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596TH ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL, WESTMINSTER, ON MONDAY, FEBRUARY 18TH, 1918, AT 4.30 P.M.

E. J. SEWELL, ESQ., IN THE CHAIR.

The Minutes of the preceding Meeting were read and confirmed.

The lecture was illustrated throughout by lantern slides.

SUNSPOTS AND SOME OF THEIR PECULIARITIES.

By E. WALTER MAUNDER, F.R.A.S., Superintendent of the Solar Department, Royal Observatory, Greenwich.

MY reason for choosing Sunspots for my subject is two-fold. First, the study of the spots upon the sun has been my work for forty-four years; they are the natural objects with which I am best acquainted. Next, though the subject of sunspots occupies but a very small corner of the entire domain of the science of astronomy, and though astronomy is but one out of the large and ever-increasing number of the physical sciences, yet examination of the methods employed in one scientific inquiry may give some rough idea of the principles by which scientific research in general is guided.

It has passed into a proverb that "Science is Measurement"; in other words, the scientific inquirer tries to throw into numerical form the data which he collects from his observation of the phenomena which he studies. There may be much observation of nature, even useful observation, but it cannot rightly be called "scientific" unless it is arranged on a system, is precise in character, and is more or less directed towards numerical expression.

Thousands of years ago, the Chinese observed and recorded the appearance of spots upon the sun, but for us the history of sunspots practically begins with the invention of the telescope early in the seventeenth century. In 1609, Galileo made his first telescope, and late in 1610, or early in 1611, with one of his improved instruments, he discovered some dark objects on the body of the sun. A little later, a Jesuit Father, Christopher Scheiner, professor of mathematics at Ingolstadt, commenced a regular series of observations of these dark spots, which he termed "*Maculae*," and he also noted that some parts of the sun appeared to be brighter than the rest of the surface, and he, therefore, called them "*Faculae*," a name which is still universally given to them. Though Scheiner was able to show these spots to his pupils, he was at first forbidden to publish his observations, except anonymously, as his superiors were suspicious of his discovery. Thus, when he announced his discovery to the Provincial of his Order, the latter replied: "I have read Aristotle's writings from end to end many times, and I can assure you that nowhere have I found anything similar to what you describe. Go, my son, and tranquillize yourself; be assured that what you take for spots on the sun are the faults of your glasses or of your eyes."

Sunspots, in appearance are, as their name suggests, dark stains on the intensely brilliant surface of the sun. And a sunspot, when fully developed, shows two (or more) grades of darkness; an outer shaded ring known as the *penumbra*, and an inner, much darker, core which we call the *umbra*. The penumbra is generally striated; the umbra in very large spots shows points within itself darker still, which are usually called *nuclei*. It is characteristic of sunspots that they are associated together in *groups*, and these groups tend to conform to a certain type of development. At the first appearance, a pair of very small spots are seen near each other. The two members of the pair appear to be repelled, and they move apart; the two spots increasing in size, and other smaller spots forming between them. The group, therefore, tends to become a *stream* more or less parallel to the sun's equator. The leader spot is generally very well defined in outline, with its umbra dark and distinct; the rear spot is usually not so regular in form, or so dark as the leader, though it often is, for a time, the larger of the two. In the early days of the development of a stream, the leader moves rapidly forward from the rear spot, at the speed of about five miles a minute—that is to say, five or six times the speed of an express train. The photosphere, or bright surface of the sun, appears to be heaped up in front of the leader, and to overflow the small spots in the middle of the group, soon concealing them from sight. Then the rear spot begins to be engulfed, and many streams of bright matter cross it, forming "bridges," or flow down into it. Finally, the whole stream disappears, with the exception of the leader, which has now become large and circular. In many cases the leader now begins to move backwards towards the region from which it originally sprang; sometimes it breaks up into small fragments, but more often it simply contracts on itself, and so gradually disappears.

Groups of spots differ largely as to their size and duration. The largest group in my experience covered an area of 4000 millions of square miles; a thousand times the area of Australia or of Europe. The smallest spots which would be counted worthy of the name, would cover about a million square miles. Fully-developed circular spots very seldom exceed 600 millions of square miles in area, and more generally run to a quarter or a fifth of that extent. Whatever theory of the constitution of a sunspot is accepted, it remains marvellous that a formation covering hundreds of millions of square miles should be able to plough its way through the solar photosphere at such tremendous speed, without breaking up or suffering deformation of its outline. The differences in the duration of spots are equally marked; many spots only last a few minutes; groups of a hundred million miles or more in area frequently last a fortnight or more; and occasionally a group has been known to persist for half a year.

The nature of sunspots may be briefly explained in the following manner. The general surface of the sun is intensely hot and bright, its temperature being about 6000° Centigrade. It appears mottled in character, minute granules of intensest brilliance being thickly clustered on a slightly less luminous background. The bright granules are supposed by many to be luminous clouds, produced by the condensation of carbon at the sun's surface. Sunspots, then, are areas where these clouds have not been able to form or have been torn asunder; areas which offer a very distant analogy to the storms of our own atmosphere. Thus, in terrestrial storms, we have regions where great differences of atmospheric pressure are striving to adjust themselves; in sunspots, probably, we have regions where great differences of temperature are similarly in action. Consequently, sunspots are areas both of lowered temperature—say, 3500° Centigrade, instead of 6000°—and of unusual heat. The cooling is evidenced by the formation of compounds, the characteristic spectra of which have been clearly recognised, such as, for instance, titanium oxide, magnesium hydride and water vapour, and the absorption due to these accounts for much of the apparent darkness of the spot. Round the spot the photosphere is noticeably brighter, and in cases of great activity, very brilliant "bridges" flow into the penumbra, and cross the umbra, and the spectroscope shows many of the dark lines strongly reversed over or near the spot; all symptoms of increased temperature.

The peculiarity of sunspots which has inevitably attracted the greatest attention, is the way in which the sun's activity waxes and wanes. Thus, in the year 1913, the sun's disc was free from spots on no fewer than 312 days, and the average daily spotted area for the entire sun was only 8 millions of square miles. In 1917, on the other hand, there were no days upon which no spots were seen, and in August of that year the average daily area under sunspots exceeded 2500 millions of square miles.

This immense change in the extent to which the solar surface is disturbed does not take place capriciously, but appears to follow a progression with many features of regularity. The interval of time from one quiet period to the next, or from one very active period to the next, generally exceeds ten years, and is less than twelve; on the average, the Sunspot Cycle, as it is called, is 11·1 years in length.

When Galileo first noticed sunspots, he was not content with observing their appearance and form, and the changes which they passed through, but he measured their apparent positions on the sun's disc from day to day, and in this way proved that the spots were not dark bodies floating between the earth and the sun, but were actually upon the sun's surface. From this he learned that the sun rotated on an axis, the position of which he soon determined. Then he learned that spots were not equally distributed over the sun's surface, but were found in zones, north and south of the equator; very few, and those but small, being detected at a distance from the equator of more than 40°.

One of the most striking peculiarities of sunspots is that their distribution in latitude varies with the progress of the sunspot cycle. If we were to commence observations of the sun at a time when the solar activity was far advanced in decline, we should find that the spots were practically confined to the zone lying between north latitude 10° and south latitude 10°. Very soon, however, spots would begin to appear at about 30° from the equator, both north and south, and for a time three sunspot zones would be in evidence—the zone on both sides of the equator which had been first seen, and a zone, the centre of which was about latitude 23° or 24° in the northern hemisphere, and a similar one in the southern. As time went on, spots would increase in number and size in the two zones last named, and would diminish in the equatorial zone, until the latter was left quite free from them, and only the two higher latitude zones would show any spots. In these, however, spots would multiply, but with an increasing tendency to form in lower latitudes. The greatest display of sunspots would take place when the mean latitudes of the spotted areas north and south would lie about 13° or 14° from the equator. After this, the spots would diminish both in size and numbers; their distance also from the equator would decrease, until in eleven years or thereabouts from the first observations practically all spots would be found within a single zone extending about 10° from the equator in both directions. This peculiarity of sunspots is of great interest and importance, as it seems to suggest that the spots must be due to causes lying within the body of the sun itself, and not to any outward influence of planets or combination of planets.

TABLE I.—*Change of the Mean Spotted Area and of its Mean Distance from the Equator during the Progress of the Solar Cycle.*

Cycle 1879–1889.			Cycle 1889–1902.			Cycle 1901–1913.		
Year.	Mean daily sunspot area.	Mean distance from equator.	Year.	Mean daily sunspot area.	Mean distance from equator.	Year.	Mean daily sunspot area.	Mean distance from equator.
		Deg.			Deg.			Deg.
1879	35	23·19	1889	53	22·43	1901	5	20·41
1880	440	19·64	1890	99	21·99	1902	46	23·87
1881	681	18·30	1891	569	20·31	1903	340	19·94
1882	1000	17·81	1892	1214	18·39	1904	488	16·57
1883	1154	13·06	1893	1464	14·49	1905	1191	13·10
1884	1079	11·26	1894	1282	14·18	1906	778	13·99
1885	807	11·77	1895	974	13·54	1907	1082	12·12
1886	381	10·38	1896	543	14·33	1908	697	10·38
1887	179	8·44	1897	514	7·96	1909	692	9·71
1888	89	7·39	1898	375	10·49	1910	264	10·53
1889	26	6·39	1899	111	9·54	1911	64	6·49
			1900	75	7·74	1912	37	8·06
			1901	24	8·49	1913	1	4·43
			1902	16	8·66			

A third peculiarity of sunspots is that a different rotation period for the sun is found according to the latitude of spots under observation. Here on the earth, the same rotation period is obtained whatever be the latitude of the observing station; it is 23h. 56m. of time from the transit of a star across the meridian one night to its transit on the next night, whether the observation be made at the equator or at the polar circle or anywhere in between. In other words, the earth rotates on its axis like a solid body. The sun, on the other hand, so far as we can observe its rotation by means of its spots, does not rotate as a solid body, the time of rotation being shortest for the equator and lengthening out as we pass from the equator towards the poles. Thus, the mean siderial rotation period of the sun's equator is 24·65 days, but for latitude 35° it is two days longer.

But these values for the rotation period are *averages* only, obtained by taking the means from an immense number of independent groups. If we take groups in any one particular latitude, and treat them separately, we find that they differ very widely amongst themselves, so that there is nothing unusual in a high latitude group giving a shorter period than an equatorial group at the same time, or in the same group, whatever its latitude, giving quite different values for the rotation period at different times of its life history.

It has been already pointed out that some groups of spots attain amazing dimensions. Thus, the great sunspot group of 1892 February, had a total length of 166,000 miles, the principal spot being 93,000 miles in length. The breadth of the group was 65,000 miles, and its surface was 18 times as great as the superficial area of the entire earth. The sunspot group of 1917 August was even larger. These dimensions are enormous, but when we compare them with those of the sun itself, they appear quite small. The area of the group of 1892 February was only three parts in one thousand of the entire surface of the visible hemisphere of the sun. If the group had been absolutely black, radiating to us no light or heat at all, the sun's light and heat would have been diminished by only three parts in one thousand, but as the penumbra may be taken as being about two-thirds as bright as the disc, and the umbra as one-fourth as bright, the loss of light would be little more than one-part in a thousand. It must further be remembered that not only was the loss of light due to the spot small, but the spot itself only attained its greatest dimensions on one particular day; it was only visible for 14 days while crossing the disc, and during the last 45 years there have only been four other spots of the same order of magnitude; of which, as it happens, two formed in the year (1917) just past. It will, therefore, be seen at once that no great power of diminishing the solar radiation can be ascribed to sunspots; it is perfectly true that many spots are large, as compared with the earth, but even the very largest can have but little effect upon the total radiation of the sun.

Further, since the bright markings of the sun—the faculae—which are largely connected with sunspots, are brightest, largest, and most numerous at the very same time when the spots are darkest, largest and most numerous, it follows that any loss of radiation from the sun at the time of sunspot maximum is compensated by the fact that that very time is the time of the maximum of faculae; indeed, the evidence appears to point to an over-compensation, so that the time of maximum sunspot activity would appear to be also the time of maximum radiation.

However great, therefore, the actual scale of the disturbances of which we see the evidence in the outbreaks of spots and faculae, their scale is so small as compared with that of the entire sun itself, that they can but represent a variation in the sun's total output of light and heat which is relatively insignificant. It is, therefore, not a very hopeful task to inquire as to whether we have any evidence of a direct effect upon the earth of these changes in the sun's condition.

Table II., which gives a comparison between the annual rainfall at Greenwich and the sunspot area year by year, shows clearly that there is no intimate connection between these two phenomena, and may be taken as typical of the result of most of these inquiries. Some slight and doubtful evidence has been adduced in favour of a dependence of Indian famines or tropical cyclones upon the spotted area of the sun, but researches on these lines have fallen into disfavour for a good many years past.

But the variations in the sun's spotted area are felt by the earth in one manner at all events. At Greenwich Observatory, for many years, and at many other observatories throughout the world, certain "magnetic needles" are kept in cellars or other suitable chambers, screened as carefully as possible from the sun's light and heat, and these respond sympathetically to the solar changes. For, day by day, there is an oscillation in the intensity of the earth's magnetism, and also in its direction,

TABLE II.

The Sunspot Cycle and Greenwich Rainfall.

Year.	Mean daily sunspot area.	Total annual rainfall.	Year.	Mean daily sunspot area.	Total annual rainfall.	Year.	Mean daily sunspot area.	Total annual rainfall.
Cycle 1843–1856.			Cycle 1856–1867.			Cycle 1867–1878.		
		In.			In.			In.
1843	95	24·47	1856	49	23·27	1867	131	28·46
1844	171	23·20	1857	201	21·16	1868	434	25·15
1845	419	22·34	1858	714	17·70	1869	972	24·02
1846	626	25·29	1859	1404	25·83	1870	2761	18·55
1847	1021	17·61	1860	1172	31·90	1871	2004	22·30
1848	986	30·10	1861	1258	20·45	1872	1462	30·02
1849	765	23·58	1862	1363	26·32	1873	766	23·36
1850	494	19·53	1863	702	19·66	1874	604	19·95
1851	683	23·53	1864	784	16·38	1875	248	27·97
1852	545	34·01	1865	407	28·70	1876	126	24·10
1853	436	29·99	1866	318	30·72	1877	108	27·28
1854	113	19·01	1867	131	28·46	1878	22	28·98
1855	64	23·59						
1856	49	23·27						
Cycle 1878–1889.			Cycle 1889–1901.			Cycle 1901–1913.		
		In.			In.			In.
1878	22	28·98	1889	78	23·28	1901	29	20·29
1879	38	31·36	1890	99	21·86	1902	62	19·34
1880	440	29·68	1891	569	25·04	1903	340	35·54
1881	681	25·72	1892	1214	22·31	1904	488	20·66
1882	1000	25·18	1893	1464	20·12	1905	1191	23·02
1883	1154	21·91	1894	1282	26·89	1906	778	24·74
1884	1079	18·05	1895	974	19·72	1907	1082	22·25
1885	807	24·00	1896	543	22·42	1908	697	23·78
1886	381	24·21	1897	514	22·13	1909	692	25·71
1887	179	19·86	1898	375	18·85	1910	264	28·06
1888	89	27·50	1899	111	22·33	1911	64	23.66
1889	78	23·28	1900	75	22·32	1912	37	24·86
			1901	29	20·29	1913	7	22·44

The sunspot areas are expressed in millionths of the sun's visible hemisphere both in this table and in Table I.

and the amount of this oscillation is, roughly speaking, twice as great during years of great solar activity as it is in years of solar quiescence. As the curves representing the areas of sunspots or of faculæ mount up, so do the curves representing the daily range of the earth's magnetism mount also; as the curves of the solar activity decline, so do the curves of the daily magnetic range.

But this is only a general relationship. There is a particular one, and it fell to my lot to trace it out. My own interest was with sunspots, not with terrestrial magnetism. But in 1882, April, a group of spots appeared on the sun much larger than any that I had seen in nine years' experience, and during its progress across the sun's disc, a remarkable disturbance of the magnetic needles took place, not at Greenwich alone, but at magnetic observatories all over the world. While this great sunspot group was crossing the disc, a second group sprang up, and another great disturbance of the magnetic needles occurred. Then, in the November of the same year, a spot was seen on the sun greater than either of these two, and again a very violent magnetic storm broke out, accompanied by a wonderful display of the aurora borealis. From that time forth, I had no doubt in my own mind that there was a direct connection between these great displays of solar activity and the great displays of activity in the earth's magnetism.

Other similar coincidences were observed; there was, for instance, a great magnetic storm in 1892, February 13, when the great group already referred to was a little past the central meridian of the sun's disc. But though sunspot observers were, in general, convinced that there was a real connection between the two activities, many of the great authorities on terrestrial magnetism took an entirely different view, and Lord Kelvin, in his annual address to the Royal Society in that very year, 1892, laid it down that the great magnetic storm could not possibly be ascribed to any solar action. Dr. Rudolf Wolf, of Zurich, the most indefatigable observer of sunspots then living, replied to the effect that if physicists said that the connection was impossible, he would not dispute it; nevertheless, he could affirm that it existed.

But the connection was not easy to establish. It often happened that a great sunspot would pass across the sun's disc and the magnetic needle would make no sign; it sometimes happened that the magnetic needles would be disturbed and the sun present a spotless disc; though, on the other hand, there were many striking instances of apparent correspondence. At length I decided that the only possible way of arriving at the solution was to make a complete catalogue of all the magnetic disturbances from 1882 onward (in which year Greenwich Observatory began to publish reproductions of the traces of the chief storms) and to ascertain the condition of the sun at the moment of the commencement of each. To facilitate the comparison, I computed the solar longitude of the centre of the sun's disc for the time of commencement of each storm, and Table III. gives a small extract from it.

TABLE III.

List of Magnetic Disturbances.

1886, *September*—1887, *November.*

No.	Character.	Date of Commencement.				Long. of centre of sun's disc.	No. of rotation of sun.
				d.	h.	Deg.	
75	Active ...	1886,	September	9	13	124·6	440
76	Active ...		October	6	17	126·0	441
77	Moderate ...		November	2	15	131·2	442
78	Active ...		,,	30	13	123·3	443
79	Moderate ...	1887,	February	12	18	225·6	446
80	Moderate ...		April	4	14	275·7	448
81	Moderate ...		August	1	11	143·4	452
82	Moderate ...		,,	28	20	141·7	453
83	Very active ...		September	25	16	134·2	454
84	Moderate ...		October	22	15	138·5	455

The mystery was solved. Of the ten magnetic disturbances that occurred in the 14 months from 1886, September, to 1887, November, eight fell into two sets of four each, the members of the same set occurring when the same meridian of the sun was near the centre of the disc, that is to say, was fully presented to the earth. When that meridian next came round to the same position, the storm recurred. These two sets each showed a storm occurring four times at intervals of a complete rotation of the sun as seen from the earth. Further examination of the catalogue showed that similar recurrences were a feature of it. In one particular instance, brought to light by a further examination of the Greenwich magnetic records, a storm was found to have occurred in eight consecutive rotations when the same solar longitude was on the centre of the disc, and no other magnetic disturbances took place in the intervals between them.

A little reflection showed what this implied. Lord Kelvin's objection to the supposed connection between the two activities as cause and effect was based on the assumption that the solar action must, like its emanation of light and heat, be emitted from all points of the solar surface, and be radiated equally in all directions. This would involve an expenditure of energy quite inadmissible.

But the return of magnetic disturbances at the end of a complete rotation of the sun showed that the solar action was not radiative, but of an altogether different kind. Instead of coming from every part of the sun's surface as is the case with its light and heat, it proceeded only from restricted regions; instead of being radiated equally in all directions, it travelled to the earth in certain defined directions. It was due, therefore, to the emission from certain special areas of the sun of minute particles shot out in narrow streams, which, as they rose from certain particular areas and were continually supplied from those same areas, inevitably appeared in their effect to rotate with the sun's rotation. Therefore as the sun, as seen from the earth, appears to rotate in a little over 27 days, the magnetic disturbances tended to be repeated at like intervals of time. The streams of particles from the sun overtook the earth in its orbit, and struck it on that arc of the earth's surface to which the sun was then setting.

It was already known that particles are shot off from the sun in this manner. Photographs of the corona during total solar eclipses had shown straight rays, extending from the sun in several directions, and in the eclipse of 1898, January 22, Mrs. Maunder obtained a pair of very small photographs of the corona on which no fewer than four of these long straight rays were clearly seen. The longest of these was traced to a distance of fully 6,000,000 miles. If, as is most likely, it was foreshortened in its presentation to us, then its actual length must have been so much the greater.

It has been pointed out above that sunspots are very small as compared with the sun, but very large as compared with the earth, and that the influence of spots upon the earth, though perceptible, is not of a pronounced and obvious nature. It would therefore seem to be absurd to suppose that the earth should have any effect upon sunspots ; yet there is evidence of at least an apparent effect.

Quite early in my work at the Observatory I was impressed with the frequency with which groups of spots appeared to increase in size and compactness as they approached the centre of the disc, and to break up and diminish in size after they had passed it. This was evidently due in part to the fact that spots when near the circumference of the sun are seen edgeways—that is to say, they are not fully presented towards us as they are when they are near the centre of the sun's disc—but are seen foreshortened. But after careful correction for this effect of foreshortening, it was still found that this tendency remained for spots to be largest when east of the central meridian.

The irregularities in the behaviour of groups of spots are so great that it was impossible to come to any safe conclusion on the subject until many years' observations had been accumulated ; but in 1906 and 1907 Mrs. Maunder undertook an investigation of the problem, and found that if the sun's surface be divided into strips corresponding to the distance passed over by a spot in a single day, then, on the whole, taking these strips or "lunes" one by one, and comparing each lune on the east of the meridian of the sun's centre with the corresponding one to the west, the total spotted area in the eastern lune was always greater than that of the corresponding western lune when the totals were taken for a great number of years.

But a much more striking effect is seen when simply the numbers of spot groups and not their areas are taken. If we compare the number of groups found in the corresponding lunes east and west, the eastern lune always shows a greater number of groups than the western. Or, to put the matter a little differently, in the sunspot cycle which lasted from 1889 to 1901, no fewer than 947 groups came round the eastern limb of the sun into view of the earth, but only 777 passed out of sight from the earth at the western limb into the invisible hemisphere. During this period of 12 years, therefore, no fewer than 170 spot groups faded out in the course of their progress across the disc more than came into existence, so that the earth was apparently responsible for the extinction of about 170 groups—that is to say, of more than one-sixth the whole number that came into view at the east limb.

This predominance of east over west is *relatively* much more obvious when the numbers of spot groups are considered than when the areas are taken, since it is the small groups that die out most easily.

The "prominences" or red flames seen round the circumference of the sun seem to show a slight, yet quite distinct, want of symmetry of the same kind, the eastern prominences being more numerous than the western, except in years when there are very few prominences seen at all.

The earth then has an influence, or, at least, an apparent influence, over the sun, since the groups of spots are, on the whole, considerably more numerous in the eastern half of the sun's disc than they are on the western half, and a similar relation is noticed in the case of prominences and of the total spotted area. Now the central meridian of the sun, dividing the eastern half from the western, is distinguished from any other solar meridian only in this—that it is central as seen from the earth. It is defined entirely by the position of the earth, not by any solar feature. Every part of the sun's surface passes in its turn under that meridian. If then spots and prominences form and dissolve, wax and wane, with some numerical relationship to the central meridian, they do so with a numerical relationship to the position of the earth as such. And that implies a causative relation between the position of the earth and this want of symmetry between the eastern and western segments of the sun as seen from it.

Yet the relation may be merely apparent. First of all, this disproportion between east and west is not very large. It is important therefore to increase—to increase very greatly—the statistics in question before we can be quite sure that we are not dealing with a relationship merely accidental and temporary. It may have held good for the period covered in Mrs. Maunder's inquiry, but may not hold equally good for other periods. Or a different way of dealing with the same statistics might have led to a different conclusion, and such re-examination of the statistics from different points of view must be made, and, no matter how great the labour, will be made when the opportunity serves, to ascertain if the discordance between east and west always holds good or not; and if not, what are the conditions under which it disappears. And if it always holds good, what then? Even in that case, it still may be merely an effect of our standpoint, some effect, if not of perspective, yet of something analogous. But we may not *assume* that this, or its contrary, is the case; the point must be examined into and the evidence presented. Thus far, at least, all attempts to explain the apparent difference between spot and prominence numbers east and west, as due to any kind of perspective effect, have been unsuccessful. Thus far we are *at present* justified in saying that the earth does appear to have an appreciable influence on the sun in the way of damping down solar disturbances, whether they be spots or prominences.

We make this statement with all the reservations to which I have just alluded, reservations that amount to saying that the evidence, though good so far as it goes, must be increased as much as possible. But there is one reservation we do not make. We do *not* make the reservation that no amount of evidence can establish the earth's influence upon the sun, because it is impossible that so small a world should exercise an influence upon a body so great as the sun, an influence visible to us across the gulf of 93 millions of miles. Still less do we make the reservation that no evidence could establish it, because the fact itself would be morally or theologically wrong. This question, like all the questions with which the physical sciences deal, must be decided upon the evidence, quite apart from any previous assumptions.

May I remind you of the little anecdote which I quoted near the beginning of my paper of the reply of Scheiner's Provincial when he told him of his discovery of sunspots, that there could not be spots on the sun because Aristotle had not mentioned them? Another learned doctor contended that it was impossible that the Eye of the Universe should suffer from ophthalmia. You will see that the present attitude of science towards preconceived assumptions has not always prevailed. It does not prevail universally even now. When Mrs. Maunder was pursuing this research, she came across an artisan who was out of work, and knowing him to be a religious man and in need she employed him to carry through a number of simple but lengthy computations for her. After he had completed these, he asked what all these figures were about, and he was unfeignedly distressed when he heard the conclusion of the whole matter. "That is quite impossible," he said, "for the sun is the type of our Lord Jesus Christ, and we cannot conceive that the earth would be permitted to have any effect upon that which is a type of Him." You see, therefore, that the attitude of the Jesuit Father 300 years ago is not unknown amongst some good and pious people at the present day. I may mention two other instances. A friend once sent me a pamphlet written to prove that the earth was flat. When I told her, as I was bound to do, that it was rubbish, she said: "Oh! I am so sorry to hear you say that; it seemed to me so exactly to agree with the Bible." Again, I have known a Christian minister who objected strongly to the practice of astronomers of assuming in their first calculations of the orbit of a new comet that the orbit was parabolic. "They ought," he said, "to assume that it is circular, because the circle is the perfect figure."

A great many years ago, when I was new to scientific inquiry, a leading biologist, himself a believer in Christianity, the father of one of my schoolfellows, said to me, "Religion has come into conflict with Science three times over; and three times over Science has been the victor. Religion has had to lower her flag, first to astronomy, next to geology, and now to biology." In one respect this venerable old man stated the case wrongly. In none of the three cases was it really a contest between Religion and Science; it was a contest between the Science of the Past and the Science of the Present. But the reputation of Religion suffered enormous loss, because those who stood forth to champion it declared that the Science of the Past derived its sanction, not merely from observation and reasoning, but from the authority of Holy Scripture, and that therefore it was infallible and unchanging.

I will not debate the questions of geology and biology; these are not my branches of science. But there is no doubt that in the case of astronomy 300 years ago those who spoke in the name of Christianity denounced the discoveries of Galileo as contrary to the teaching of Holy Scripture, and the condemnation of Galileo has been made a reproach to Christianity ever since. Well would it have been had they listened to the wise counsel of the greatest doctor of the Church then living—Cardinal Bellarmine—who laid it down that if the facts which Galileo asserted were established they would have to admit—not that Holy Scripture was in error—but that their interpretation of it had been faulty.

Galileo taught that the Earth moved; the Holy Office declared that the opinion of the motion of the earth was contrary to the Holy Scriptures. Really they had learned the doctrine that the earth was immovable from the astronomer Ptolemy, who was a heathen, and not from the Bible at all; but having learned the doctrine from Ptolemy they proceeded to identify it in the Bible also, and the Holy Congregation of the Index of 300 years ago has faithful analogues even amongst Protestants at the present day.

If any of us believe that the Bible was meant to teach us the physical sciences, and that the most literal interpretation of its words is the most authoritative, then we must admit that there is no scientific fact more plainly taught in it than that the earth is immovable, and that the sun does move round it. But none of us now interpret any passage of Scripture in this sense. If the earth is spoken of as being immovable, it is understood that the sacred writer is simply using the ordinary language of the day without any reference to a scientific controversy at all.

Surely then the Papal authorities of 300 years ago were putting Holy Scripture to a wrong use when they tried to support a theory of physical science not by observation and experiment, but by claiming that the theory was taught in the Bible. The Scriptures never claim such a purpose for themselves, but a different and a far higher one. "All Scripture is given by inspiration of God, and is profitable for doctrine, for reproof, for correction, for instruction in righteousness, that the man of God may be perfect, thoroughly furnished unto all good works."

If we wish to learn about natural objects, we must go for instruction to the natural objects themselves. If we wish to learn of spiritual things, of the things of God, it is to God Himself that we must go for instruction. And He has revealed Himself in His Son and in the Written Word. It is true, not only of the Gospel of St. John, but of all the books of the Bible: "These are written, that ye might believe that Jesus is the Christ, the Son of God, and that believing ye might have life through His Name."

The Meeting adjourned at 6.20 p.m.