night before being prepared for the food. This amount of food is sufficient for about 30 half-pint milk-bottles. We have been using this culture medium for the last few years, and find it quite satisfactory. In fact, it is practically just as good as the banana-agar food for *D. melanogaster* or *D. immigrans*, and is apparently better than the banana for *D. virilis*. The greatest advantage of the food is, however, that it is much cheaper than the banana food, costing only about one third of the latter in Kyoto at least. Thus, in Kyoto:

100 gr. kôji costs ca.	5.5 sen	
100 gr. peeled banana costs ca.	6 sen	(average cost of a year)
10 gr. agar-agar costs ca.	9 sen	
total	20.5 sen	
while, 800 gr. peeled banana costs ca.	48 sen	
16 gr. agar-agar costs ca.	12 sen	
total	60 sen	

We recommend this culture medium to the workers who can easily obtain kôji. We have not yet tried malt as a substitute for kôji, though it might be worth while trying.

TAKU KOMAI

KYOTO IMPERIAL UNIVERSITY,
JAPAN

SPECIAL ARTICLES

ON THE ORIGIN OF SUN-SPOT VORTICES

IT is well known that sun spots are the visible manifestations of great cyclonic storms in the surface gases of the sun. It is also known that the gases carried around in the sun-spot vortices carry with them great electric charges, apparently of negative sign. In his estimate of the magnitude of the elements of a given sun spot, Carl Störmer[1] concluded that the negative charge over the sun spot area was equivalent to $5.5 \cdot 10^{15}$ electrons over each square centimeter.

The origin of these great cyclones and the source of the charges carried by the revolving gases have never been explained. The only known way by which such a charged area could be isolated upon a good conductor, such as the sun is supposed to be, is by electrostatic induction from a charge upon some other body in the vicinity of the conductor, and aside from this possibility the only conclusion possible in the present state of our knowledge is that the whole surface of the sun is charged to a potential as great, or nearly as great, as the sun-spot area.

There are other reasons for believing the sun to be charged to an enormous negative potential. It is known that the sun has a magnetic field many times as strong as the magnetic field of the earth, and the only known way in which such a field could be maintained is by electrical currents flowing around the sun, presumably caused by negative charges carried around by the sun's rotation.

Another argument for a negatively charged sun is the apparent impossibility of explaining the slight density of gases at the base of the solar corona except by electric repulsion. The corona has every appearance of a gaseous atmosphere several millions of miles in height, yet the gas pressure at its base has been estimated by astronomers as low as 10^{-13} atmosphere, a lower pressure than we are able to produce in our best air pump vacuum.

The explanation most frequently proposed for this low atmospheric pressure is that the coronal gases are supported by radiation pressure, though it has been shown that this assumption is impossible. According to careful measurements, the total radiation of the sun if it were completely absorbed would be capable of supporting a pressure of about 2.3 milligrams to the square centimeter near the sun's surface. The corona was photographed by Maunder[2] in 1898 to a height of at least five million miles above the sun's surface. In order to be supported by radiation pressure the total weight of a column of coronal gas five million miles high and one square centimeter in cross section could weigh only 2.3 milligrams on a body where gravitation is twenty-seven times as great as upon the earth, and provided it absorbed the total solar radiation.

But the solar radiation is only slightly absorbed by the corona. From measurements made on the brightness of the corona it seems to be about one eight-hundred-thousandth that of the sun. This must mean that all the light absorbed and re-emitted and all the light reflected in the corona is about one eight-hundred-thousandth of the total solar radiation.

Schwarzschild,[3] in a theoretical analysis of radiation pressure, showed that the pressure of sunlight upon particles of the dimensions of gas molecules would be insignificant as compared with the sun's gravitation attraction. He accordingly proposed the hypothesis that the solar corona consists of free electrons, and he calculated that such an atmosphere would reflect light of all wave-lengths with equal facility (which is not true of other gases) and that it would partly polarize the reflected light, both of which phenomena appear in the corona. The one objection

[1] *Astrophys. Jour.*, 43, 347 (1916).

[2] Arrhenius, "Kosmische Physik," p. 119.

[3] Sitzungsber, d. K. Bayer, Akad., Math.-Phys. Kl., 31, 293–338 (1901).

which Schwarzschild could find to the electron gas theory of the corona was the great electric charge which it would give to the sun. He estimated that it would require 10^{18} electrons over each square centimeter of the sun's surface.

In 1909, Debye[4] made a more extensive analysis of radiation pressure than had been made by Schwarzschild. He based his analyses upon the classical theory of radiation and upon the Lorentz electron theory, and he reached the same conclusion as did Schwarzschild, *viz.*, that on particles of the dimensions of gas molecules the radiation pressure of sunlight would be insignificant as compared with the gravitational attraction.

Wilhelm Anderson[5] has recently published a series of five papers on the physical nature of the solar corona in which he examines all the coronal theories heretofore proposed and concludes that none except the Schwarzschild theory of an electron gas can be sustained. More recently, Pettit and Nicholson[6] have shown that their measurements of the distribution of energy in the coronal spectrum made during the total eclipse of January 24, 1925, agree within the limits of the probable error of measurement with the calculation of the energy distribution of sunlight as diffused by an atmosphere of electron gas, as computed by Woltjer in Bulletin of the Astronomical Society of The Netherlands, Vol. **3**, p. 103 (1926).

All these researches, as well as those upon the magnetic fields of sun spots and the general magnetic field of the sun, agree in pointing to the conclusion that the surface of the sun must carry an enormous negative electric charge.

In addition to these theoretical considerations, the present writer has an almost continuous record for five years of a diurnal variation in the electrical potential of the earth at Palo Alto which he believes to be due to the electrostatic induction of the sun's negative charge, and a similar, though smaller, lunar diurnal variation which he attributes to the electrostatic induction of the negative charge of the moon.

If the sun is a highly electrified body, the presumption is that the same is true of the planets. In this event there will be a mutual electrostatic induction between the sun and each of the planets. The effect of such planetary induction upon the sun will be a repulsion of the electrified atmosphere of the sun, causing descending currents upon the side toward the planet and ascending currents upon the opposite side. These conditions correspond respectively to the conditions over regions of high and low barometric pressures in the earth's atmosphere. Thus on the side of the sun opposite to the charged planet there will be an area over which there will be ascending currents in the solar atmosphere, and surface winds will be blowing toward this area from all directions. These are exactly the conditions under which cyclonic storms are produced upon the earth, and their tendency will be to produce similar vortex conditions in the solar atmosphere. On the other hand, the descending currents on the side toward the charged planet will aid in suppressing the cyclones already formed.

In *Monthly Notices* of the Royal Astronomical Society, May, 1907, is an article by A. S. D. Maunder, entitled "An Apparent Influence of the Earth on the Numbers and Areas of Sun Spots in the Cycle 1889–1901." The article is made up from photo-heliographic results published by the Astronomer Royal in the Greenwich Observations. These results consist of the measurements of sun spots on photographs of the sun taken daily at Greenwich, at the Kodaikanal Observatory, in India, and at Mauritius. The question considered by Mrs. Maunder is where, and especially on which side of the sun, do most of the sun spots originate? The wholly unexpected result was that more spots come into view around the east limb of the sun than pass out of view around the west limb. That is, more spots die out on the visible side of the sun than are formed on it.

As a summary of Mrs. Maunder's work we have the following table:

Spots born on visible hemisphere,	394.
" " " invisible "	572.
Spots died on visible hemisphere,	564.
" " " invisible "	402.

All told, 947 groups came into view around the east limb or formed close to it, while only 777 groups disappeared around the west limb or dissolved close to it. This leaves a difference of 170 or 22 per cent. of the disappearances which must be laid to some influence exerted by the earth. Mrs. Maunder says:

> These disproportions either in area or in number can not be put down to any cause connected with the history or growth of the spots themselves, or to any solar cause whatever. East is east and west is west solely from an earthly point of view. From the solar standpoint, the east limb, central meridian and west limb are purely conventional lines behind which every portion of the sun's surface moves; they are not fixed landmarks upon the sun. The cause of the disproportion must be terrestrial and terrestrial only.

In *Observatory*, London, **42**, 51–2 (1919), is an article by Evershed, then director of the Kodaikanal Observatory, on "The Displacement of Solar Lines Reflected by Venus," in which the author finds that

[4] *Ann. d. Phys.*, 30, 57–136 (1909).

[5] *Zeitsch. f. Phys.*, 28, 299 (1924); 33, 273 (1925); 34, 433 (1925); 35, 757 (1926) and 37, 342 (1926).

[6] *Astrophys. Jour.*, 64, 136 (Sept., 1926).

the mean wave-length of the iron lines in the light reflected from Venus is

quite appreciably smaller when the angle Venus-Sun-Earth exceeds 90 degrees. At 45 degrees the sun-arc displacements are nearly the same as in ordinary sunlight, but there is a progressive diminution of wave-length as Venus passes round toward superior conjunction; and those lines which ordinarily show larger displacements toward the red than the average diminish in wave-length more than those lines which show smaller displacements. The September series, taken from a hemisphere of the sun turned 135 degrees from the Earth, show a shift to the *violet* of the solar Fe lines.

. . . . . .

Whether we like it or not it seems necessary to admit that the Earth does affect the Sun, causing a movement of gases analogous to that taking place in a comet. Is it possible that this action controls to some extent the distribution of sun spots and prominences, which seem also to betray an earth influence?

It has long been suspected that the occurrence of sun spots is influenced in some way by planetary configurations, though the small gravitational influence of the planets upon the sun seemed to make such an influence improbable. In *Philosophical Transactions* of 1869 and 1870 and in *Philosophical Magazine* of 1870, De La Rue, Stewart and Loewy give data for every day for a long term of years on the portion of the visible hemisphere of the sun which was covered with spots. These records are from solar photographs which were made at Kew and were all carefully measured. In addition to their own records they used the most reliable records back to 1832. They give the variation in millionths of the sun's visible surface from the mean spottedness for the period of the investigation, the plus sign indicating an excess and the minus sign a deficiency of spottedness as compared with the mean.

They then relate these data to planetary configurations, and give a table showing the relative spottedness of the sun for each 30 degrees of the orbit of Mercury, starting at perihelion, and for each 30 degrees of separation of Jupiter and Venus, Jupiter and Mercury, Venus and Mercury and Jupiter and Mars. The earth was not included in this comparison. In the following table their data are tabulated by combining the two sets taken when the planets are at the same angular distance on opposite sides of their conjunction, and in the case of Mercury, when the planet is at the same angular distance from perihelion on opposite sides of its orbit.

TABLE I

PLANETARY CONFIGURATIONS AND SUN SPOTTEDNESS

Angular separation	Jupiter and Venus	Venus and Mercury	Mercury and perihelion	Mars and Jupiter
0– 30	+1107	+1979	+103	−136
30– 60	+ 210	+ 89	+ 47	− 76
60– 90	− 191	− 718	+ 74	−220
90–120	− 421	− 962	− 90	−369
120–150	− 728	− 885	−389	−348
150–180	− 826	−1042	−773	−453

The data given in Table I seem to show conclusively two facts concerning the influence of planetary configuration upon sun spottedness. They show, in the first place, that the spottedness of the sun *is* affected by the relative positions of some of the planets, and, in the second place, that the planetary effects are not due to gravitational tides; for the tide-raising influence of two planets would be combined both at conjunction and at opposition, while their resultant influence would be at a minimum when their angular separation was 90 degrees. On the other hand, if the planetary influence is of the nature of electrostatic induction the resultant effect of two planets will be a maximum when they are in conjunction and a minimum when they are in opposition, as is seen to be the case.

The comparison of Jupiter-Venus with Mercury-Venus indicates that Mercury is more effective than Jupiter in the production of sun spots. Since the electric potentials of the different planets are not known, it is impossible to compute their relative inductional effects upon the sun. If we assume them to be charged to the same potential, their separating effect upon the sun's charge will be as follows, calling that of the earth 1: Mercury, 6:5; Venus, 2.6; Earth, 1; Mars, 0.16; Jupiter, 0.08. This leads us to suspect that the three inner planets are the ones most influential in the formation of sun spots.

The relation of planetary configurations to the periodicity of sun spots deserves more consideration than can be given it in this paper.

Since it is now possible to detect cyclonic disturbances upon the sun which are not sufficiently intense to produce visible spots, perhaps a test of the theory here set forth might be made by observing whether the region of the sun opposite to the planet Mercury is especially susceptible to cyclonic disturbances.

FERNANDO SANFORD

PALO ALTO, CAL.

EXPERIMENTS WITH BACTERIAL FILTERS AND FILTERABLE VIRUSES

WE have come to divide bacteria and viruses into filterable and non-filterable, and we have come to think that those organisms, visible or invisible, which are smaller than the pores of our filter are filterable. That size, however, can not be the sole criterion we