 rotations	6	5	1	2
3 „	3	0	1	2
4 „	1	0	0	0
5 „	1	0	0	0
Total No. of groups	128	79	54	32
Total No. of separate groups, deducting for reappearances	110	75	51	26
Mean observed duration of a group	10 days	7 days	6 days	11 days

The following table gives the four regions where intermittent action was observed in 1889 :—

No. of Group.	First Seen.	Last Seen.	Hel. Long.	Hel. Lat.	Mean Area.
2081	Feb. 1	Feb. 6	31°·9	− 3°·5	60
2090	June 16	June 28	30·7	− 5·5	501

Group 2090 was seen in the two succeeding rotations as groups 2092 and 2099.

2093	July 14	July 20	84·4	− 7·7	33
2098	Aug. 9	Aug. 17	79·5	− 7·2	335
2101	Sept. 3	Sept. 4	83·6	− 9·4	7
2103	Sept. 24	Oct. 4	152·5	−20·9	141
2107	Oct. 23	Oct. 23	154·1	−22·5	2

Group 2103 had been seen in the two preceding rotations as groups 2097 and 2100.

2087	April 11	April 12	203·0	− 1·2	15
2096	July 29	Aug. 4	200·5	− 0·9	64

Distribution in Latitude.

The most striking feature of the spot-groups of 1889 was the appearance of a number of spots in high latitudes. In accordance with their behaviour in previous cycles the spots had tended to approach more and more nearly to the equator from the time of the previous minimum in 1879.

Year.	Mean Distance from Equator of all Spots.	Year.	Mean Distance from Equator of all Spots.
1879	22°·82	1884	11°·27
1880	19·80	1885	11·76
1881	18·21	1886	10·38
1882	17·81	1887	8·44
1883	13·04	1888	7·39

In 1888 only one spot out of the fifty-four groups had a higher latitude than 15°, and that spot lasted but for a single day; but ten lay between 15° and 10°, whilst the remaining forty-three clustered still nearer to the equator. The downward tendency was continued in 1889. Up to June 29 no spot had a higher latitude than 10°, and throughout the year there was only one instance of a group lying within either of the zones 20° to 10°, and in that case it was only for a part of its duration that its latitude was less than 20°; its mean latitude on the whole being 20°·5 S. But in the latter half of the year there were several instances of groups in latitudes higher than 20°, so that the groups of 1889 were divided into three well-defined and widely separated zones—a high northern zone, an equatorial zone, and a high southern zone, with a barren belt 10° wide separating the equatorial zone from the zones of high latitude on either hand.

We may look upon the equatorial zone as containing the last remains of the spots of the expiring cycle, whilst the high zones show the first efforts of the new cycle.

	Mean Daily Area of Sun-spots.			
	Under 10°.	10° 20°.	Above 20°.	Total.
1886, Jan.–June	352	255	1	608
July–Dec.	100	59	1	159
1887, Jan.–June	84	49	0	134
July–Dec.	194	29	0	223
1888, Jan.–June	89	4	0	93
July–Dec.	66	20	0	86
1889, Jan.–June	53	0	0	53
July–Dec.	52	0	51	103

The southern hemisphere has still preserved that predominance which it has shown, almost without break, ever since the closing up of the great northern spot of November 1882.

	Equatorial Zone.		Above 20° Lat.	
	No. of Groups.	Mean Daily Area.	No. of Groups.	Mean Daily Area.
Northern	4	4	2	1
Southern	16	48	10	25

Distribution in Longitude.

In years of minimum such spots as appear are usually confined to two or three limited areas. This was very remarkably the case in 1889. The great group of June 16 in its three appearances as groups 2090, 2092, and 2099 contributed more than 41 per cent. of the spotted area of the year, or, including the preliminary outbreak in the same region in February, 42 per cent. The great group of August 2 made up 26 per cent. in its successive appearances as groups 2097, 2100, and 2103. These

two groups, therefore, embraced between them about 68 per cent. of the entire spotted area. The region of longitude 83° and latitude —8° came third with 12 per cent., so that all the other groups put together contained but little more than 20 per cent.

Localities of Formation and Dissolution.

Of the twenty-six separate groups of the year, eighteen formed and dissolved in the visible hemisphere, and were seen only in one rotation; three formed and dissolved in the visible hemisphere, but were seen in more than one rotation; two formed on this side of the Sun, but were dissipated on the other; one formed on the other side, but was dissipated on this; and two, of which one was seen only in one rotation, but the other in three, formed and dissolved in the unseen hemisphere.

Dividing the visible hemisphere into thirteen lunes, each 13°·2 of longitude in breadth, so that each lune corresponds to the mean apparent distance traversed by a spot in a single day, and placing the seventh so that the central meridian should bisect it, the number of cases of spot-formation and spot-dissolution for each lune or day are as follows:—

Lune or Day.	Formations.	Dissolutions.	Ephemeral Spots.	Total No. of Separate Spots.	Total Area.
First	0	0	0	9	1293
Second	1	0	0	13	1695
Third	5	0	1	33	1866
Fourth	2	2	0	50	1756
Fifth	2	1	1	76	1806
Sixth	2	2	0	65	2242
Central	1	0	0	72	2459
Eighth	0	1	1	102	2527
Ninth	1	2	0	102	2407
Tenth	2	1	0	73	2568
Eleventh	2	1	0	50	2642
Twelfth	0	8	0	34	2701
Thirteenth	1	0	1	14	1720

It will be seen that neither the total spotted area nor the number of separate spots was divided symmetrically with respect to the central meridian, the western quarter-sphere having a most distinct advantage over the eastern in both particulars. On the other hand, more groups formed to the east of the central meridian, and more were dissipated to the west of it; the third day being the most favourable for spot-formation, and the twelfth for their extinction. But the number of groups under observation in either quarter-sphere was nearly the same; seven groups being seen only in the east, and nine only in the west, whilst six-

teen were observed on both sides of the central meridian. The preponderance of number of spots and of spotted area observed in the western half of the visible hemisphere was therefore due to the tendency of groups to increase in size and complexity after the central meridian was passed.

Though the example of a single year, and that a year of minimum, is wholly insufficient to base any deductions upon, it will be at once recognised that if a long series of years showed any similar want of symmetry in spot-distribution, it would lead us to the conclusion that our Earth exercised a real influence over the behaviour of the spot-groups, and would render it highly probable that *Venus* and *Jupiter* exerted an influence considerably greater, whilst the establishment of a practical symmetry over a term of years would disprove the existence of any appreciable planetary influence at all. It seems to me, therefore, that this is a point for very careful investigation in the future. The want of symmetry in the present instance may, I think, be regarded as purely accidental, being due to the sudden revival of activity on the ninth day in the case of two important groups, and to the formation of another considerable group at the same apparent meridian.

Characteristics of Spot-groups.

Thirteen of the groups of 1889 were seen only on one, two, or three days. Of these, twelve were but small in size and presented no important peculiarities, except that of position; six of them lying in high latitudes as under:—

No. of Group.	First Seen.	Last Seen.	Hel. Long.	Hel. Lat.	Mean Area.
2091	June 29	June 30	251°·1	−40°·3	5
2094	July 26	July 27	342·1	−24·2	66
2104	Oct. 8	Oct. 8	12·1	−28·8	12
2105	Oct. 9	Oct. 11	23·4	−25·3	8
2106	Oct. 16	Oct. 18	328·9	+22·3	15
2107	Oct. 23	Oct. 23	154·1	−22·5	2

The thirteenth group, group 2102, was distinguished by the development of a large spot in advance of the rest of the group, on the last day on which it was visible before passing out of sight at the west limb. The group followed group 2100 on the same parallel of latitude but at a distance of about 10° in longitude, and there appeared to be a species of attraction between the two groups, the preceding group moving backwards, and the following group forwards. It is far more common to see examples of apparent repulsion.

Of the remaining thirteen groups the five following consisted

of a number of small spots irregularly scattered. In each case the group underwent very rapid changes, increasing to a maximum in two or three days, and then fading away almost as quickly.

Group.	First Seen.	Last Seen.	Hel. Long.	Hel. Lat.	Mean Area.
2081	Feb. 1	Feb. 6	31°·9	− 3°·5	60
2082	Feb. 22	March 3	111·9	− 7·1	55
2093	July 14	July 20	84·4	− 7·7	33
2096	July 29	Aug. 4	200·5	− 0·9	64
2109	Dec. 18	Dec. 22	168·1	+24 1	34

One group, group 2088, consisted of a large circular spot, which broke up on the third day into a stream of small spots. The course of a number of groups as watched in the visible hemisphere suggests that this group had been in existence some ten or twelve days before its appearance at the east limb.

Three groups, groups 2083, 2098, and 2110, illustrate to some extent a type of spot-history often witnessed amongst the more important groups, but three of the four groups of long duration afford much better examples of it. In this type of spot the outbreak commences with a few small faint spots very irregularly distributed. By the second or the third day a great change has taken place; there is a strong forward motion in the group; the spots tend to arrange themselves in a long straight stream, generally along or but slightly inclined to a parallel of latitude. The spots rapidly increase in number and size, especially towards the two ends of the stream. Soon the group consists of two large spots with a few much fainter and smaller spots between them. Of the two large spots the leader is usually the larger, is very regular and well defined in outline, and for a time moves forward very rapidly in longitude. The last spot of the group is nearly stationary, not so regular in shape, and soon breaks up. The fainter and smaller spots in the centre of the group disappear, leaving the two principal spots alone. The following spot after breaking up soon disappears also, and the leader is left alone. The lifetime of the leader as a solitary circular spot is of very various duration, sometimes only a day or two, sometimes it continues through several complete rotations. It disappears either by breaking up into small fragments, or, preserving its shape, gradually contracts until nothing is left.

Of the four long-duration groups of the year, the group seen in two rotations as groups 2108 and 2111 was a single circular spot. The other three groups, the positions of which are given below, are examples of the type of spot just described:—

Group.	First Seen.	Last Seen.	Hel. Long.	Hel. Lat.	Mean Area.
2085	March 13	March 17	308°·2	+ 6°·2	110
2086	April 1	April 11	315·1	+ 5·3	71
2090	June 16	June 28	30·7	− 5·5	501
2092	July 12	July 24	36·3	− 7·9	318
2099	Aug. 9	Aug. 20	36·9	− 8·1	73
2097	Aug. 2	Aug. 11	161·5	−20·7	336
2100	Aug. 27	Sept. 7	160·4	−19·3	198
2103	Sept. 24	Oct. 4	152 5	−20 9	141

All three groups were distinguished by the remarkable manner in which they moved about on the solar surface, not only in longitude but also in latitude.

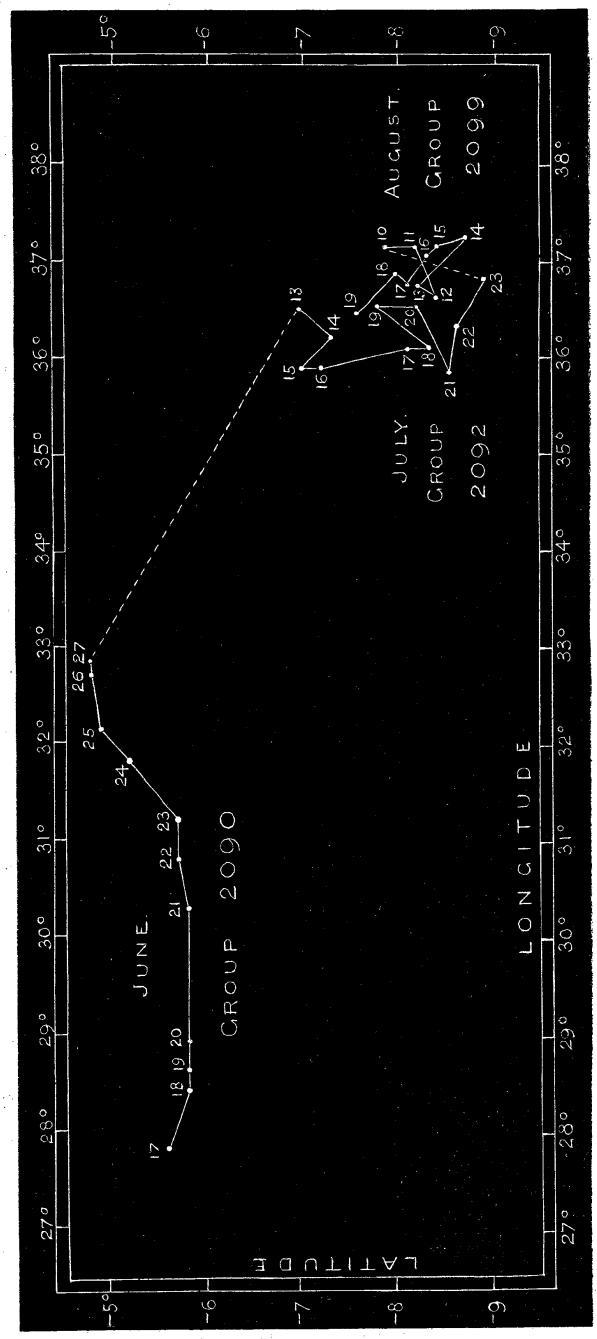
The first group moved forward 5°·2 in longitude, and 0°·6 upward in latitude, in the four days following its formation. In the fortnight that it was on the further side of the Sun it moved forward 4°·0 in longitude, and 1°·1 downward in latitude. It was now a single circular spot, and remained nearly stationary till its disappearance.

The second group, that of June 16, the principal group of the year, showed the most extraordinary drift, as the first diagram will show.

Some of the minor irregularities are probably due to faculous or photospheric matter drifting above portions of the group and concealing certain districts of it, revealing them again by their withdrawal later on. But as for the greater part of its history, the group practically consisted of but one well-defined circular spot, there can be no doubt that the apparent change of place from day to day corresponds very closely to the real movement of the centre of the group upon the solar surface. In this and in the second diagram the observed positions for the first and last days at each appearance are not given, as only a portion of the group was visible on some of those occasions, and the centre of the part observed was therefore not the true centre of the group.

The third group of long duration, that of August 2, was a very perfect example of the type above described. The first faint spots were seen on August 2. By August 4 the long stream of spots with a large spot at either end had fully formed; and by August 11 the leader alone remained. During the next rotation the group consisted only of one large circular well-defined spot. At its third appearance this circular spot was preceded by a number of small spots, but after September 26 the entire group, and especially the smaller spots, began to diminish, and the group had disappeared before reaching the west limb. The most striking feature in the history of the group was the rapid backward drift shown after its first appearance. The forward movement during the first rotation, the retrogression whilst on the

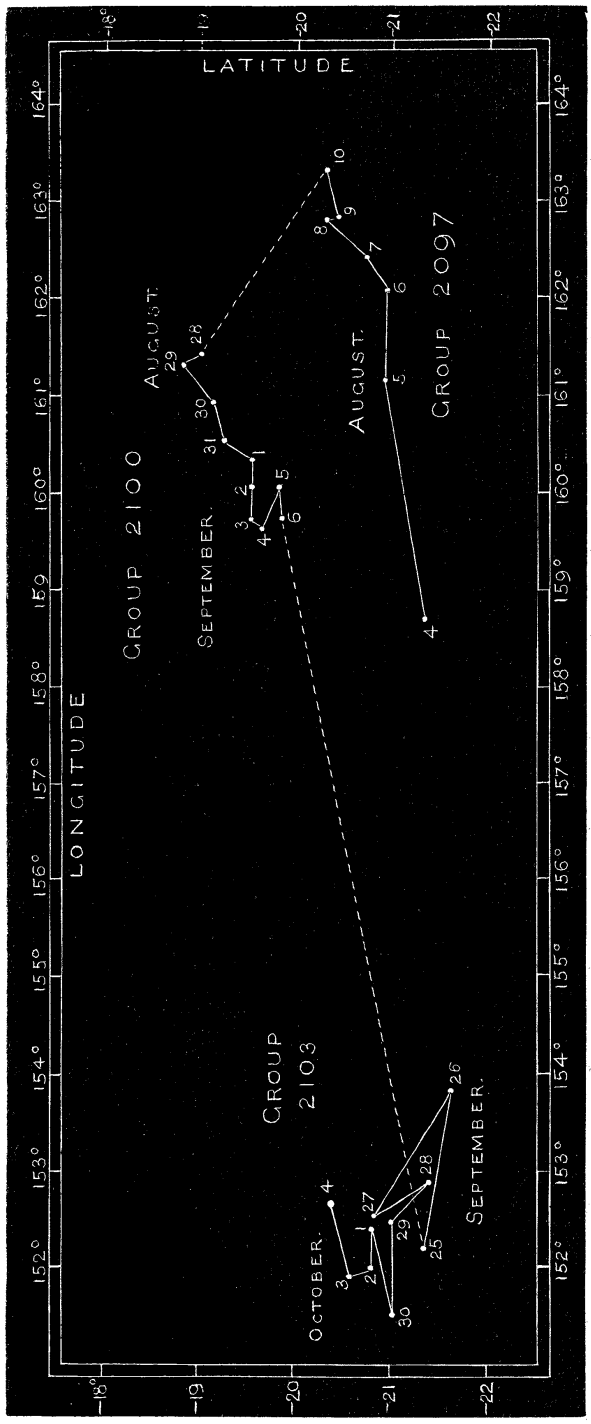
further side of the Sun, and during the second appearance, and the irregular drifting shown in the third illustrate well the difficulty in obtaining any trustworthy rotation period. This



one group would have given three very different rotation periods from its three different appearances, viz. 24·1 days, 25·8 days, and 25·5 days. Carrington's period for this latitude would be 25·7 days. The rotation-period adopted in this paper for the

computation of the heliographic longitudes has been 25·38 days throughout.

The following diagram shows the apparent course of the group during the three appearances.



Summary.

The chief features of the Sun-spots of 1889 are:—

1. The Sun-spots were fewer and smaller than in 1888.
2. But the second half of 1889 was more prolific than the first half.
3. In the second half of the year several spot-groups appeared in high latitudes, so that the spots were congregated in three distinct zones.
4. The average duration of a group was double what it was in 1888. There was less tendency to intermittent action, and a greater tendency to continued action.
5. Some of the larger groups showed a drift remarkable for rapidity and irregularity.

A Mechanical Theory of the Solar Corona. By J. M. Schaeberle.

(*Communicated by E. B. Knobel.*)

My investigations seem to prove conclusively that the solar corona is caused by light emitted and reflected from streams of matter ejected from the Sun by forces which, in general, act along lines normal to the surface These forces are most active near the centre of each Sun-spot zone.

On account of the rotation of the Sun the nearer portions of the stream will have a greater angular velocity than the more distant parts, resulting in a stream of double curvature, each individual particle of the stream, however, describing the same conic section, which for velocities less than about 383 miles per second is a very eccentric ellipse (assuming that the Sun's atmosphere is very rare, as is apparently shown by various observations).

Owing to the change in the position of the observer with reference to the plane of the Sun's equator (according as he is above, below, or in this plane), the perspective overlapping and interlacing of the two sets of streamers causes the observed apparent change in the type of the corona.

In the diagrams numbered 5, 6, and 7 I have purposely exaggerated the curvature of the streams in order to show more forcibly the perspective effect when viewed from different parts of the Earth's orbit. All the other illustrations are prints made from the same model, in which the Sun is represented by a ball something over an inch in diameter, from which radiate a number of needles to represent the streams of matter. All these needles are contained between two small circles corresponding to 30° of north and south latitude, the longer ones being found near the middle of each zone, and slightly more inclined to the normal than the shorter ones, in order that the more distant portions of