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UPON THE FREQUENCY OF VISIBLE
SUN SPOTS

BY
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Palo Alto, California



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INFLUENCE OF PLANETARY CONFIGURATIONS UPON THE FREQUENCY OF VISIBLE SUN SPOTS

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In any discussion of sun-spot frequency it should be borne in mind that only one-half of the Sun is visible to us at one time, and that all sun-spot data refer only to spots on the terrestrial side of the Sun.

In 1907 A. S. D. Maunder published a paper entitled "An Apparent Influence of the Earth on the Numbers and Areas of Sun-spots in the Cycle 1889-1901."¹ Mrs. Maunder found that for the years under consideration more spots came into view around the east limb of the Sun than passed out of view around the west limb; that is, that more spots died out on the visible side of the Sun than were formed on it. As a summary of Mrs. Maunder's observations we have the following table:

Spots born on visible hemisphere.....	384
Spots born on invisible hemisphere.....	572
Spots died on visible hemisphere.....	564
Spots died on invisible hemisphere.....	402

All told, 947 groups came into view around the east limb or formed close to it, and only 777 groups passed around the west limb or dissolved close to it. This leaves a difference of 170 groups, or 22 per cent of the disappearances, which seem to be due to some influence exerted by the Earth. Apparently, the Earth exerts an inhibitive influence upon the formation of sun spots upon its own side of the Sun or aids their formation upon the opposite side, or, perhaps, both. This plain inference seems not to have been tested in the case of other planets.

It is reasonable to infer that whatever influence the Earth may have on sun spots, a similar influence may be exerted by the planet Venus, which is comparable in size and mass to the Earth and is less than

¹ Monthly Not. Roy. Astronom. Soc., May 1907.

three-fourths the Earth's distance from the Sun. If such should prove to be the case, the visible spottedness of the Sun should be decreased when Venus and the Earth are on the same side of the Sun, or increased when they are on opposite sides, or both phenomena should appear.

In the publications of The International Astronomical Union are given the daily values of the sun-spot relative numbers beginning with 1917. The mean synodical period of Venus is 584 days. The daily sun-spot numbers for 10 synodical periods of Venus, beginning at superior conjunction of Venus and the Sun on April 25, 1917, and ending June 29, 1932, were arranged in regular order in their respec-

TABLE I

Superior conjunction						Inferior conjunction					
Apr. 25, 1917	103	88	104	102	96	29	24	26	20	67	Feb. 9, 1918
Nov. 20, 1918	187	127	135	80	107	47	53	65	53	53	Sept. 12, 1919
July 3, 1920	38	38	40	46	41	50	41	47	37	28	Apr. 22, 1921
Feb. 8, 1922	17	42	30	27	34	0	0	0	0	0	Nov. 24, 1922
Sept. 9, 1923	19	33	22	23	10	13	14	26	34	32	July 1, 1924
Apr. 24, 1925	44	36	30	31	26	34	29	35	44	32	Feb. 7, 1926
Nov. 21, 1926	20	53	101	112	113	40	44	47	68	92	Sept. 10, 1927
July 1, 1928	131	121	124	130	128	50	58	62	57	47	Apr. 20, 1929
Feb. 6, 1930	111	117	110	111	82	57	63	66	68	48	Nov. 22, 1930
Sept. 8, 1931	14	15	18	13	24	26	31	22	24	21	June 29, 1932
Sum.....	684	670	714	675	661	346	357	396	405	420	

Average value at superior conjunction, 681.

Average value at inferior conjunction, 385.

tive periods and their average values for the 10 synodical groups were determined. The actual values for 5 days, 2 days before and 2 days after the day of conjunction, for the 10 superior conjunctions and the 10 inferior conjunctions of the 5,840 days under consideration, are given in table I.

It will be seen from the above table that the sun-spottedness was 76.9 percent greater when Venus and the Earth were on opposite sides of the Sun than when they were on the same side. In the actual days of conjunction this difference is 80 percent.

During the 10 synodical periods of Venus there were 20 days when Venus and the Earth differed in heliocentric longitude by 90 degrees. Five days were taken at each of these periods—2 days before and 2 after the exact day on which Venus and the Earth were

at an angular distance of 90 degrees—and the sun-spot numbers for each of these 100 days are given in table 2.

TABLE 2.—*The Earth and Venus at an angular separation of ninety degrees*

Sept. 18, 1917	97	119	140	149	182	Sept. 15, 1925	20	29	41	58	38
July 3, 1918	99	101	115	146	142	July 1, 1926	111	109	104	76	79
Apr. 2, 1919	16	25	33	29	58	Apr. 16, 1927	138	131	157	124	120
Feb. 6, 1920	22	26	22	30	31	Feb. 4, 1928	50	65	41	46	34
Nov. 26, 1920	24	47	42	35	33	Nov. 24, 1928	28	33	16	7	29
Sept. 15, 1921	26	23	35	29	26	Sept. 13, 1929	39	31	53	25	32
July 2, 1922	0	0	0	0	0	June 19, 1930	16	15	9	14	8
Apr. 17, 1923	0	0	14	13	7	Apr. 16, 1931	38	37	31	41	22
Feb. 3, 1924	0	0	0	0	0	Feb. 2, 1932	17	19	16	17	8
Nov. 26, 1924	53	54	46	33	23	Nov. 24, 1932	12	0	0	0	0
Sum.....	337	395	447	464	502		469	469	468	408	370

The mean sun-spot number for the 100 days of the above table is 43.29, whereas for the 50 days near superior conjunction it was 68.1 and for the 50 days near inferior conjunction it was 38.5.

It would appear from these results that the influence of Venus on visible sun-spottedness is much greater when the planet is on the opposite side of the Sun from the Earth than when it is on the same side as the Earth. That is, the apparent effect of Venus upon sun spots is to repel them to the farther side of the Sun. The phenomena observed by Mrs. Maunder indicate that the Earth also apparently repels sun spots to the farther side of the Sun.

In the case of Mercury and the Earth, the eccentricity of the elliptical orbit of Mercury is so great that the distance of the planet from the Sun is more than 1.5 times as great at aphelion as at perihelion. It seems probable that the distance of Mercury from the Sun must influence whatever effect it may have on total sun-spottedness, and its position relative to the Earth must influence the visibility of these spots.

The period of sidereal revolution of Mercury is 88 days. Its synodical period is 116 days. Accordingly, superior conjunction with the Sun will occur every 116 days, and perihelions will be 88 days apart. If we assume that both of these positions are favorable to the production of visible sun spots, their resultant influence is very hard to determine. Also, Mercury moves in its orbit 2.3 times as fast at perihelion as at aphelion, and is 33 days on the perihelion side of the Sun and 55 days on the aphelion side.

Taking the above facts into consideration along with the known disturbing influence of Venus, it seems, if not hopeless, yet very difficult to detect with certainty any effects of the relative positions of Mercury and the Earth upon the visible spottedness of the Sun.

Nevertheless, the sun-spottedness of 20 periods of 116 days each, starting from the inferior conjunction of Mercury and the Sun, were added and their mean sun-spot numbers were represented graphically. The resulting curve was very irregular and gave no plain indication of a marked sun-spot activity at either conjunction. However, in the twenty 116-day periods the sun-spot numbers at inferior conjunction averaged 48, and on the 58th day after inferior conjunction they averaged 57, showing an increase of about 15 percent when the Earth and Mercury were on opposite sides of the Sun.

It seems unwise to lay too much stress upon this one set of observations. A very large number of such series taken at widely distributed intervals would be necessary to determine with certainty the influence upon visible sun spots of the relative positions of Mercury and Earth.

An attempt was made to determine whether there is an appreciable difference in sun-spottedness as seen from the Earth when Venus and Mercury are on the same, or on opposite, sides of the Sun. Twenty-two groups of 5 days each were taken when Venus and Mercury were at the same heliocentric longitude, and the mean value of the sun-spot numbers for the 110 days so taken was 35.4.

Twenty-three groups of 5 days each, covering the same period taken when the heliocentric longitudes of Venus and Mercury differed by 180 degrees, gave a mean value for the sun-spot numbers of 44.2 for the 115 days.

Forty-four groups of 5 days each, covering the same period, were taken when the heliocentric longitudes of the planets differed by 90 degrees. The mean value of the sun-spot numbers for these 220 days was 38.5.

The mean value of the observed sun-spot numbers when the planets were on opposite sides of the Sun was 24.9 percent greater than when they were on the same side. The observed spottedness when the planets were at an angular separation of 90 degrees was 8.8 percent greater than when they were on the same side of the Sun and 12.9 percent less than when they were on opposite sides of the Sun.

The above data do not take into consideration the relation of either planet to the Earth during the period under consideration, and it seems probable that a similar set of data taken at a different time would show different results. Nevertheless, they seem significant and are given for whatever they are worth.

Similar comparisons were made with Mars and the Earth and with Jupiter and the Earth and with the two planets taken together. In all cases the observed effects were virtually inappreciable, being less than 3 percent in every case.

From the above data it seems safe to assert that sun spots are influenced by the configurations of Venus and the Earth and probably by Mercury and the Earth, and Mercury and Venus. In the case of the other planets no such effect has been shown.

In the foregoing discussion no attempt has been made to propose any theory of the formation of sun spots. It has merely been shown that sun spots are as if repelled by the Earth and the nearer planets. Any sun-spot theory must account at least for this effective repulsion.

In spite of the prevailing opinion of astronomers as expressed by Stratton in "Astronomical Physics" that enormous electric fields in and near the Sun "must be ruled out," it seems to be universally agreed that the rotating gases which give rise to the powerful magnetic fields of sun spots are highly electrified.

The only known body which can repel an electrically charged body is another body similarly electrified. If the planets which are known to repel the charged sun spots are themselves electrified in the same manner as the repelled sun spots, we have a probable explanation of this repulsion.

Whether the planets are so charged or not is a purely qualitative question which cannot be answered by any mathematical theory, but only in the same manner that we may determine the electrification of any insulated body, namely, whether it repels or attracts a known electrified body and whether its rotation may generate a magnetic field.

The author has shown in his monograph on "Terrestrial Electricity"² that the Sun, the Earth, and the Moon have all given what seems to him conclusive proofs of their negative electrification. If this should be suspected in the case of the other planets, it only remains to inquire what other phenomena which have been observed between electrified bodies may be detected between the planets and the electrified gases of the Sun.

² Sanford, Fernando, *Terrestrial Electricity*, Stanford University Press, 1931.