which nevertheless elude amalgamation, it is evident that stamps are not suited to this class of ores unless another manipulation is introduced between them and the amalgamator, and to our mind a most efficient one would be to heat the fine ore to a bright red or white heat and suddenly cool it with water, the theory being that the expansion by heat and instant contraction by cold will scale off or crack the coating so that the mercury can get at the gold by the usual processes of amalgamation.

We remember somewhere to have read of a furnace especially designed for this purpose, but do not at present recall its history, but the feasibility of the plan seems to us undoubted. Another method which has been suggested and which has a practical look about it is to reduce the ore to a fine powder in some machine which will cause so violent an attrition of the particles one against another as to rub off the interfering casing or coating and leave them clean and bright for the action of the quicksilver.

It is claimed that this is effectually done by one or more of the pulverizers or attrition mills now in the market, and that they also separate the metal from the gangue or matrix much more thoroughly than can be or at any rate is done by stamps, and that they deliver it in a condition more favorable for the action of the amalgamator, in pellets instead of in thin, flattened particles which so largely escape with the overflow of the water; but of these points mining superintendents can best judge of actual trial; and the importance of finding a solution of them should warrant the expense of thorough investigation.

Neither tradition nor modern practice has helped us to such understanding of the working of the refractory gold ores as they have of the ores of silver, and, in consequence, to this day we are neglecting many of our richest gold mines for the comparatively poor but more easily worked ones of the other metal.

A successful process is not necessarily—indeed must not be—a complicated or expensive one, and these which we have suggested seem, in these respects at least, to answer the requirements for a certain class of ores; but there are other ores of gold—notably the tellurides, which are among the richest—demanding improved methods of working, and sure to amply reward the successful inventor.

The action of these ores under the blow pipe frame would seem to indicate that two of the conditions necessary to successful reduction must be an exceptionally high temperature in combination with an abundant supply of air.

◆

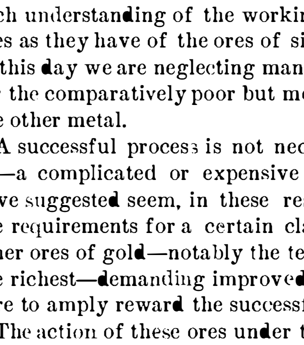
THE SUN.

BY S. P. LANGLEY, ALLEGHENY OBSERVATORY, PA.

In giving a brief account of our knowledge of the sun, which I have been asked to prepare for the readers of the SCIENTIFIC AMERICAN, it may be presupposed that all know how within a few years we have come to a new sense of the sun's immediate importance in every action of life. Men have always known that it lighted them, and ripened their grain for the harvest, but lately we have discovered that our own bodies are grown by it as much as the corn in the fields, and that in fact everything that has life on earth is made by it.

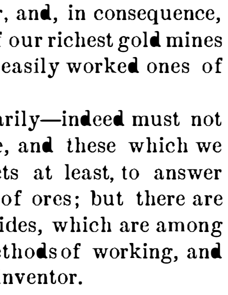
George Stephenson, according to a well known anecdote, used to believe that the sun, in some way, drove his engines, though he could not exactly explain how; but now we know, exactly speaking, that not only every movement of every living thing comes from a motion that once started from the sun, but that, whether it is an ant lifting a grain of sand, or an engine raising a forty ton hammer, it is there the power comes from, as clearly as that which moves the piston comes from the boiler. These being not figures of speech, but statements meant to be taken literally and in their plain meaning, it is easy to see why the study of solar physics is growing in importance, as it is being found to have a bearing on almost every branch of human knowledge, and in unlooked for places. Thus the geologist shows not only that the sun put the coal in the ground for us, but that it piled the ice in the glaciers, which were once dragged along the northern continent; the chemist finds its rays affecting the most intimate properties of matter, and so on through the range of natural science, while the writers of the new history are bringing to notice the way in which it has affected the mental differences between the races of the North and South, and has in the course of ages imprinted its effect on the human mind itself.

Fig. 1.



SPHERE OF SUN & LUNAR ORBIT

Fig. 2.



We shall now try to give, in the plainest way, the principal facts known about this great source of power; some intelligible idea of the means by which they have been discovered; of the apparatus of research, and of the direction original research is now taking. To do this we must begin with the knowledge of a few things about its distance and size, which given in round numbers can be easily remembered.

The sun's distance, then, is 92,000,000 miles; its diameter 860,000 miles; its surface between 11,000 and 12,000 times and its volume about 1,300,000 times that of our globe. It is easier to read such figures than to grasp the reality they convey, but this latter is all the more necessary because we have a disposition to look on the heavenly bodies as less real and material than things at hand. The sun, though, is just as material a thing as a hot coal in the grate, and we can tell, for instance, exactly how many million tons of coal would keep up its heat supply during one minute. Let us try to make these great numbers more comprehensible by comparison. In rapid railway travel, continued day and night at the rate of 600 miles in twenty-four hours, we should be forty days in making the circuit of the earth. The same uninterrupted speed would take us to the sun in rather over 400 years. An ordinary telegraphic signal, if a continuous wire were laid round the earth, would circuit the globe in very nearly one second. If the wire stretched from the sun to the earth, the armature would not move in the terrestrial station till over an hour after the solar operator had pressed the key, or, as it has been ingeniously said, in reference to the fact that sensation requires a certain known though very brief time to travel up the nerves from the hand to the brain, "if a man's arm were long enough to let him touch the sun, it would be over three years before he felt that his fingers were burnt."

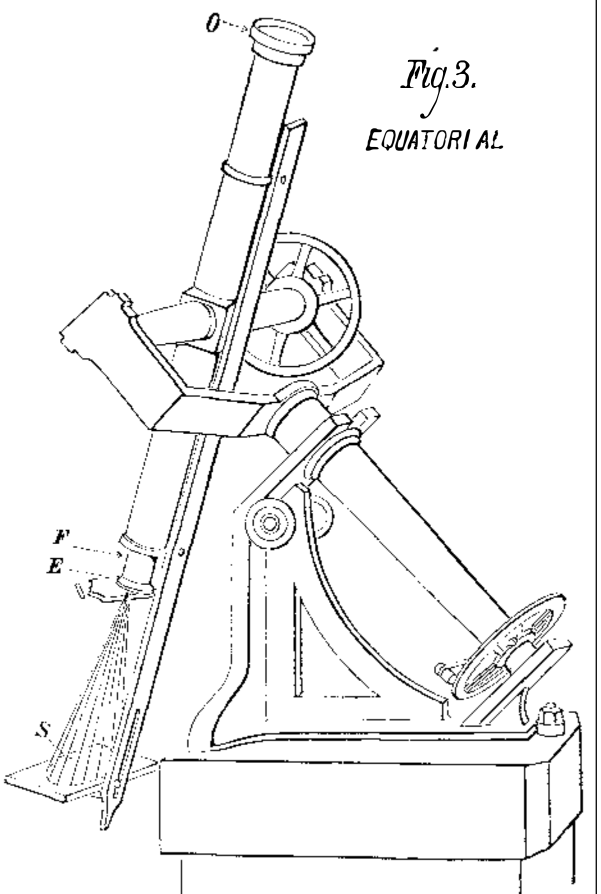


Fig. 3.
EQUATORIAL

The actual size of the sun must evidently be immense to appear as large as it does at such a distance, but this known diameter of 860,000 miles, applied to a sphere of continuous matter, is again nearly inconceivable. To get some notion of it, suppose the sun were hollowed out, and that the earth were placed in the center of the empty shell. Now if the large circle in the figure, Fig. 1, represent the globe of the sun, the dot at its center represents with approximate correctness the size of our earth, and the small circle the actual orbit of the moon, which might revolve at the same distance from the earth as now within the globe of the sun, and still have nearly 200,000 miles clearance between it and the surface! As for figures representing its bulk we must simply forego any attempt to "realize them," and we shall find a similar difficulty when we come to measure its heat.

We must leave the description of the methods by which astronomers have determined these dimensions, untouched, and pass to an account of the solar surface and the means by which we study it, some of which are simple enough to be within the reach of any reader who wishes to see for himself.

The most primitive apparatus by which we can ordinarily see the sun's spots consists of a darkened room with a pinhole in the shutter, letting a single beam of light in. The little circle of light seen on a paper held in the course of the rays, and which enlarges as we go away from the pinhole, is an image of the sun itself, and if the room be long enough to admit of a circle of two inches or more being formed, any considerable spots may be seen without the use of any lenses whatever. I have seen even a small spot in this way, but would hardly advise any one to take much pains with the experiment, for the results are not worth it; though by this rude means the first transit of Mercury ever seen was observed by an early astronomer, Gassendi. A very much better view can be obtained by any one who has a good spyglass, and will take the trouble to secure the necessary steadiness by mounting it on a post, with the help of two small blocks of wood and two thumb-screws, so as to turn in any direction and be clamped there. If the two screws about which the blocks pivot, Fig. 2, are one horizontal, the other vertical, the telescope moves "in altitude," or up and down, with the block turning about the horizontal screw, and "in azimuth," or parallel to the horizon, when the second block turns about the vertical screw, carrying the first with it. A combination of the two motions enables it to be pointed anywhere, and such an instrument, whether made at the cost of a few cents by the roughest carpentry, or in brass and steel by the optician at the cost of thousands of dollars, is the same in principle, and is what astronomers call an "alt-azimuth."

When we first look at the sun through a telescope so mounted and clamped, we are surprised to see how fast it moves out of view, and how busy we are kept in following it. In the morning we not only have to be moving the telescope around the vertical axle to follow the sun's westward motion, but upward about the other, to keep pace with its rising one; and in the afternoon, while still changing to the westward, we have at each such change to point lower also. To avoid this double motion let the top of the post be sawed with a slope to the north, so that if one side of a carpenter's square be laid on the incline, the other will point to the north pole. If the screw which before was vertical be set into the sloping face, and the arrangement be otherwise unaltered, the telescope will now follow the sun with a single motion, which is parallel to the equator, since the pivot on which it turns now points to the pole, the instrument thus turning about part of the same axis the heavens themselves appear to revolve on.

An instrument so mounted, whether roughly or elaborately, is called an "equatorial," and this is the form almost universally employed by astronomers in physical research. The annexed engraving, Fig. 3, shows the principal parts of a small equatorial which is being used to view the image of the sun by projection.

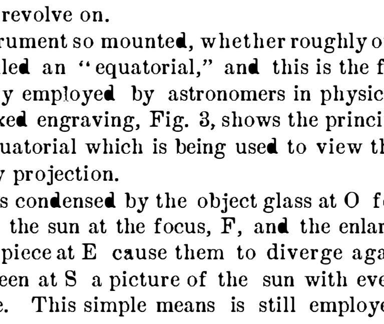
The rays condensed by the object glass at O form a small picture of the sun at the focus, F, and the enlarging lenses of the eyepiece at E cause them to diverge again, making on the screen at S a picture of the sun with everything on its surface. This simple means is still employed with advantage even on the large instruments of observatories, and it gives a much better view than the direct one with common darkening glasses. The screen can be attached to any telescope or spyglass in the way shown in the sketch. If a very low magnifying power be used the whole sun can be seen at once, and the appearance of the spots, the progress of a solar eclipse, or the transit of a planet watched with ease by a number of persons.

If the screen be replaced by a collodion surface at the focus, the little picture may be permanently fixed by photography, and in this way very admirable records have been obtained by Mr. Rutherfurd of New York, Mr. De la Rue in England, and quite recently by M. Jannsen in France. Of these we shall speak later.

STUDY OF THE SUN'S SURFACE.

Let us place our screen at a proper distance, say from one to two feet from the eyepiece, and turn the telescope on the sun, observing that it will usually be best to diminish the aperture of the object glass (by a paper diaphragm) to at least one twentieth of its focal length, and thus lessen the danger of breaking the other lenses by the heat.

Fig. 4.



SUN SEPT. 19. 1870.

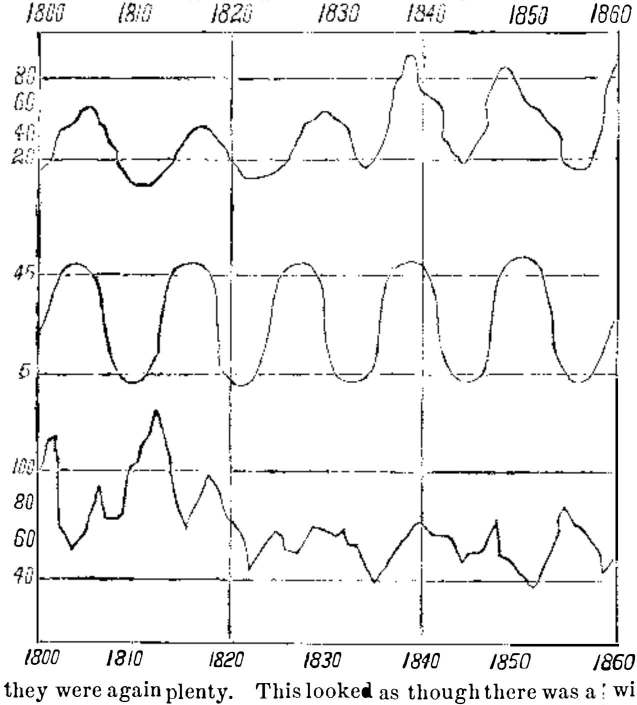
When we point near the sun but not on it, a circle of light will appear on the paper which must not be mistaken for the solar image. This latter, unless a very low power be used, will appear as a larger circle invading the first one, and it will be blurred and indistinct until the eyepiece and then the screen have been adjusted to a correct focus. This is done by moving the eyepiece in or out until the "limb" (that is, the edge) of the sun appears sharply defined. Here is a miniature copy of a tracing of the sun's face, thus made directly on the paper at the Allegheny Observatory on September 19, 1870. (Fig. 4.)

In the intense whiteness of the solar image we see a number of small spots, and these are not on the paper, for they will not move with it, nor in the glasses, for they do not change when those are turned round. They must be, then, in the sun itself. Some of them are hardly more than specks, but we will select one of the largest (that at A) for further examination, and see afterward what it looks like when more magnified. First, however, trace the outline of the image with a pencil and in the same way pencil over the spots, and we have just such a little permanent picture as this. The astronomical telescope reverses everything, but the true cardinal points are easily found. Thus we notice the direction in which the sun moves off the paper, and find it will always be the western side which moves off first. One of the most important, perhaps the most important, of modern discoveries was made by no more elaborate apparatus than this just described.

Schwabe, a German observer, not a professional astronomer, began in 1825 to make daily a little sun drawing the size of our sketch. When he began the spots could be seen almost any day in numbers, but they grew fewer, as he noticed, year by year, till in 1833 they had almost ceased to appear at all. Though scarcely anything was now to be seen, he continued his daily observation till 1836, when they were again plenty. This looked as though there was a cycle during which their number and size waxed and waned; an important fact if true. To determine its reality, Schwabe, with German patience, kept up his daily drawing for forty-two years! His labors were rewarded by the discovery of the law which brought the latter part of his life abundant honor. Their result may be seen from the following table, prepared by Messrs. De la Rue, Stewart, and Loewy, after measuring with persevering labor the great number of drawings Schwabe put into their hands:

Fig. 5.

SUNSPOTS AND PRICE OF GRAIN.



First	minimum of	spots	about	November, 1833.
"	maximum	"	"	December, 1836,
Second	minimum	"	"	September, 1843.
"	maximum	"	"	November, 1847.
Third	minimum	"	"	April, 1856.
"	maximum	"	"	September, 1859.
Fourth	minimum	"	"	February, 1867.

Thus, the sun was remarkably free from spots in 1833; they increased in number and area till 1836, after which they diminished till 1843, and so on. We can see readily that the increase and decrease are not uniform. Thus from the 1st to 2d minimum is 9·8 years; from the 2d to 3d, 12·6 years; from the 3d to 4th, 10·8 years. Adding, and then dividing by three, we find the average period from one minimum to another to be about 11·1 years, and we notice also that in every case the time from one minimum to the next maximum is less than from that on to the next minimum again, or the spot quantity decreases through a little over seven years, and increases through less than four. We do not in the least know why this is so, and though many attempts have been made to show that certain planets affect spots by their attraction, in the opinion of those who have considered the matter most judicially there is no proof that they are due to any influence external to the sun itself. Now the interest of the question to us lies in the fact that we can hardly doubt that an increase or diminution of the sun's brilliant surface is in some was of consequence to our lives on the earth, when, as we know, these hang from day to day on the maintenance of its heat within certain limits, and it is something at any rate to be able to prophesy from past experience, as we now can, what the condition of the sun's surface will be many years in the future. Thus it will be seen that the next minimum (found by adding 11 years to 1867, when the last occurred) falls in the present year, and the sun's face is at present free from spots, almost beyond any past remembrance. Day after day it is examined here now, to find only a blank, but, as we have seen, there are grounds for confidence that this is not to be the case much longer.

Assertions that laws have been discovered affecting the sun's influence on the weather, in such a way that we can predict whether a coming year will be good or bad for the harvest, are so constantly being made that it seems worth while to let the reader judge for himself of the kind of evidence on which they rest. The best known way to detect the influence of spots, if they have any, on the harvests, or their possible agreement with planetary motions, is to draw curves representing the known fluctuations of each in the past, one above another, when if there be any hidden connection it will be made apparent by the ups and downs of the different curves agreeing. The curves showing the fluctuation of the gold, grain, and stock markets are an example of the same method, which is borrowed from that long used by physical investigators.

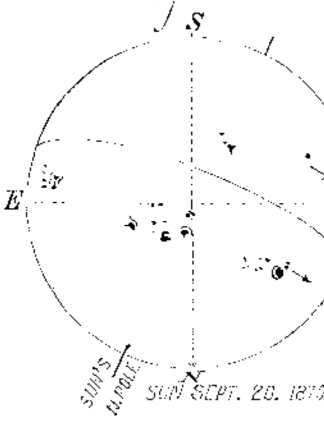
Thus, in the annexed figure (Fig. 5) let an inch measured parallel to the bottom of the page represent in every case 20 years of time, and let the figures on the line parallel to the side of the page represent, in the first case, the relative frequency of sun spots (traced back to the beginning of the century through some old observations discovered by Wolf), so that the more spots there are in any year the higher the curve will rise. In the second curve, changes along the vertical line are proportional to the increase or diminution of Jupiter's distance from the sun. In the third and lowest the figures at the side are proportional to the price of wheat in the English market—rising when wheat ruled high, falling when it was cheap. In all three curves $\frac{1}{20}$ of an inch along the top or bottom corresponds to one year; and in this way we have at a glance the condensed result of observations and statistics for 60 years, which otherwise stated would fill volumes. The result is instructive in more ways than one. The variations of Jupiter's distance certainly do present a striking coincidence with the changes in spot frequency, and this may indicate a real connection between the phenomena; but before we decide that they certainly do so we must remember that the number of cycles of change presented by the possible combination of planetary periods is all but infinite. Thus, we might safely undertake with study enough to find a curve, depending solely on certain planetary configurations, which yet would represent with quite striking agreement for a time the rise and fall in any given railroad stock, the relative numbers of Democratic and Republican congressmen from year to year, or anything else with which the heavenly bodies have in reality as little to do. The third curve (meant by the price of wheat to test the possible influence of sun spots on years of good or bad harvests) is not open to the least objection, but involves a fallacy of another kind. In fact, the price of wheat depends on many things quite apart from the operations of Nature—on wars and legislation, for instance—and here the great rise in the first years of the century is as clearly connected with the great Continental wars of the first Napoleon, which shut up foreign ports, as the sudden fall about 1815 (the year of Waterloo) is with the subsequent peace.

It is not meant that all such attempts are always to prove futile, but our example shows how plausible they may seem, without being necessarily worthy any confidence, and on the whole it is at least doubtful whether the great labor and pains constantly being bestowed on such comparisons are producing, so far, any adequate result.

But let us come back to our telescope and look again at the spots themselves. Here is another view of the sun, taken one day later than the first (Fig. 6), and on comparing it with Fig. 4 we see that all the spots have moved a little toward the west, the one which was just appearing round the eastern edge having come further on to the disk. There are changes among the separate groups also, new spots having broken out in the 24 hours. As all move together, in a general sense the sun must itself be revolving, and thus carrying them along, and, in fact, if we watched we should see the spots go entirely across the sun's face in about 13 days, and disappear round the western side, many of them (not all) reappearing at the east again in about 13 days more. Shall we say that the sun revolves upon its axis like the earth, but in 26 of our days? Not exactly like the earth, for if we observe closer we shall find one feature in its motion which is so extraordinary as to seem at first sight impossible. First let us, by following the directions of the spots from day to day, trace, as we easily can, a line which must nearly coincide with the sun's equator, and notice, as we shall, that all spots lie either some way to the north or south of it (none of them on it) and move in belts on the solar surface, roughly corresponding to our temperate zones. Now if we time them from month to month, we shall notice that those near the equator rotate in less time than those nearer the poles, it being meant, not merely that the sun's equatorial regions move faster in miles per hour, but that their angular velocity is greater. This anomaly will be seen better by reflecting that if such a thing could be, here, the average day might have but 23 hours in Washington and 25 in New York. It is much as though the rim of a great flywheel were observed to make more revolutions per minute than one of the spokes; the outer end of any spoke more revolutions per minute than a part nearer the axle, and so on! We should doubt the evidence of our own senses if we saw the flywheel of an engine appear to do this, without being wrenched in pieces. Yet the sun does it, incontestably. This all but incomprehensible fact (as we may surely call it) was not established till of comparatively late years, Dr. Peters, of Hamilton College, having been the first, or among the first, to announce it over thirty years ago, since which time Mr. Carrington, of England, and others have established it by overwhelming evidence.

If we look attentively we shall also notice that the sun is not equally bright all over, there being a faint shade toward the edge (not shown in the cut), so that the central parts are slightly more brilliant than those nearer the circumference.

Fig. 6.



SUN SEPT. 20. 1870.

This little circumstance is an indication of no slight importance, since it shows that the sun is surrounded by an atmosphere, for if there were none there would be no such shading from the sun's mere rotundity. This follows from the well known laws of emission, to be found in any physical text book; but to make a practical test we may heat a cannon ball white hot, and then, however we view it, we shall see it presents the appearance of a perfectly flat, uniformly brilliant disk. Mr. Ericsson has been at the pains to perform the experiment, though we have independent evidence that the result described must follow. But if the sun be surrounded by an imperfectly transparent atmosphere, this will cut off part of its heat and light everywhere, but most toward the edge, for we, as it is easy to see, must be looking through greater depths of it, where the line of sight makes a considerable angle with the surface, than at the center, where it is vertical to it. This at first sight insignificant feature is of the utmost consequence to us, for without this protecting vail the heat we received on the earth would almost at once put an end to human existence, which could only linger, if at all, for a brief time in the Arctic regions, themselves become the seat of more than tropical temperature.

Let us now put a higher magnifying power on the telescope, and with it project upon the screen the portion of the eastern side, where the large spot already seen in Figs. 4 and 6 is coming into view. Here is the same spot magnified as seen at a certain given moment (for it is now perceived to be rapidly altering in shape) on the two successive days and also on September 22 (Figs. 7, 8, 9). We can now see that it is an immense ragged hole in the crust (or what at first looks like the crust) of the solar surface, followed by a number of smaller size. It is plainly a cavity, and not an elevation, for the slope is visible on the further or eastern side, and hidden by that next to us, and the same feature is repeated in the smaller ones. It is like looking across the edge of a shallow saucer, only that the outline is irregular, and that where the bottom should be there is nothing but the blackness of what seems an immeasurably deep chasm. To get rough measurement of its size we draw a line on the paper, and, with watch in hand, count the time it takes the spot to move across it, which is something like 4 seconds. Then note the time again from the moment the sun's western side touches the line till its eastern side has also passed over. This will be 128 seconds. The diameter of the spot, then, is (very roughly) to that of the sun as 4 to 128, or as 1 to 32, and $\frac{1}{32}$ part of the sun's diameter in miles (already given) is 860,000 ÷ 32, or over 26,000 miles. The diameter of this spot and its immediate connections, then, is over three times that of our earth, and this terrestrial globe might be dropped into the central chasm, as a pea into a thimble, without touching the sides! The whole surface about this vast cavity is changing and breaking up while we are looking on, and there must be a perpetual commotion there for which the most violent earthquake gives no comparison. What is going on in these wonderful regions? We must get nearer, and to do this employ the more powerful means to be now described, and which will virtually carry us to within a few hundred thousand miles of the surface.

Fig. 7.

SEPT. 19. 70.

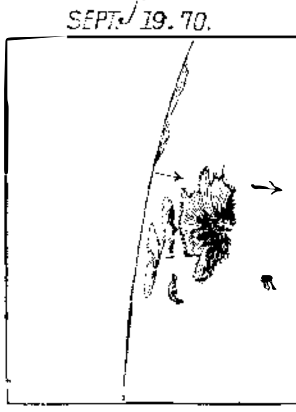


Fig. 8.

SEPT. 20. 70.

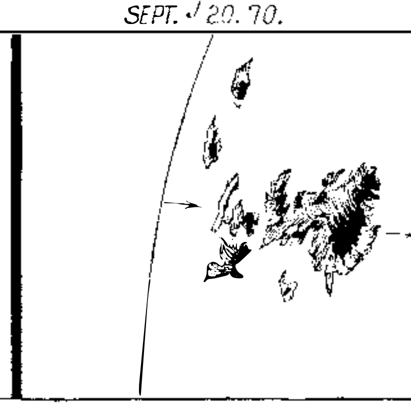


Fig. 9.

SEPT. 22. '70.