THE NEW ASTRONOMY. I.

SPOTS ON THE SUN.

THE visitor to Salisbury Plain sees around him a lonely waste, utterly barren except for a few recently planted trees, and otherwise as desolate as it could have been when Hengist and Horsa landed in Britain, for its monotony is still unbroken except by the funeral mounds of ancient chiefs, which dot it to its horizon, and contrast strangely with the crowded life and fertile soil which everywhere surrounds its borders. In the midst of this loneliness rise the rude, enormous monoliths of Stonehenge, circles of gray stones, which seem as old as time, and were there, as we now are told, the temple of a people which had already passed away, and whose worship was forgotten, when our Saxon forefathers first saw the place.

In the center of the inner circle is a stone which is believed once to have been the altar, while beyond the outmost ring, quite away to the north-east upon the open plain, still stands a solitary stone, set up there evidently with some special object by the same unknown builders. Seen under ordinary circumstances, it is difficult to divine its connection with the others; but we are told that once in each year, upon the morning of the longest day, the level shadow of this distant, isolated stone is projected at sunrise to the very center of the ancient sanctuary, and falls just upon the altar. The primitive man who devised this was both astronomer and priest, for he not only adored the risen god whose first beams brought him light and warmth, but could mark its place; and, though utterly ignorant of its nature, had evidently learned enough of its motions to embody his simple astronomical knowledge in a record so exact and so enduring that, though his very memory has gone, common men are still interested in it; for, as I learned when viewing the scene, people are accustomed to come from all the surrounding country, and pass in this desolate spot the short night preceding the longest day of the year, to see the shadow touch the altar at the moment of sunrise.

Most great national observatories, like Greenwich or Washington, are the perfected development of that kind of astronomy of which the builders of Stonehenge represent the infancy. Those primitive men could know where the sun would rise on a certain day, and make their observation of its place, as we see, very well, without knowing anything of its physical nature. At Greenwich the moon has been observed with scarcely an intermission for one hundred and fifty years, but we should mistake greatly did we suppose that it was for the purpose of seeing what it was made of, or of making discoveries in it. This immense mass of Greenwich observations is for quite another purpose — for the very practical purpose of forming the lunar tables, which, by means of the moon's place among the stars, will tell the navigator in distant oceans where he is, and conduct the fleets of England safely home.

In the observatory at Washington one may see a wonderfully exact instrument, in which circles of brass have replaced circles of stone, all so bolted between massive piers, that the sun can be observed by it but once daily, as it crosses the meridian. This instrument is the completed attainment along that long line of progress in one direction, of which the solitary stone at Stonehenge marks the initial step — the attainment, that is, purely of precision of measurement; for the astronomer of to-day can still use his circles for the special purpose of fixing the sun's place in the heavens, without any more knowledge of that body's chemical constitution than had the man who built Stonehenge.

Yet the object of both is, in fact, the same. It is true that the functions of astronomer and priest have become divided in the advance of our modern civilization, which has committed the special cultivation of the religious aspect of these problems to a distinct profession; while the modern observer has possibly exchanged the emotions of awe and wonder for a more exact knowledge of the equinox than was possessed by his primitive brother, who both observed and adored. Still, both aim at the common end, not of learning what the sun is made of, but of where it will be at a certain moment; for the prime object of astronomy, until very lately indeed, has still been to say *where* any heavenly body is, and not *what* it is. It is this precision of measurement, then, which has always — and justly — been a paramount object of this oldest of the sciences, not only as a good in itself, but as leading to great ends; and it is this which the poet of Urania has chosen rightly to note as its characteristic, when he says:

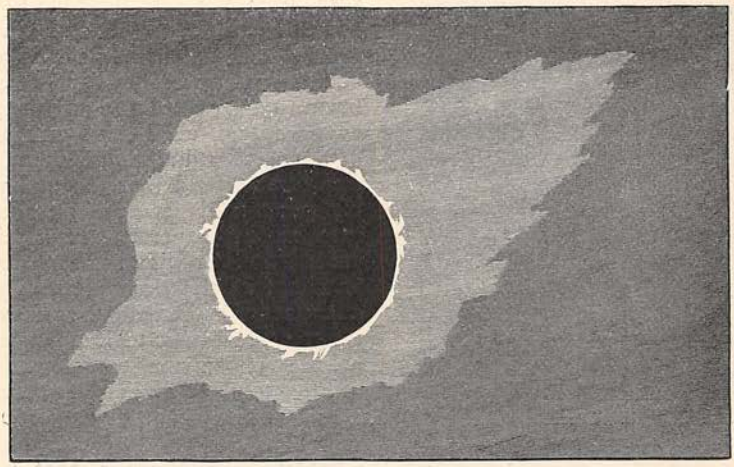

FIG. 1.—THE SUN'S SURROUNDINGS.

"That little Vernier, on whose slender lines
The midnight taper trembles as it shines,
Tells through the mist where dazzled Mercury burns,
And marks the point where Uranus returns."

But within a comparatively few years a new branch of astronomy has arisen, which studies sun, moon, and stars for what they are in themselves, and in relation to ourselves. Its study of the sun, beginning with its external features (and full of novelty and interest, even, as regards those), led to the further inquiry as to what it was made of, and then to finding the unexpected relations which it bore to the earth and our own daily lives on it, the conclusion being that, in a physical sense, it made us and re-creates us, as it were, daily, and that the knowledge of the intimate ties which unite man with it brings results of the most practical and important kind, which a generation ago were unguessed at.

This new branch of inquiry is sometimes called Celestial Physics, sometimes Solar Physics, and is sometimes more rarely referred to as the New Astronomy. I will call it here by this title, and try to tell the reader something about it which may interest him, beginning with the sun.

The whole of what we have to say about the sun and stars presupposes a knowledge of their size and distance, and we may take it for granted that the reader has at some time or another heard such statements as that the moon's distance is two hundred and forty thousand miles, and the sun's ninety-three million (and very probably has forgotten them again as of no practical concern). He will not be offered here the kind of statistics which he would expect in a college text-book; but we must linger a moment on the threshold of our subject — the nature of these bodies — to insist on the real meaning of such figures as those just quoted. We are accustomed to look on the sun and moon as far off together in the sky; and though we know the sun is greater, we are apt to think of them vaguely as things of a common order of largeness, away among the stars. It would be safe to say that, though nine out of ten intelligent readers have learned that the sun is larger than the moon, and, in fact, larger than the earth itself, most of them do not at all realize that the difference is so enormous that if we could hollow out the sun's globe and place the earth in the center, there would still be so much room that the moon might go on moving in her present orbit at two hundred and forty thousand miles from the earth, — *all within the globe of the sun itself*, — and have plenty of room to spare.

As to the distance of ninety-three million miles, a cannon-ball would travel it in about fifteen years. It may help us to remember that at the speed attained by the Limited Express on our railroads a train which had left the sun for the earth when the *Mayflower* sailed from Delfhaven with the Pilgrim Fathers, and which ran at that rate day and night, would in 1884 still be a journey of some years away from its terrestrial station. The fare, at the customary rates, it may be remarked, would be rather over two million five hundred thousand dollars, so that it is clear that we should need both money and leisure for the journey.

Perhaps the most striking illustration of the sun's distance is given by expressing it in terms of what the physiologists would call velocity of nerve transmission. It has been found that sensation is not absolutely instantaneous, but that it occupies a very minute

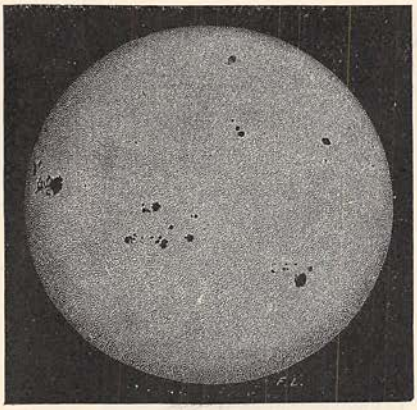

FIG. 2.—VIEW OF THE SUN ON SEPTEMBER 20, 1870. (FROM A PHOTOGRAPH.)

time in traveling along the nerves; so that if a child puts its finger into the candle, there is a certain almost inconceivably small space of time, say the one-hundredth of a second, before he feels the heat. In case, then, a child's arm were long enough to touch the sun, it can be calculated from this known rate of transmission that the infant would have to live to be a man of over a hundred before it knew that its fingers were burned.

Trying with the help of these still inadequate images, we may get some idea of the real size and distance of the sun. I could wish not to have to dwell so long upon figures, that seem, however, indispensable; but we are now done with these, and are ready to turn to the telescope and see what the sun itself looks like.

The sun, as we shall learn later, is a star, and not a particularly large star. It is, as has been said, "only a private in the host of heaven," but it is one of that host; it is one of those glittering points to which we have been brought near. Let us keep in mind, then, from the first, what we shall see confirmed later, that there is an essentially similar constitution in them all, and not forget that when we study the sun, as we now begin to do, we are studying the stars also.

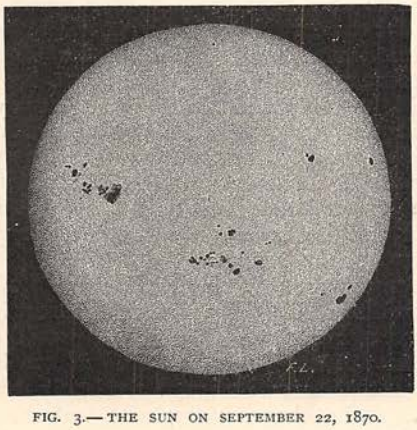

FIG. 3.—THE SUN ON SEPTEMBER 22, 1870.

If we were called on to give a description of the earth and all that is on it, it would be easily understood that the task was impossibly great, and that even an account of its most striking general features might fill volumes. So it is with the sun; and we shall find that in the description of the general character of its immediate surface alone there is a great deal to be told. First, let us look at a little conventional representation (Fig. 1), as at a kind of outline of the unknown regions we are about to explore. The circle represents the Photosphere, which is simply what the word implies, that "sphere" of "light" which we have daily before our eyes,

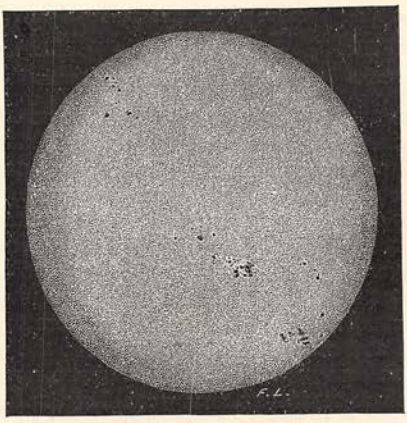

FIG. 4.—THE SUN ON SEPTEMBER 26, 1870.

or which we can study with the telescope. Outside this there is a thin envelope, which rises here and there into irregular prominences, some orange-scarlet, some rose-pink. This is the Chromosphere, a thin shell, mainly of crimson and scarlet tints, invisible even to the telescope except at the time of a total eclipse, when alone its true colors are discernible, but seen as to its form at all times by the spectroscope. It is always there, not hidden in any way, and yet not seen, only because it is overpowered by the intenser brilliancy of the Photosphere, as a glow-worm's shine would be if it were put beside an electric light. Outside all is the strange shape, which represents the mysterious Corona, seen by the naked eye in a total eclipse, but at all other times invisible even to telescope and spectroscope, and of whose true nature we are nearly ignorant from lack of opportunity to study it.

Disregarding other details, let us carry in

FIG. 5.—SEPTEMBER 19, 1870.

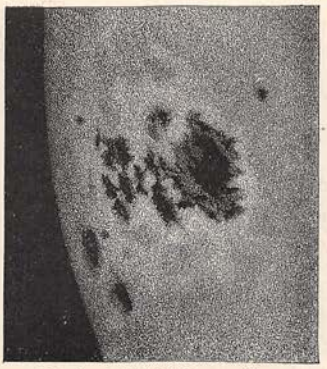

FIG. 6.—SEPTEMBER 20, 1870.
(ENGRAVED FROM A PHOTOGRAPH BY RUTHERFURD.)

our minds the three main divisions:—the Photosphere, or daily visible surface of the sun, which contains nearly all its mass or substance; the Chromosphere; and the unsubstantial Corona, which is nevertheless larger than all the rest. We begin our examination with the Photosphere.

There are records of spots having been seen with the naked eye before the invention of the telescope, but they were supposed to be planets passing between us and the surface; and the idea that the sun was pure fire, necessarily immaculate, was taught by the professors of the Aristotelian philosophy in mediæval schools, and regarded almost as an article of religious faith. We can hardly conceive now the shock of the first announcement that spots were to be found on the sun, but the notion partook in contemporary minds at once of the absurd and the impious; and we notice here, what we shall have occasion to notice again, that these physical discoveries from the first affect men's thoughts in unexpected ways, and modify their scheme of the moral universe as well as of the physical one.

Very little indeed was added to the early observations of Fabricius and Galileo until a time within the remembrance of many of us; for it is since the advent of the generation now on the stage that nine-tenths of the knowledge of the subject has been reached.

Let us first take a general view of the sun, and afterward study it in detail. What we see with a good telescope in this general view is something like this. Opposite are three successive views (Figs. 2, 3, 4) taken on three successive days,—quite authentic portraits, since the sun himself made them; they being, in fact, projected telescopic images which have been fixed for us by photography, and then exactly reproduced by the engraver. The first was taken (by Mr. Rutherfurd, of New York) on the 20th of September, 1870, when a remarkably large spot had come into view. It is seen here not far from the eastern edge (the left hand in the engraving), and numerous other spots are also visible. The reader should notice the position of these, and then on turning to the next view (Fig. 3, taken on September 22d) he will see that they have all shifted their places, by a common motion toward the west. The great spot on the left has now got well into view, and we can see its separate parts; the group which was on the left of the center has got a little to the right of it, and so on. From the common motion of them all, we might suspect that the sun was turning round on an axis like the earth, carrying the spots with it, and as we continue to observe, this suspicion becomes certainty. In the third view (Fig. 4), taken on September 26th, the spot we first saw on the left has traveled more than half across the disk, while others we saw on September 20th have approached to the right-hand edge or passed wholly out of sight behind it. The sun does rotate, then, but in twenty-five or twenty-six of our days—I say twenty-five *or* twenty-six, because (what is very extraordinary) it does not turn all-of-a-piece like the earth, but some parts revolve faster than others,—not only faster in feet and inches, but in the number of turns,—just as though the rim of a carriage wheel were to make more revolutions in a mile than the spokes, and the spokes more than the hub. Of course no solid wheel could so turn without wrenching itself in pieces, but that the great solar wheel does is incontestable; and this alone is a convincing proof that the sun's surface is not solid, but liquid or gaseous.

FIG. 7.—SEPTEMBER 21, 1870.

FIG. 8.—SEPTEMBER 22, 1870.

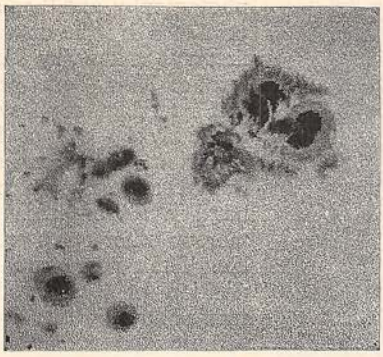

FIG. 9.—SEPTEMBER 23, 1870.

FIG. 10.—SEPTEMBER 26, 1870.

But let us return to the great spot which we saw coming round the eastern edge. Possibly the word "great" may seem misapplied to what was but the size of a pin-head in the first engraving, but we must remember that the disk of the sun there shown is in reality over 800,000 miles in diameter. We shall soon see whether this spot deserves to be called "great" or not.

Next we have six enlarged views of it on the 19th, 20th, 21st, 22d, 23d, and 26th. On the 19th it is seen very near the eastern limb, showing like a great hole in the sun, and foreshortened as it comes into view around the dark edge; for the edge of the sun is really darker than the central parts, as it is shown here, or as one may see even through a smoked glass by careful attention. On the 20th we have the edge still visible, but on the 21st the spot has advanced so far that the edge cannot be shown for want of room. We see distinctly the division of the spot into the outer shades which constitute the penumbra, and the inner darker ones which form the umbra and nucleus. We notice particularly in this enlarged view, by comparing the appearances on the 21st, 22d, and 23d, that the spot not only turns with the sun (as we have already learned), but moves and changes within itself in the most surprising way, like a terrestrial cloud, which not only revolves with the rest of the globe, but varies its shape from hour to hour. This is seen still more plainly when we compare the appearance on the 23d with that on the 26th, only three days later, where the process has begun by which the spot finally breaks up and forever disappears. On looking at all this, the tremendous scale on which the

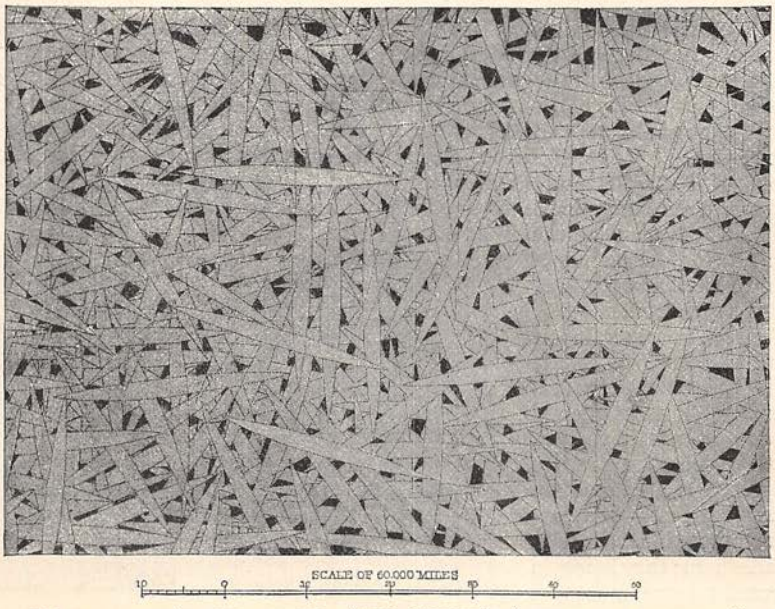

FIG. 11.—NASMYTH'S WILLOW LEAVES. (FROM HERSCHEL'S "OUTLINES OF ASTRONOMY.")

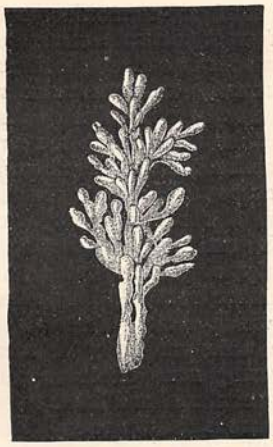

FIG. 12.—THE CACTUS TYPE. (FROM SECCHI'S "LE SOLEIL.")

action occurs must be borne in mind. On the 21st, for instance, the umbra, or dark central hole, alone was large enough to let the whole globe of our own earth drop in without touching the sides! We shall have occasion to recur to this view of the 21st September again.

In looking at this spot and its striking changes, the reader must not omit to notice, also, a much less obvious feature: the vaguely seen mottlings which show all over the sun's surface, both quite away from the spots and also close to them, and which seem to merge into them.

I think if we assign one year rather than another for the birth of the youthful science of solar physics, it should be 1861, when Kirchhoff and Bunsen published their memorable research on Spectrum Analysis, and when Nasmyth observed what he called the "willow-leaf" structure of the solar surface (See Fig. 11). Mr. Nasmyth, with a very powerful reflecting telescope, thought he had succeeded in finding what these faint mottlings really are composed of, and believed that he had discovered in them some most extraordinary things. This is what he thought he saw: The whole sun is, according to him, covered with huge bodies of most definite shape, that of the oblong willow leaf, and of enormous but uniform size; and the faint mottlings the reader has just noticed are, according to him, made up of these. "These," he says, "cover the whole disk of the sun (except in the space occupied by the spots) in countless millions, and lie crossing each other in every imaginable direction." Sir John Herschel took a particular interest in the supposed discovery, and, treating it as a matter of established fact, proceeded to make one of the most amazing suggestions in explanation that ever came from a scientific man of deserved eminence. We must remember how much there is unknown in the sun still, and what a great mystery even yet overhangs many of our relations to that body which maintains our own vital action, when we read the following words, which are Herschel's own. Speaking of these supposed spindle-shaped monsters, he says:

"The exceedingly definite shape of these objects, their exact similarity to one another, and the way in which they lie across and athwart each other — all these characters seem quite repugnant to the notion of their being of a vaporous, a cloudy, or a fluid nature. Nothing remains but to consider them as separate and independent sheets, flakes, or scales, having some sort of solidity. And these . . . are evidently *the immediate sources of the solar light and heat*, by whatever mechanism or whatever processes they may be enabled to develop, and as it were elaborate, these elements from the bosom of the non-luminous fluid in which they appear to float. Looked at in this point of view, we cannot refuse to regard them as *organisms* of some peculiar and amazing kind; and though it would be too daring to speak of such organization as partaking of the nature of life, yet we do know that vital action is competent to develop at once heat and light and electricity."

Such are his words; and when we consider that each of these solar inhabitants was supposed to extend about two hundred by one thousand miles upon the surface of the fiery ocean, we may subscribe to Mr. Proctor's comment, that "Milton's picture of him who on the fires of hell 'lay floating many a rood,' seems tame and commonplace compared with Herschel's conception of these floating monsters, the least covering a greater space than the British Islands."

I hope I may not appear wanting in respect for Sir John Herschel — a man whose memory I reverence — in thus citing views which, if his honored life could have been prolonged, he would have abandoned. I do so because nothing else can so forcibly illustrate the field for wonder and wild conjecture solar physics

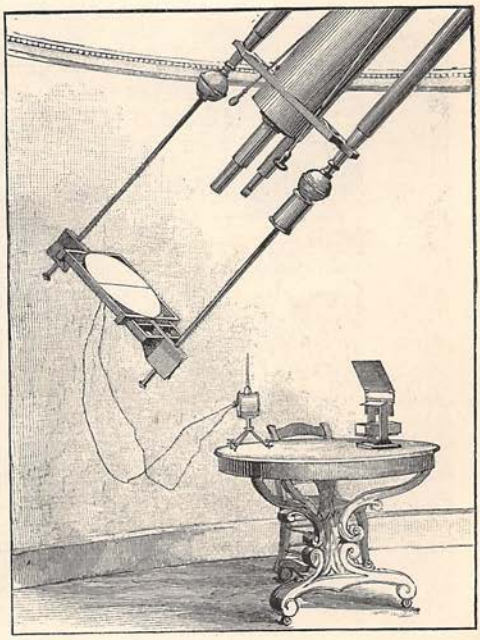

FIG. 13.—EQUATORIAL TELESCOPE AND PROJECTION.

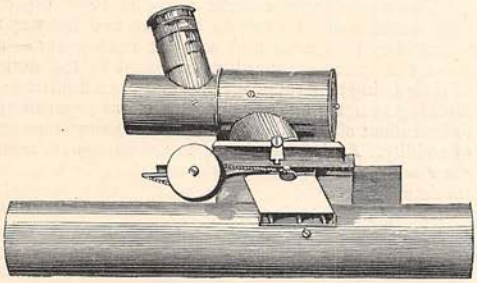

FIG. 14.— POLARIZING EYE-PIECE.

presented even a few years ago; and its supposed connection with that "Vital Force," which was till so lately accepted by physiology, serves as a kind of landmark on the way we have come.

This new science of ours, then, youthful as it is, has already had its age of fable.

After a time Nasmyth's observation was attributed to imperfect definition, but was not fairly disproved. He had, indeed, a basis of fact for his statement, and to him belongs the credit of first pointing out the existence of this minute structure, though he mistook its true character. It will be seen later how the real forms might be mistaken for leaves, and *in certain particular cases* they certainly do take on a very leaf-like appearance. Here is a drawing (Fig. 12) which Father Secchi gives of some of them in the spot of April 14th, 1867, and which he compares to a branch of cactus. He remarks somewhere else that they resemble a crystallization of sal-ammoniac, and calls them veils of most intricate structure. This was the state of our knowledge in 1870. And it may seem surprising that such wonderful statements had not been proved or disproved, when they referred to mere matters of observation. But direct observation is here very difficult on account of the incessant tremor and vibration of our own atmosphere.

The surface of the sun may be compared to an elaborate engraving, filled with the closest and most delicate lines and hatchings, but an engraving which during ninety-nine hundredths of the time can only be seen across such a quivering mass of heated air as makes everything confused and liable to be mistaken, causing what is definite to look like a vaguely seen mottling. It is literally true that the more delicate features we are about to show are only distinctly visible even by the best telescope during less than one-hundredth of the time, coming out as they do in brief instants when our dancing air is momentarily still, so that one who has sat at a powerful telescope all day is exceptionally lucky if he has secured enough glimpses of the true structure to aggregate five minutes of clear seeing, while at all other times the attempt to magnify only produces a blurring of the image. This study, then, demands not only fine telescopes and special optical aids, but endless patience.

My attention was first particularly directed to the subject in 1870, shortly after the

FIG. 15.— SPOT OF SEPTEMBER 21, 1870. (REDUCED FROM AN ORIGINAL DRAWING BY S. P. LANGLEY.)

regular study of the Photosphere was commenced at the Allegheny Observatory by means of its equatorial telescope of thirteen inches aperture, with the view of finding out what this vaguely seen structure really is. Nearly three years of constant watching were given to obtain the results which follow. The method I have used for it is indicated in the drawing, which shows the preliminary step of projecting the image of the sun directly upon a sheet of paper divided into squares and attached to the eye-end of a great equatorial telescope. When this is directed to the sun in a darkened dome, the solar picture is formed upon the paper as in a camera obscura, and this picture can be made as large or as small as we please by varying the lenses which project it. As the sun moves along in the sky its image moves across the paper; and as we can observe how long the whole sun (whose diameter in miles is known) takes to cross, we can find how many miles correspond to the time it is in crossing one of the squares, and so get the scale of the future drawing, and the true size in miles of the spot we are about to study. Then a piece of clock-work attached to the telescope is put in motion, and it commences to follow the sun in the sky, and the spot appears fixed on the paper. A tracing of the spot's outline is next made, but the finer details are not to be observed by this method, which is purely preliminary, and only for the purpose of fixing the scale and the

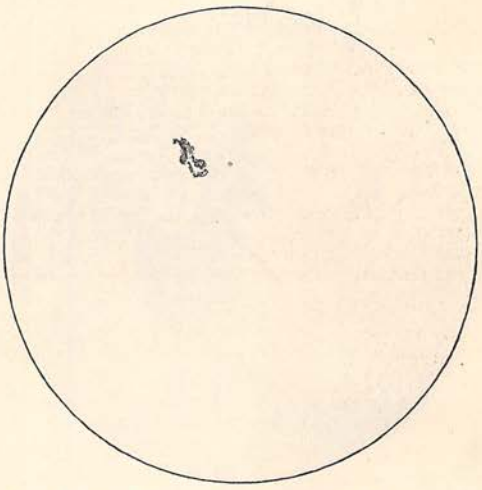

FIG. 16.—SUN ON MARCH 5, 1873. (FROM A DRAWING BY S. P. LANGLEY.)

points of the compass (so to speak) on the sun's face. The projecting apparatus is next removed and replaced by the polarizing eyepiece. Sir William Herschel used to avoid the blinding effects of the concentrated solar light by passing the rays through ink and water, but the phenomena of "polarization" have been used to better advantage in modern apparatus. This instrument, one of the first of its kind ever constructed, and in which the light is polarized with three successive reflections through the three tubes seen in the drawing,

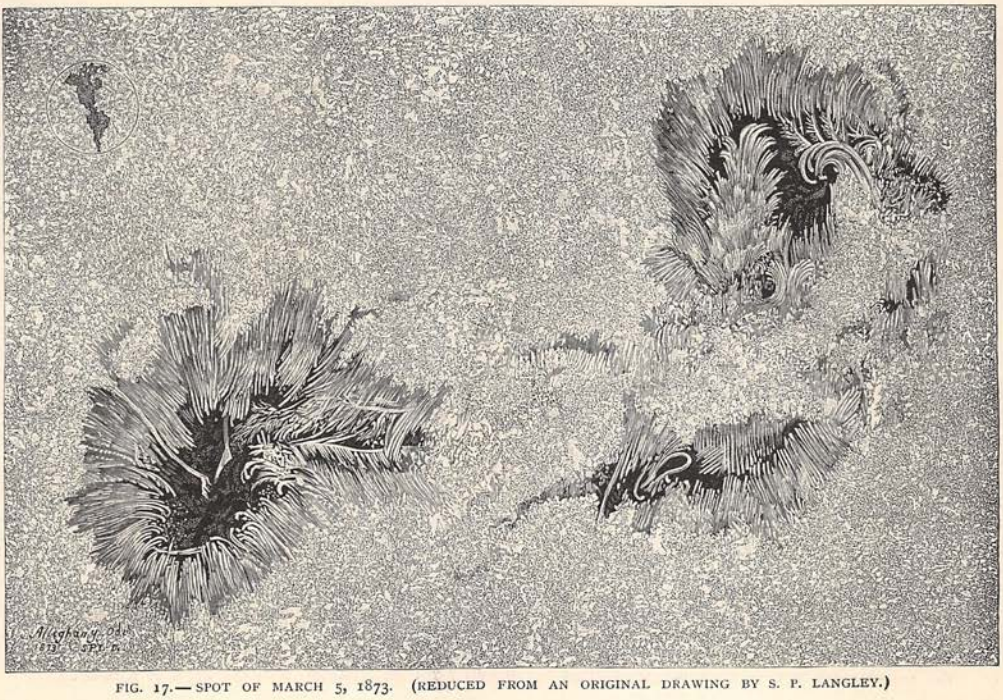

FIG. 17.—SPOT OF MARCH 5, 1873. (REDUCED FROM AN ORIGINAL DRAWING BY S. P. LANGLEY.)

FIG. 18.—"THE PLUME" SPOT OF MARCH 5 AND 6, 1873. (FROM AN ORIGINAL DRAWING BY S. P. LANGLEY.)

was made in Pittsburgh as a part of the gift of apparatus by one of its citizens to the Observatory, and has been most useful. By its aid the eye can be safely placed where the concentrated heat would otherwise melt iron. In practice I have often gazed through it at the sun's face without intermission from four to five hours, with no more fatigue or harm to the eye than in reading a book. By its aid the observer fills in the outline already projected on the paper.

The photograph has transported us already so near the sun's surface that we have seen details there invisible to the naked eye. We have seen that what we have called "spots" are indeed regions whose actual vastness surpasses the vague immensity of a dream, and it will not cause surprise that in them is a temperature which also surpasses greatly that of the hottest furnace. We shall see later, in fact, that the whole surface is composed largely of metals turned into vapor in this heat, and that if we could indeed drop our great globe itself upon the sun, it would be dissipated as a snow-flake. Now, we cannot suppose this

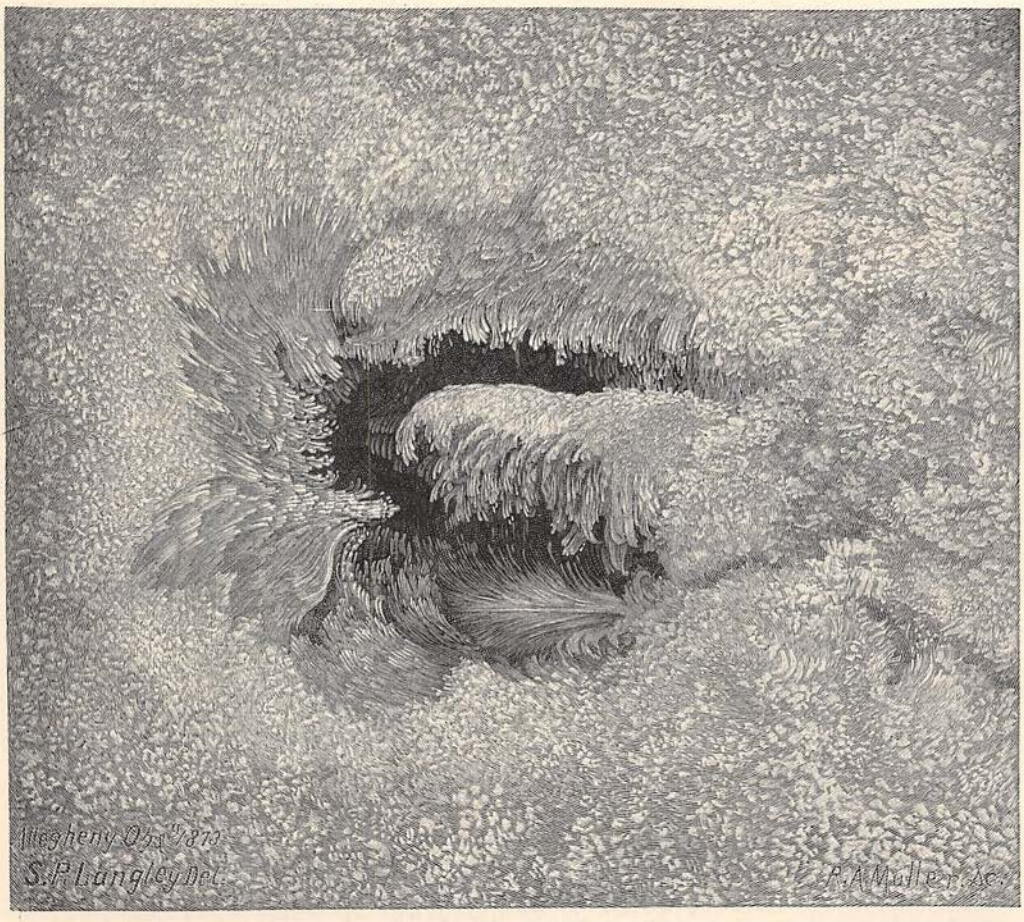

FIG. 19.—TYPICAL SUN SPOT OF DECEMBER, 1873. (REDUCED FROM AN ORIGINAL DRAWING BY S. P. LANGLEY.)

great space is fully described when we have divided it into the penumbra, umbra, and nucleus, or that the little photograph has shown us all there is, and we rather anticipate that these great spaces must be filled with curious things, if we could get near enough to see them. We cannot advantageously enlarge our photograph further; but if we could really come closer, we should have the nearer view that the work at Allegheny, I have just alluded to, now affords. On page 718 there is a drawing (Fig. 15) of the central part of the same great spot already cited, made on the 21st of September, 1870, and which may be compared with the photograph of that day. We have now a greatly more magnified view than before, but it is not blurred by the magnifying, and is full of detail. We have been brought within two hundred thousand miles of the sun, or rather less than the actual distance of the moon, and are seeing for ourselves what was a few years since thought out of the reach of any observer. See how full of intricate forms that void, black, umbral space in the photograph has become! The penumbra is filled with detail of the strangest kind, and there are two great "bridges," as they are called, which are almost wholly invisible in the photograph. Notice the line in one of the bridges which follows its sinuosities through its whole length of twelve thousand miles, making us suspect that it is made up of smaller parts as a rope is made up of cords (as, in fact, it is); and look at the end, where the cords themselves are unraveled into threads, fine as threads of silk, and these again resolved into finer fibers, till in more and more web-like fineness it passes beyond the reach of sight! I am speaking, however, here rather of the wonderful original, as I so well remember it, than of what my sketch, or even the engraver's skill, can render.

On page 719 is quite another "spot," belonging to another year (1873). First, there is a view (Fig. 16) of the sun's disk with the spot on it (as it would appear in a small telescope), to show its relative size, and then a larger drawing of the spot itself (Fig. 17), on a scale of twelve thousand miles to the inch, so that the region shown to the reader's eyes, though but a "spot" on the sun, covers an area of over one billion square miles, or more than five times the entire surface of the earth, land and water. To help us to conceive its vastness, I have drawn in one corner the continents of North and South America on the same scale as the "spot." Notice the evidence of solar whirlwinds, and the extraordinary "plume" (Fig. 17), which is a something we have no terrestrial simile for. The appearance of the original would have been described most correctly by such incongruous images as "leaf-like," and "crystalline," and "flame-like"; and even in this inadequate sketch there may remain some faint suggestion of the appearance of its wonderful archetype, which was indeed that of a great flame leaping into spires and viewed through a win-

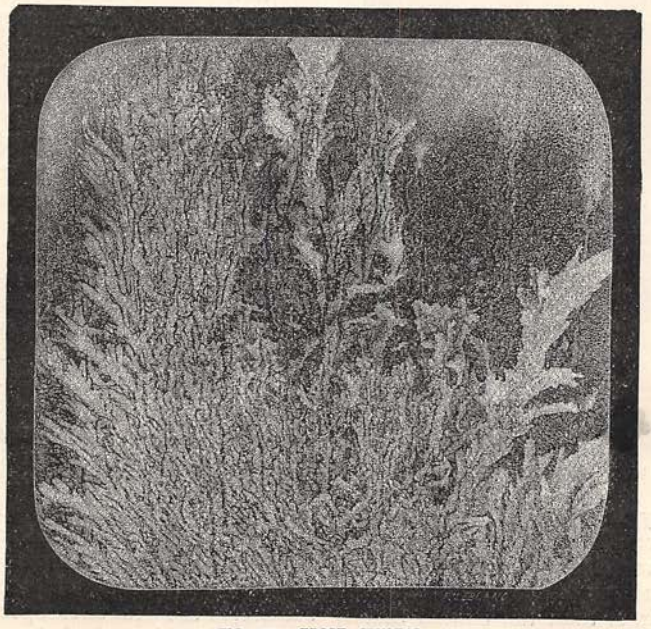

FIG. 20.—FROST CRYSTAL.

dow covered with frost crystals. Neither "frost" nor "flame" is really there, but we cannot avoid this seemingly unnatural union of images, which was fully justified by the marvelous thing itself. The reader must bear in mind that the whole of this was actually in motion, not merely turning with the sun's rotation, but whirling and shifting within itself, and that the motion was in parts occa-

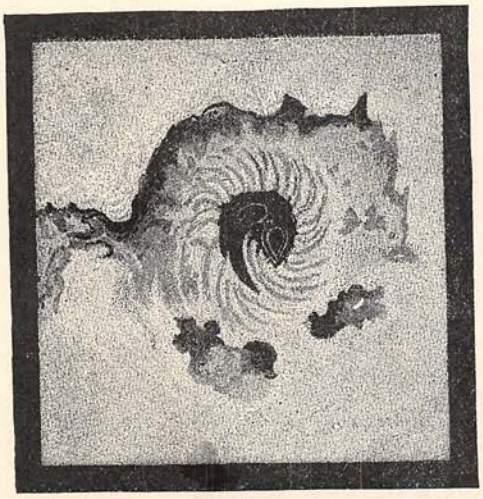

FIG. 21.—CYCLONE SPOT. (DRAWN BY FATHER SECCHI.)

sionally probably as high as fifty miles per second,—per *second*, remember, not per hour, —so that it changed under the gazer's eyes. The hook-shaped prominence in the lower part (actually larger than the United States) broke up and disappeared in about twenty minutes, or while the writer was engaged in drawing it. The imagination is confounded in an attempt to realize to itself the true character of such a phenomenon.

On page 720 is a separate view of the plume (Fig. 18), a fac-simile of the original sketch, which was made with the eye at the telescope. The pointed or flame-like tips are not a very common form, the terminals being more commonly clubbed, like those in Father Secchi's "branch of cactus" type given on page 717. It must be borne in mind, too, if the drawing does not seem to contain all that the text implies, that there were but a few minutes in which to attempt to draw, where even a skilled draughtsman might have spent hours on the details momentarily visible, and that much must be left to memory. The writer's notebook at the time contains an expression of despair at his utter inability to render most of what he saw.

Let us now look at another and even more wonderful example. Figure 19 shows part of a great spot which the writer drew in December, 1873, when the rare coincidence happened of a fine spot and fine terrestrial weather to observe it in. In this, as well as in the preceding drawing, the pores which cover the sun's surface by millions may be noted. The luminous dots which divide them are what Nasmyth imperfectly saw, but we are hardly more able than he to say what they really are. Each of these countless "dots" is larger than England, Scotland, and Ireland together! The wonderful "crystalline" structure in the center cannot be a real crystal, for it is ten times the area of Europe, and changed slowly while I drew it; but the reader may be sure that its resemblance to some crystallizations has not been in the least exaggerated. I have sought to study various actual crystals for comparison, but found none quite satisfactory. That of sal-ammoniac in some remote way resembles it, as Secchi says; but perhaps the frost crystals on a window-pane are better. Figure 20 shows one selected among several windows I had photographed in a preceding winter, which has some suggestions of the so-called crystalline spot-forms in it, but which lacks the filamentary thread-like components presently described. Of course the reader will understand that it is given as a suggestion of the appearance merely, and that no similarity of nature is meant to be indicated.

There were wonderful fern-like forms in this spot, too, and an appearance like that of pine-boughs covered with snow; for, strangely enough, the intense whiteness of the solar surface, in the best telescopes, constantly suggests cold. I have had the same impression vividly in looking at the immense masses of molten-white iron in a great puddling furnace. The salient feature here is one very difficult to see, even in good telescopes, but one which is of great interest. It has been shown in the previous drawings, but we have not enlarged on it. Everywhere in the spot are long white threads, or filaments, lying upon one another, tending in a general sense toward the center, and each of which grows brighter toward its inner extremity. These make up, in fact, as we now see, the penumbra, or outer shade, and the so-called "crystal" is really affiliated to them. Besides this, on closer looking we see that the inner shade, or umbra, and the very deepest shades, or nuclei, are really made of them, too. We can look into the dark center, as into a funnel, to the depth of probably over five thousand miles; but as far as we may go down we come to no liquid or solid floor, and see only volumes of whirling vapor, disposed not vaguely like our clouds, but in the singularly definite, fern-like, flower-like forms which

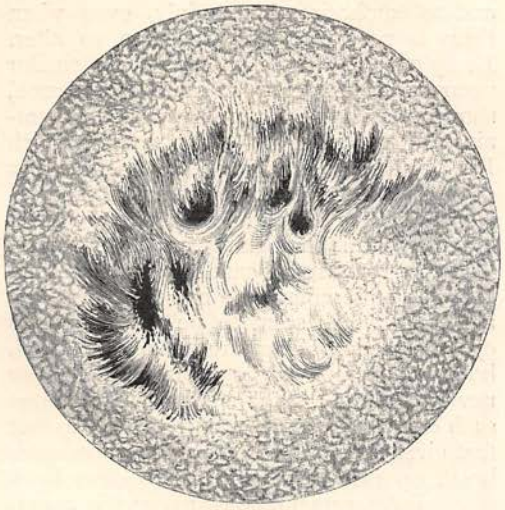

FIG. 22.—SPOT OF MARCH 31, 1875. (FROM AN ORIGINAL DRAWING BY S. P. LANGLEY.)

are themselves made of these "filaments," each of which is from three to five thousand miles long, and from fifty to two hundred miles thick, and each of which (as we saw in the first spot) appears to be made up like a rope, of still finer and finer strands, looking, in the rare instants when irradiation makes an isolated one visible, like a thread of gossamer, or the finest of cobweb. These suggest the fine threads of spun glass; and here there is something more than a mere resemblance of form, for both appear to have one causal feature in common, due to a viscous or "sticky" fluid; for there is much reason to believe that the solar atmosphere, even where thinner than our own air, is rendered viscous by the enormous heat, and owes to this its tendency to pull out in strings, in common with such otherwise dissimilar things, as honey, or melted sugar, or melted glass.

We may compare those mysterious things, the filaments, to long grasses growing in the bed of a stream, which show us the direction and the eddies of the current. The likeness holds in more ways than one. They are not lying, as it were, flat upon the surface of the water, but *within* the medium; and they do not stretch along in any one plane, but they bend down and up. Moreover, they are, as we see, apparently rooted at one end, and their tips rise above the turbid fluid and grow brighter as they are lifted out of it. But perhaps the most significant use of the comparison is made if we ask whether the stream is moving in an eddy like a whirlpool or boiling up from the ground. The question in other words is, "Are these spots themselves the sign of a mere chaotic disturbance, or do they show us by the disposition of these filaments that each is a great solar maelstrom, carrying the surface matter of the sun down in to its body? or, finally, are they just the opposite — something comparable to fiery fountains or volcanoes on the earth, throwing up to the surface the contents of the unknown solar interior?"

Before we try to answer this question, let us remember that the astonishing rapidity with which these forms change, and still more the fact that they do not, by any means always change by a bodily removal of one part from another, but by a dissolving away and a fading out into invisibility, like the melting of a cloud into thin air — let us remember that all this assimilates them to something cloud-like and vaporous, rather than crystalline, and that as we have here seen, we can ourselves pronounce from such results of recent observation that these are not lumps of scoriæ floating on the solar furnace (as some have thought them), and still less, literal crystals. We can see for ourselves, I believe, that so far there is no evidence here of any solid, or even liquid, but that the surface of the sun is purely vaporous. Figure 23 shows a cirrous cloud in our own atmosphere, caught for us by photography, and which the reader will find it interesting to compare with the apparently analogous solar cloud-forms.

"Vaporous," we call them, for want of a better word, but without meaning that it is like the vapor of our clouds. There is no exact terrestrial analogy for these extraordinary

FIG. 23.—CIRROUS CLOUD. (FROM A PHOTOGRAPH.)

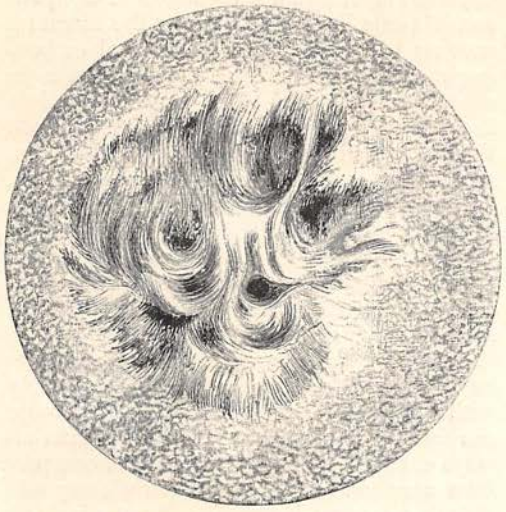

FIG. 24.—SPOT OF MARCH 31, 1875. (FROM AN ORIGINAL DRAWING BY S. P. LANGLEY.)

forms, which are in fact, as we shall see later, composed of iron and other metals—not of solid iron nor even of liquid, but iron heated beyond even the liquid state to that of iron-steam or vapor.

With all this in mind, let us return to the question, "Are the spots, these gigantic areas of disturbance, comparable to whirlpools or to volcanoes?" It may seem unphilosophical to assume that they are one or the other, and, in fact, they may possibly be neither; but it is certain that the surface of the sun would soon cool from its enormous temperature, if it were not supplied with fresh heat, and it is almost certain that this heat is drawn from the interior. As M. Faye has pointed out, there *must* be a circulation up and down, the cooled products being carried within, heated and brought out again, or the sun would, however hot, grow cold outside; and, what is of interest to us, the earth would grow cold also, and we should all die. No one, I believe, who has studied the subject, will contradict the statement, that, if the sun's surface were absolutely cut off from any heat supply from the interior, organic life in general upon the earth (and our own life in particular), would cease much within a month. This solar circulation, then, is of nearly as much consequence to us as that of our own bodies, if we but knew it; and now let us look at the spots again with this in mind.

Fig. 21 shows a drawing by Father Secchi of a spot in 1854; and it is, if unexaggerated, quite the most remarkable case of distinct cyclonic action recorded. I say "if unexaggerated" because there is a strong tendency in most designers to select what is striking in a spot, and to emphasize that unduly, even when there is no conscious disposition to alter. Every one who sketches, may see a similar unconscious tendency in himself or herself, shown in a disposition to draw all the mountains and hills too high,—a tendency on which Ruskin, I think, has remarked. In drawings of the sun there is a strong temptation to exaggerate these circular forms, and we must not forget this in making up the evidence. There is great need of caution, then, in receiving such representations; but there certainly are forms which seem to be clearly due to cyclonic action. They are usually scattered, however, through larger spots, and I have never, in all my study of the sun, seen one such complete type of the cyclone spot as that first given from Secchi. Instances where spots break up into numerous subdivisions by a process of "segmentation" under the apparent action of separate whirlwinds are much more common. I have noticed, as an apparent effect of this segmentation what I may call the "honeycomb structure" from its appearance with low powers, but which with higher ones turns out to be made up of filamentary masses disposed in circular and ovoid curves, often apparently overlying one another, and frequently presenting a most curious resemblance to vegetable forms, though we appear to see the real agency of whirlwinds in making them. I add some transcripts of my original pencil memoranda themselves, made with the eye at the telescope, which, though not at all finished drawings, may be trusted the more as being quite literal transcripts at first hand.

Figs. 22 and 24, for instance, are two sketches of a little spot, showing what, with low powers, gives the appearance I have called the honeycomb structure, but which we see here to be due to whirls which have disposed the filaments in these remarkable forms. The first was drawn at eleven in the forenoon of March 31, 1875, the second at three in the afternoon

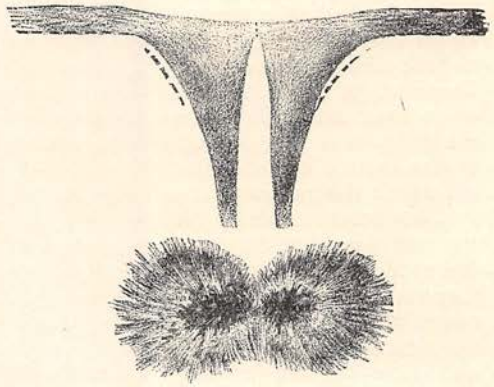

FIG. 25.—TYPICAL ILLUSTRATION OF FAYE'S THEORY.

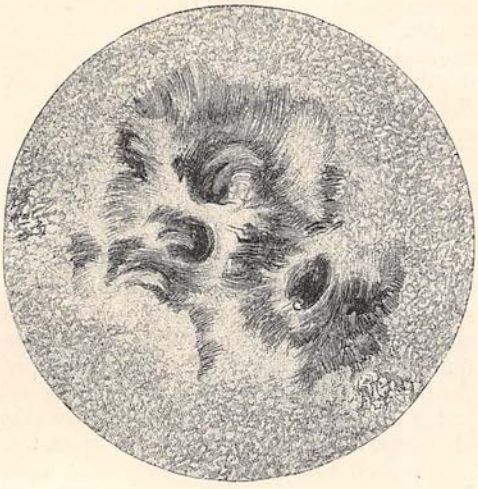

FIG. 26.— SPOT OF OCTOBER 13, 1876. (FROM ORIGINAL DRAWING BY S. P. LANGLEY.)

of the same day. The scale of the drawing is fifteen thousand miles to the inch, and the changes in this little spot in these few hours imply a cataclysm compared with which the disappearance of the American continent from the earth's surface would be a trifle.

The very act of the solar whirlwind's motion seemed to pass before my eyes in some of these sketches; for while drawing them as rapidly as possible, a new hole would be formed where there was none before, as if by a gigantic invisible auger boring downward.

M. Faye, the distinguished French astronomer, believes that, owing to the fact that different zones of the sun rotate faster than others, whirlwinds analogous to our terrestrial cyclones, but on a vaster scale, are set in motion, and suck down the cooled vapors of the solar surface into its interior, to be heated and returned again, thus establishing a circulation which keeps the surface from cooling down. He points out that we should not conclude that these whirlwinds are not acting everywhere, merely because our bird's-eye view does not always show them. We see that the spinning action of a whirlpool in water becomes more marked as we go below the surface, which is comparatively undisturbed, and we often see one whirl break up into several minor ones, but all sucking downward, and never upward. According to M. Faye, something very like this takes place on the sun, and in Fig. 25 he gives this section to show what he believes to occur in the case of a spot which has "segmented," or divided into two, like the one whose (imaginary) section is shown above it. This theory is to be considered in connection with such drawings as we have just shown, which are themselves, however, no way dependent on theory, but transcripts from nature.

I do not here either espouse or oppose the "cyclonic" theory, but it is hardly possible for any one who has been an eye-witness of such things to refuse to regard some such disturbance as a real and efficient cause in such instances as this.

Fig. 26, on nearly the same scale as the last, shows a spot which was seen on October 13, 1876. It looked at first, in the telescope, like two spots without any connection; then, as vision improved and higher powers were employed, the two were seen to have a subtle bond of union, and each to be filled with the most curious foliage-forms, which I could only indicate in the few moments that the good definition lasted. The reader may be sure, I think, that there is no exaggeration of the curious shapes of the original; for I have been so anxious to avoid the overstatement of curvature that the error is more likely to be in the opposite direction.

We must conclude that the question as to the cyclonic hypothesis cannot yet be decided, though the probabilities from telescopic evidence at present seem to me on the whole in favor of M. Faye's remarkable theory, which has the great additional attraction to the student that it unites and explains numerous other quite disconnected facts.

Turning now to the other solar features, let us once more consider the sun as a whole.

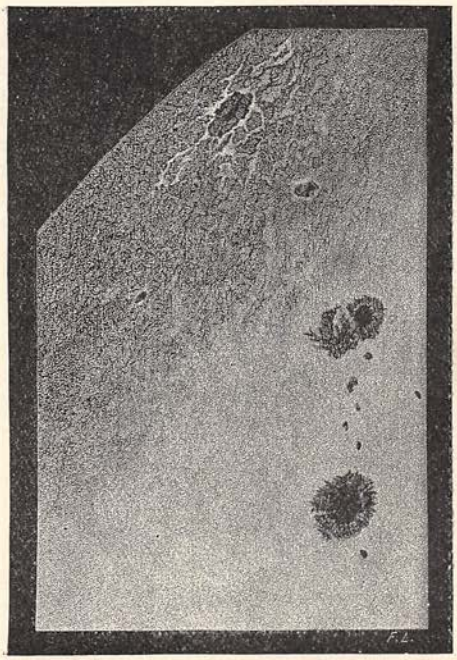

FIG. 27.— PHOTOGRAPH OF EDGE OF SUN. (BY PERMISSION OF WARREN DE LA RUE, LONDON.)

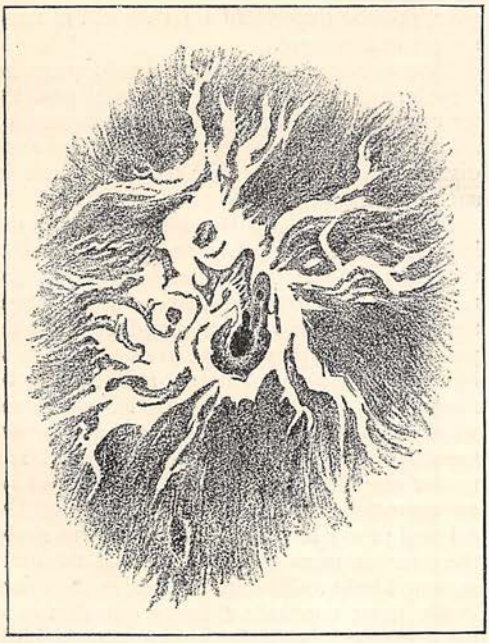

FIG. 28.—FACULA. (FROM A DRAWING BY CHACORNAC.)

Fig. 27 is a photograph taken from a part of the sun near its edge. We notice on it, what we see on every careful delineation of the sun, that its general surface is not uniformly bright, but that it grows darker as we approach the edge, where it is marked by whiter mottlings called faculæ, "something in the sun brighter than the sun itself," and looking in the enlarged view which we present of one of them (Fig. 28), as if the surface of partly cooled metal in a caldron had been broken into fissures showing the brighter glow beneath. These "faculæ," however, are really above the solar surface, not below it, and what we wish to direct particular attention to is that darkening toward the edge which makes them visible.

This is very significant, but its full meaning may not at first be clear. It is owing to an atmosphere which surrounds the sun, as the air does the earth. When we look horizontally through our own air, as at sunrise and sunset, we gaze through greater thicknesses of it than when we turn our eyes to the zenith. So when we look at the edge of the sun, the line of sight passes through greater depths of this solar atmosphere, and it dims the light shining behind it more than at the center, where it is thin.

This darkening toward the edge, then, means that the sun has an atmosphere which tempers its heat to us. Whatever the sun's heat supply is within its globe, if this atmosphere grow thicker, the heat is more confined within, and our earth will grow colder; if the solar atmosphere grow thinner, the sun's energy will be expended more rapidly and our earth will grow hotter. This atmosphere, then, is in considerable part, at least, the subject of the action of the spots; this is what they are supposed to carry down or to spout up.

We shall return to the study of it again; but what I want to point out now is that the temperature of the earth, and even the existence of man upon it, depends very much upon this, at first sight, insignificant phenomenon. What, then, is the solar atmosphere? Is it a permanent thing? Not at all. It is more light and unsubstantial than our own air, and is being whirled about by solar winds as ours toss the dust of the streets. It is being sucked down within the body of the sun by some action we do not clearly understand, and returned to the surface by some counter effect which we comprehend no better; and upon this imperfectly understood exchange depends in some way our own safety.

There used to be recorded in medical books the case of a boy, who, to represent Phœbus in a Roman masque, was gilded all over to produce the effect of the golden-rayed god, but who died in a few hours, because all the pores of the skin being closed by the gold-leaf, the natural circulation was arrested. We can count with the telescope millions of pores upon the sun's surface, which are in some way connected with the interchange which has just been spoken of; and if this, his own natural circulation, were arrested, or notably diminished, we should see his face grow cold, and know that our own health, with the life of all the human race, was waiting on his recovery.

S. P. Langley.

THE NEW ASTRONOMY. II.

THE SUN'S SURROUNDINGS.

As I WRITE this, the fields glitter with snow-crystals in the winter noon, and the eye is dazzled with a reflection of the splendor which the sun pours so fully into every nook that by it alone we appear to see everything.

Yet, as the day declines, and the red glow of our recent wonderful sunsets spreads up to the zenith, there comes out in it the white-shining evening star, which not the light, but the darkness, makes visible; and as the last ruddy twilight fades, not only this neighbor-world, whose light is fed from the sunken sun, but other stars appear, themselves self-shining suns, which were above us all through the day, unseen because of the very light.

As night draws on, we may see the occasional flash of a shooting-star, or perhaps the auroral streamers spreading over the heavens; and, remembering that these will fade as the sun rises, and that the nearer they are to it the more completely they will be blotted out, we infer that if the sun were surrounded by a halo of only similar brightness, this would remain forever invisible,—unless, indeed, there were some way of cutting off the light from the sun without obscuring its surroundings. But if we try the experiment of holding up a screen which just conceals the sun, nothing new is seen in its vicinity, for we are also lighted by the neighboring sky, which is so dazzlingly bright with reflected light as to effectually hide anything which may be behind it, so that to get rid of this glare we should need to hang up a screen *outside* the earth's atmosphere altogether.

Nature hangs such a screen in front of the earth when the moon passes between it and the sun; but as the moon is far too small to screen all the earth completely, and as so limited a portion of its surface is in complete shadow that the chances are much against any given individual's being on the single spot covered by it, many centuries usually elapse before such a *total* eclipse occurs at any given point; while yet almost every year there may be a partial eclipse, when, over a great portion of the earth at once, people may be able to look round the moon's edge and see the sunlight but partly cut off. Nearly every one, then, has seen a partial eclipse of the sun, but comparatively few a total one, which is quite another thing, and worth a journey round the world to behold; for such a nimbus, or glory, as we have suggested the possibility of, does actually exist about the sun, and becomes visible to the naked eye on the rare occasions when it is visible at all, accompanied by phenomena which are unique among celestial wonders.

The "corona," as this solar crown is called, is seen during a total eclipse to consist of a bright inner light next the invisible sun, which melts into a fainter and immensely extended radiance (the writer has followed the latter to the distance of about 10,000,000 miles), and all this inner corona is filled with curious detail. All this is to be distinguished from another remarkable feature seen at the same time; for close to the black body of the moon are prominences of a vivid crimson and scar-

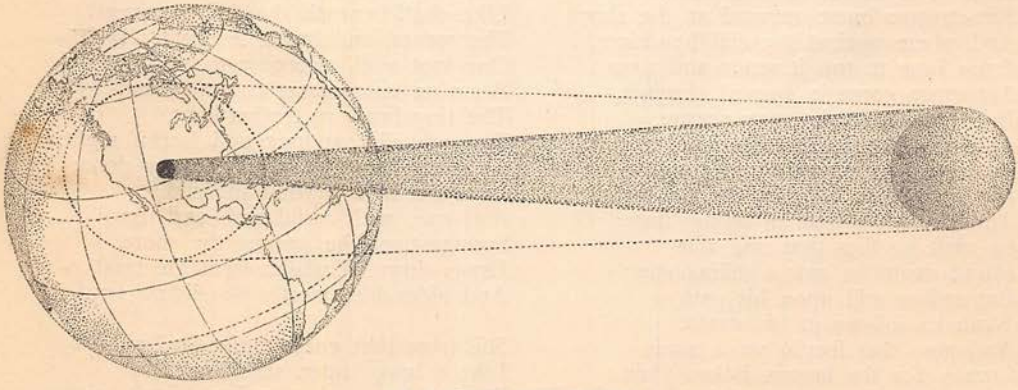

FIG. 1.—LUNAR CONE SHADOW.

let, rising up like mountains from the hidden solar disk, and these, which will be considered later, are quite distinct from the corona, though seen on the background of its pearly light.

To understand what the lunar screen is doing for us, we may imagine ourselves at some station outside the earth, whence we should behold the moon's shadow somewhat as in Figure 1, where we see that since the orbit is not a circle, but nearly an ellipse, the moon is at some times further from the earth than at others. Here it is shown at its nearest point, and the extremity of its shadow is represented as just touching the surface of the globe, while it is evident that if the moon were at its greatest distance its shadow might come to a point before reaching the earth at all. We speak, of course, only of the central cone of shade; for there is an outer one, indicated by the faint dotted lines, within whose much more extended limits the eclipse is partial, but with the latter we have at present nothing to do. The figure however, for want of room, is made to represent the proportions incorrectly, the real ones of the shadow being actually something like those of a sewing-needle,—this very long attenuated shadow sometimes, as we have just said, not reaching the earth at all, and when it does reach it, covering at the most a very small region indeed. Where this point touches, and wherever it rests, we should, in looking down from our celestial station, see that part of the earth in complete shadow, looking like a minute dark spot, whose lesser diameter is seldom over a hundred and fifty miles.

The eclipse is total only to those inhabitants of the earth within the track of this dark spot, though the spot itself travels across the earth with the speed of the moon in the sky; so that if it could leave a mark, it would in a few hours trace a dark line across the globe, looking like a narrow black tape stretched across the side of the world next the sun. In figure 2, for instance, is the central track of the eclipse of July 29, 1878, as it would be visible to our celestial observer, beginning in Alaska in the forenoon, and ending in the Gulf of Mexico, which it reached in the afternoon. To those on the earth's surface within this shadow it covered everything in view, and, for anything those involved in it could see, it was all-embracing and terrible, and worthily described in such lines as Milton's:

> "As when the sun . . .
> In dim eclipse, disastrous twilight sheds
> On half the nations, and with fear of change
> Perplexes monarchs."

We may enjoy the poet's vision, but here, while we look down on the whole earth at once, we must admit that the actual area of the "twilight" is very small indeed. Within

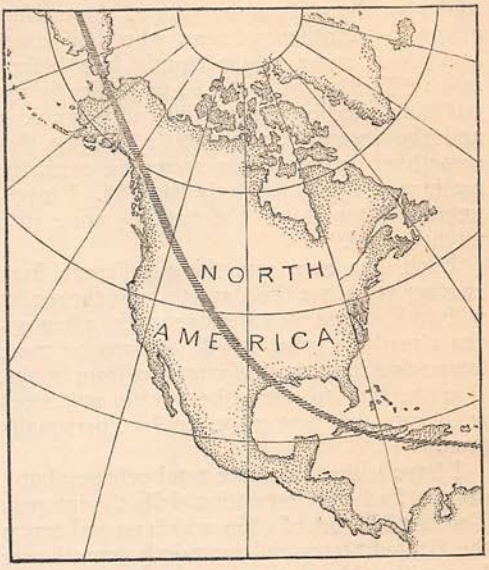

FIG. 2.—TRACK OF LUNAR SHADOW.

this area, however, the spectacle is one of which, though the man of science may prosaically state the facts, perhaps only the poet could render the impression.

We can faintly picture, perhaps, how it would seem, from a station near the lunar orbit, to see the moon—a moving world—rush by with a velocity greater than that of the cannon-ball in its swiftest flight; but with equal speed its shadow actually travels along the earth; and now, if we return from our imaginary station to a real one here below, we are better prepared to see why this flying shadow is such a unique spectacle; for, small as it may be when seen in relation to the whole globe, it is immense to the observer, whose entire horizon is filled with it, and who sees the actual velocity of one of the heavenly bodies, as it were, brought down to him.

The reader who has ever ascended to the Superga, at Turin, will recall the magnificent view, and be able to understand the good fortune of an observer (Forbes) who once had the opportunity to witness thence this phenomenon, and under a nearly cloudless sky. "I perceived," he says, "in the south-west a black shadow like that of a storm about to break, which obscured the Alps. It was the lunar shadow coming toward us." And he speaks of the "stupefaction"—it is his word—caused by the spectacle. "I confess," he continues, "it was the

most terrifying sight I ever saw. As always happens in the cases of sudden, silent, unexpected movements, the spectator confounds real and relative motion. I felt almost giddy for a moment, as though the massive building under me bowed on the side of the coming eclipse." Another witness, who had been looking at some bright clouds just before, says: "The bright cloud I saw distinctly put out like a candle. The rapidity of the shadow, and the intensity, produced a feeling that something material was sweeping over the earth at a speed perfectly frightful. I involuntarily listened for the rushing noise of a mighty wind."

Each one sees something different from another at such a time, and though the reader will find minute descriptions of the phenomena already in print, it will perhaps be more interesting if, instead of citations from books, I invite him to view them with me, since each can tell best what he has personally seen.

I have witnessed three total eclipses, but I do not find that repetition dulls the interest. The first was that of 1869, which passed across the United States and was nearly central over Louisville My station was on the southern border of the eclipse track, not very far from the Mammoth Cave in Kentucky, and I well remember that early experience. The special observations of precision in which I was engaged would not interest the reader, but while trying to give my undivided attention to these, a mental photograph of the whole spectacle seemed to be taking without my volition. First, the black body of the moon advanced slowly on the sun, as we have all seen it do in partial eclipses, without anything noticeable appearing, nor till the sun was very nearly covered did the light of day about us seem much diminished. But when the sun's face was reduced to a very narrow crescent, the change was sudden and startling, for the light which fell on us not only dwindled rapidly, but became of a kind unknown before, so that a pallid appearance overspread the face of the earth with an ugly livid hue; and as this strange wanness increased, a cold seemed to come with it. The impression was of something *unnatural*, but there was but a moment to note it, for the sun went out as suddenly as a blown-out gas-jet, and I became as suddenly aware that all around, where it had been, there had been growing into vision a kind of ghostly radiance, composed of separate pearly beams, looking distinct each from each, as though the black circle where the sun once was bristled with pale streamers, stretching far away from it in a sort of crown.

This was the mysterious corona, only seen during the brief moments while the shadow is flying overhead; but as I am undertaking to recall faithfully the impressions of the instant, I may admit that I was at the time equally struck with a circumstance that may appear trivial in description—the extraordinary globular appearance of the moon herself. We all know well enough that the moon is a solid sphere, but it commonly *looks* like a bright, flat circle fastened to the concave of the starry vault; and now, owing to its unwonted illumination, the actual rotundity was seen for the first time, and the result was to show it as what it really is—a monstrous, solid globe, suspended by some invisible support above the earth, with nothing apparent to keep it from tumbling on us, looking at the moment very near, and more than anything else like a gigantic black cannon-ball, hung by some miracle in the air, above the neighboring corn-field. But in a few seconds all was over; the sunlight flashed from one point of the moon's edge and then another, almost simultaneously, like suddenly kindled electric lights, which as instantly flowed into one, and it was day again.

I have spoken of the "unnatural" appearance of the light just before totality. This is not due to excited fancy, for there is something so essentially different from the natural darkness of twilight, that the brute creation shares the feeling with us. Arago, for instance, mentions that in the eclipse of 1842, at Perpignan, where he was stationed, a dog which had been kept from food twenty-four hours was, to test this, thrown some bread just before "totality" began. The dog seized the loaf, began to devour it ravenously, and then, as the appearance already described came on, he dropped it. The darkness lasted some minutes, but not till the sun came forth again did the poor creature return to the food. It is no wonder, then, that men, also, whether educated or ignorant, do not escape the impression. A party of the courtiers of Louis XV. is said to have gathered round Cassini to witness an eclipse from the terrace of the Paris observatory, and to have been laughing at the populace, whose cries were heard as the light began to fade, when, as the unnatural gloom came quickly on, a sudden silence fell on them too, the panic terror striking through their laughter. Something common to man and the brute speaks at such times, if never before or again; something which is not altogether physical apprehension, but more like the moral dismay when the shock of an earthquake is felt for the first time, and we first know that startling doubt, superior to reason, whether the solid frame of earth is real, and not "baseless as the fabric of a vision."

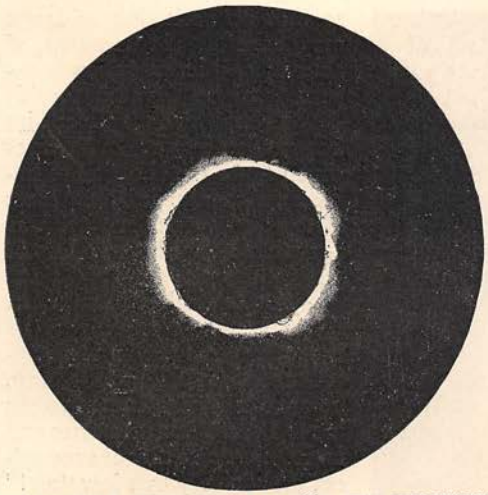

FIG. 3.—INNER CORONA ECLIPSE OF 1869. FROM SHELBYVILLE PHOTOGRAPH. (ROYAL ASTRONOMICAL SOCIETY'S MEMOIRS.)

But this is appealing for illustration to an experience which most readers have doubtless been spared,* and I would rather cite the lighter one of our central party that day, a few miles north of me, at Shelbyville. In this part of Kentucky the colored population was large, and (in those days) ignorant of everything outside the life of the plantation, from which they had only lately been emancipated. On that eventful 8th of August they came in great numbers to view the inclosure and the tents of the observing party, and to inquire the price of the show. On learning that they might see it without charge from the outside, a most unfavorable opinion was created among them as to the probable merits of so cheap a spectacle, and they crowded the trees about the camp, shouting to each other sarcastic comments on the inferior interest of the entertainment. "Those trees there," said one of the observers to me the next day, "were black with them, and they kept up their noise till near the last, when they suddenly stopped, and all at once, and as 'totality' came, we heard a wail and a noise of tumbling, as though the trees had been shaken, and then the boldest did not feel safe till he was under his own bed in his own cabin."

It is impossible to give an exact view of what our friends at Shelbyville saw, for no drawings made there appear to have been preserved, and photography at that time could only indicate feebly the portion of the corona near the sun where it is brightest. Figure 3 is a fac-simile of one of the photographs taken on the occasion, which is interesting perhaps as one of the early attempts in this direction, for comparison with later ones; but as a picture it is very disappointing, for the whole structure of the outer corona we have alluded to, is missed altogether, the plate having taken no impression of it.

A drawing (Fig. 4) made by another observer, Mr. M'Leod, at Springfield, represents more of the outer structure; but the reader must remember that all drawings must, in the nature of the case (since there are but two or three minutes to sketch in), be incomplete, whatever the artist's skill.

Up to this time it was still doubtful, not only what the corona was, but where it was; whether it was a something about the sun or moon, or whether, indeed, it might not be in our own atmosphere. The spectroscopic observations of Professors Young and Harkness at this same eclipse of a green line in its spectrum, due to some glowing gas, showed conclusively that it was largely, at any rate, a solar appendage, and partly, at least, self-luminous; and these and other results having awakened general discussion among astronomers in Europe as well as at home, the United States Government sent an expedition, under the direction of the late Professor Pierce, to observe an eclipse which,

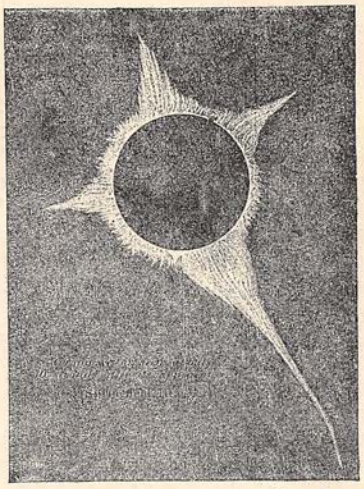

FIG. 4.—SKETCH OF OUTER CORONA, 1869. (U. S. COAST SURVEY REPORT.)

in the next year, on December 8, 1870, was total in the south of Spain. There were three parties, and of the most western of these, which was at Xeres under the charge of Professor Winlock, I was a member.

The duration of totality was known beforehand. It would last two minutes and ten

* Since this was written, the earthquake of August 10, which was felt in the Middle States and New England, has enlarged the circle of readers who will appreciate the force of the illustration.—[EDITOR.]

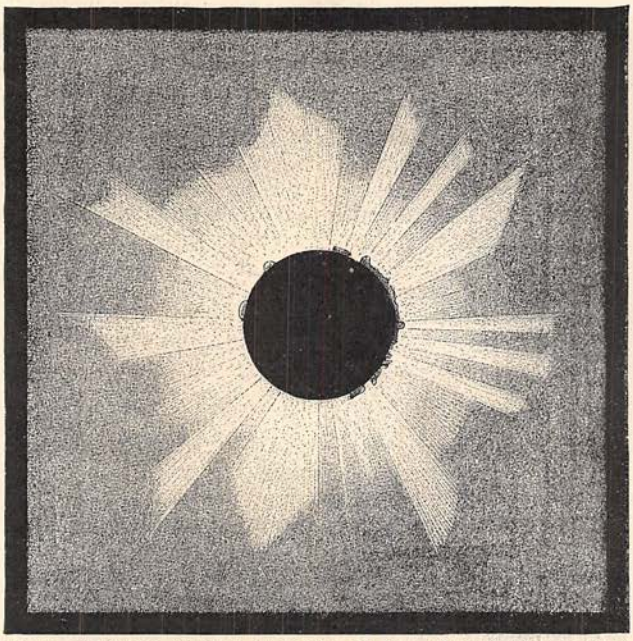

FIG. 5.—TACCHINI'S DRAWING OF CORONA OF 1870. (SECCHI'S "LE SOLEIL.")

seconds, and to secure what could be seen in this brief interval we crossed the ocean. Our station was in the midst of the sherry district, and a part of the instruments were in an orange-grove, where the ground was covered with the ripe fallen fruit, while the olive and vine about us in December, reminded us of the distance we had come to gather the results of so brief an opportunity.

To prepare for it, we had all arrived on the ground some weeks beforehand, and had been assiduously busy in installing the apparatus in the observing camp, which suggested that of a small army, the numerous instruments, some of them of considerable size, equatorials, photographic apparatus, polariscopes, photometers, and spectroscopes, being under tents, the fronts of which could be lifted when the time came for action.

To the equatorial telescopes, photographic cameras are attached instead of the eye-pieces, in the hope that the corona may be made to impress itself on the plate instead of on the eye. The eye is an admirable instrument itself, no doubt, but behind it is a brain, perhaps overwrought with excitement, and responding too completely to the nervous tension which most of us experience when those critical moments are passing so rapidly. The camera can see far less of the corona than the man, *but it has no nerves*, and what it sets down we may rely on.

At such a time each observer has some particular task assigned to him, on which, if wise, he has drilled himself for weeks beforehand, so that no hesitation or doubt may arise in the moment of action; and his attention is expected to be devoted to this duty alone, which may keep him from noting any of the features which make the occasion so impressive as a spectacle Most of my own particular work was again of a kind which would not interest the reader.

Apart from this, I can recall little but the sort of pain of expectation, as the moment approached, till within a minute before totality the hum of voices around ceased, and an utter and most impressive silence succeeded, broken only by a low "ah!" from the group without the camp, when the moment came. I remember that the clouds, which had hung over the sun while the moon was first advancing on its body, cleared away before the instant of totality, so that the last thing I saw was a range of mountains to the eastward still bright in the light; then, the next moment, the shadow rushed overhead and blotted out the distant hills, almost before I could turn my head to the instrument before me.

The corona appeared to me a different thing from what it did the year before. It was apparently confined to a pearly light of a roughly quadrangular shape, close to the limb of the sun, broken by dark rifts (one of which was a conspicuous object), while within, and close to the limb, was what looked like a mountain rising from the hidden sun, of the color of the richest tint we should see in a rose-leaf held up against the light, while others were visible of an orange-scarlet. After a short scrutiny I turned to my task of analyzing the nature of the white light.

The seconds fled, the light broke out again, and so did the hubbub of voices,—it was all over, and what had been missed then could not be recovered. The

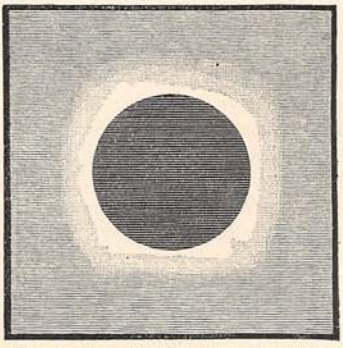

FIG. 6.—WATSON'S NAKED-EYE DRAWING OF CORONA OF 1870. (U. S. COAST SURVEY REPORT.)

FIG. 7.— PHOTOGRAPH SHOWING COMMENCEMENT OF OUTER CORONA. (ROYAL ASTRONOMICAL SOCIETY'S MEMOIRS.)

sense of self-reproach for wasted opportunity is a common enough feeling at this time, though one may have done his best, so little it seems to each he has accomplished; but when all the results had been brought together, we found that the spectroscopes, cameras, and polariscopes had each done their work, and the journey had not been taken in vain. In one point only we all differed, and this was about the direct ocular evidence, for each seemed to have seen a different corona, and the drawings of it were singularly unlike. Here are two (Figs. 5 and 6) taken at this eclipse at the same time, and from neighboring stations, by two most experienced astronomers, Tacchini and Watson. No one could guess that they represented the same object, and a similar discrepancy was common.

Considering that these were trained experts, whose special task it was, in this case, to draw the corona, which therefore claimed their undivided attention, I hardly know a more striking instance of the fallibility of human testimony. The evidence of several observers, however, pointed to the fact that the light really was more nearly confined to the part next the sun than the year before, so that the corona had probably changed during that interval, and grown smaller, which was remarkable enough. The evidence of the polariscope, on the whole, showed it to be partly due to reflected sunlight, while the spectroscope in the hands of Professor Young confirmed the last year's observation, that it was also, and largely, self-luminous. Finally, the photographs, taken at very distant stations, showed the same dark rifts in the same place, and thus brought confirmatory evidence that it was not a local phenomenon in our own atmosphere. A photograph of it, taken by Mr. Brothers in Sicily, is the subject of the annexed illustration (Fig. 7), in which the very bright lights which, owing to "photographic irradiation," seem to indent the moon are chiefly due to the colored flames I have spoken of, which will be described later.

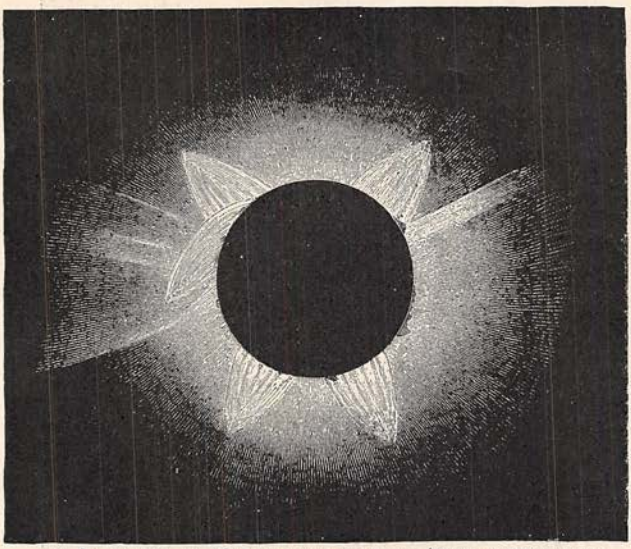

FIG. 8.—ECLIPSE OF 1857, DRAWING BY LIAIS. (ROYAL ASTRONOMICAL SOCIETY'S MEMOIRS.)

It may be observed that the photographs taken in the next year (1871) were still more successful, and began to show still more of the structure, whose curious forms, resembling large petals, had already been figured by Liais. His drawing (Fig. 8), made in 1857, was supposed to be rather a fanciful sketch than a trustworthy one; but, as it will be seen, the photograph goes far to justify it.

Figures 9 and 10 are copies published by Mr. Ranyard of the excellent photographs obtained in 1871, which are perhaps as good as anything done since, though even these do not show the outer corona. The first is an enlargement of a small portion of the detail in the second. It is scarcely possible for wood-engraving to reproduce the delicate texture of the original.

The years brought round the eclipse of 1878, which was again in United States territory, the central track (as Figure 2 has already shown) running directly over one of the loftiest mountains of the country, Pike's Peak, in Colorado. Pike's Peak, though over 14,000 feet high, is often ascended by pleasure tourists; but it is one thing to stay there for an hour or two, and another to take up one's abode there and get acclimated; for to do the latter we must first pass through the horrors (not too strong a word) of mountain-sickness. This reaches its height usually on the second or third day, and is something like violent sea-sickness, complicated with the sensations a creature may be supposed to have under the bell of an air-pump. After a week the strong begin to get over it, but none but the very robust should take its chances, as we did, without preparation; for on the night before the eclipse the life of one of our little party was pronounced in danger, and he was carried down in a litter to a cabin at an altitude of about 10,000 feet, where he recovered so speedily as to be able to do good service on the following day. The summit of the "Peak" is covered with great angular bowlders of splintered granite, among which we laid logs brought up for fire-wood, and on these, sacks of damp hay, then stretching a little tent over all and tying it down with wire to the rocks, we were fain to turn in under damp blankets, and to lie awake with incessant headache, drawing long, struggling breaths in the vain attempt to get air, and wondering how long the tent would last, as the canvas flapped and roared with a noise like that of a loose sail in a gale at sea, with occasional intervals of a dead silence, usually followed by a gust that shoved against the tent with the push of a solid body, and if a sleeper's shoulders touched the canvas, shouldered him over in his bed. The stout canvas held, but the snow entered with the wind, and lay in a deep drift on the pillow when I woke after a brief sleep toward morning, and, looking out on the gray dawn, found that the snow had turned to hail, which was rattling sharply on the rocks with an accompaniment of thunder, which seemed to roll from all parts of the horizon. The snow lay thick, and the sheets

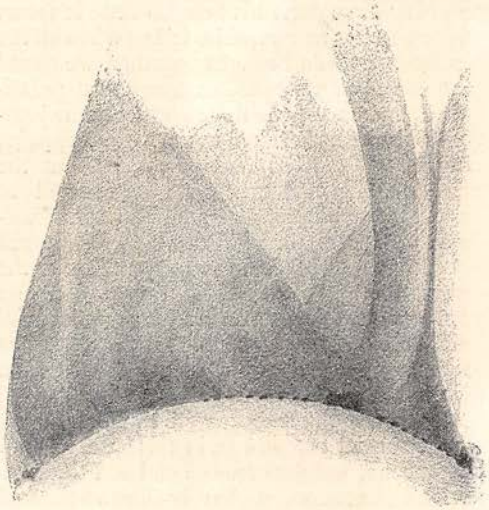

FIG. 9.—ENLARGEMENT OF PART OF FIG. 10.

of hail were like a wall, shutting out the sight of everything a few rods off, and this was in July! I thought of my December station in sunny Andalusia.

Hail, rain, sleet, snow, fog, and every form of bad weather continued for a week on the summit, while it was almost always clear below. It was often a remarkable sight to go to the edge and look down. The expanse of "the plains," which stretched eastward to a horizon line over a hundred miles distant, would be in bright sunshine beneath, while the hail was all around and above us; and the light coming *up* instead of down gave singular effects when the clouds parted below, the plains seeming at such times to be opalescent with luminous yellow and green, as though the lower world was translucent, and the sun was beneath it and shining up through. On page 930 is a picture of three of us on the mountain-top, who saw a rarer spectacle, for directly opposite the setting sun, and on the mist over the gulf beyond us, was a bright ring, in whose center were three phantom images of our three selves, which moved as we moved, and then faded as the sun sank. It was "the specter of the Brocken." These ghostly presentments were tolerably defined, as in the sketch, but did not seem to be gigantic, as some have described them. We rather thought them close at hand, but before we could determine, the vision faded.

The clouds, to our good fortune, rolled away on the 29th, and a number of pleasure-seekers, who came up to view the eclipse and the unwonted bright sunshine, made a scene which it was hard to identify with the usual one. This time my business was to draw the corona, and the extreme altitude and the clearness of the air, with perhaps some greater extension than usual in the object itself, enabled it to be followed to an unprecedented distance. During totality the sun was surrounded by a narrow ring,—hardly more than a line of vivid light,—presenting no structure to the naked eye (but a remarkable one in the telescope), and this faded with great suddenness into a circular nebulous luminosity between two and three diameters of the sun wide, but without such marked plumes, or filaments, as I had seen in 1869. The most extraordinary thing, however, was a beam of light, inclined at an angle of about forty-five degrees, about as wide as the sun, and extending to the distance of nearly six of its diameters on one side and over twelve on the other; on one side alone, that is, to the amazing distance of over ten million miles

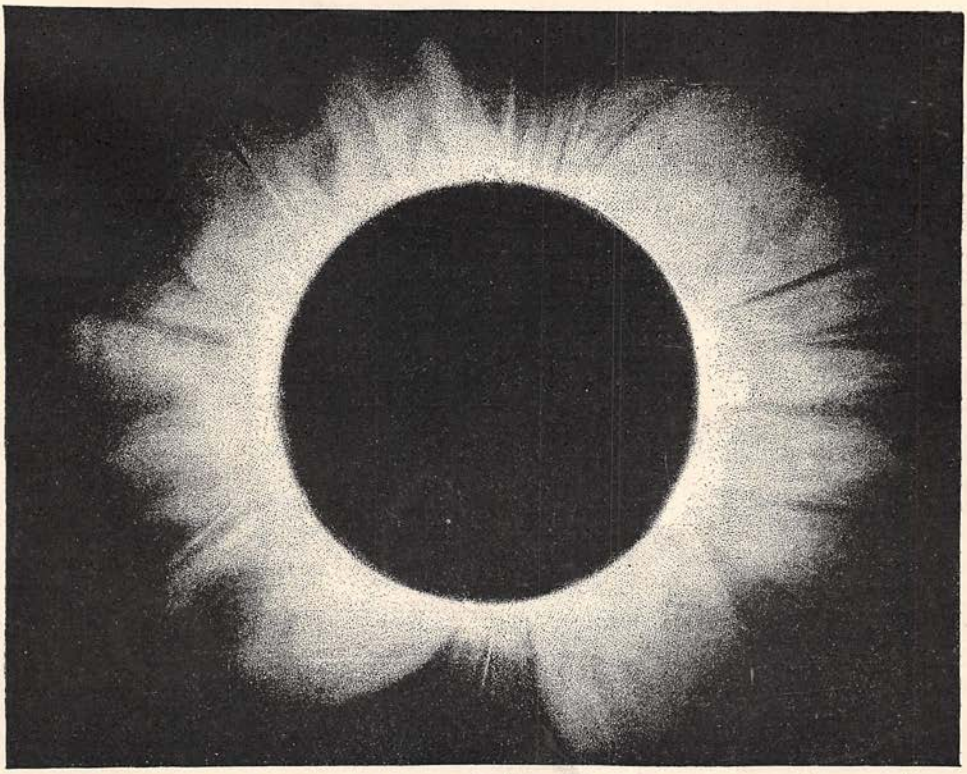

FIG. 10.—FAC-SIMILE OF PHOTOGRAPH OF CORONA OF 1871. (ROYAL ASTRONOMICAL SOCIETY'S MEMOIRS.)

FIG. 11.—"SPECTERS."

from its body. Substantially the same observation was made, as it appeared later, by Professor Newcomb, at a lower level. The direction, when more carefully measured, it was interesting to note, coincided closely with that of the Zodiacal light, and a faint central rib added to its resemblance to that body. It is noteworthy, in illustration of what has already been said as to the conflict of ocular testimony, that, though I, with the great majority of observers below, saw only this beam, two witnesses whose evidence is unimpeachable, Professors Young and Abbe, saw a pale beam at right angles to it; and that one observer did not see the beam in question at all. Figure 12 is a sketch made from my own, but necessarily on a scale which can show only its general features.

With the telescope, the whole of the bright inner light close to the sun was found to be made up of filaments, more definite even than those described in a previous chapter as seen in sun-spots, and bristling in all directions from the edge; not concealing each other, as we might expect such things to do, upon a sphere, but fringing the sun's edge in definite outline, as though it were really but a disk.

Those who were at leisure to watch the coming shadow of the moon described its curved outline as distinctly visible on the plains. "A rounded ball of darkness with an orange-yellow border," one called it. Those, again, who looked down on the bright clouds below say the shadow was preceded by a yellow fringe, casting a bright light over the clouds and passing into orange, pink, rose-red, and dark-red, in about twenty seconds. This beautiful effect was noticed by nearly all the amateur observers present, who had their attention at liberty, and was generally unseen by the professional ones, who were shut up in dark tents with photometers, or engaged otherwise than in admiring the glory of the spectacle as a spectacle merely. This strange light, forming a band of color about the shadow as seen from above, must have really covered ten miles or more in width, and have occupied a considerable fraction of a minute in passing over the heads of those below, to whom it probably constituted that lurid light

on their landscape I have spoken of as so peculiar and "unnatural." It seems to be due to the colored flames round the sun, which shine out when its brighter light is extinguished. I should add that on the summit of Pike's Peak the corona did not entirely disappear at the instant the sun broke forth again, but that its outlying portions first went and then its brighter and inner ones, till our eager gaze, trying to follow it as long as possible, only after the lapse of some minutes time have secured, in all, something like three-quarters of an hour for observation. Accordingly, what we know best about the corona is how it looks, what it is, being still largely conjecture; and it is for this reason that I have thought the space devoted to it would be best used by giving the unscientific reader some idea of the visible phenomena as they present themselves to an eye-witness. Treatises like Lockyer's "Solar Physics," Proctor's "The Sun," Secchi's "Le Soleil," and Young's

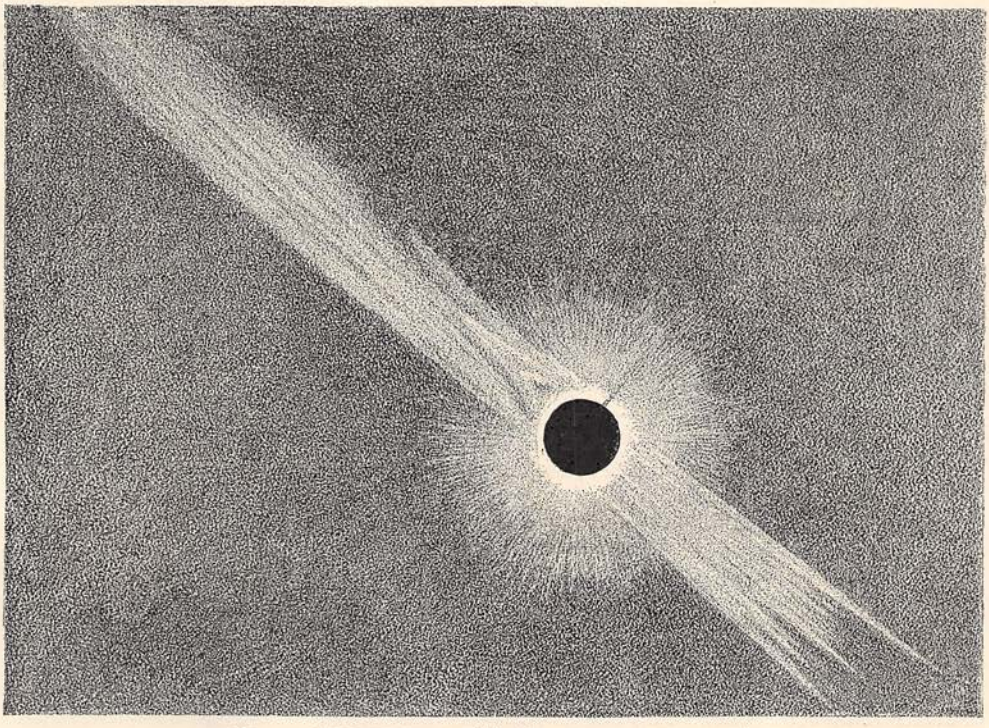

FIG. 12.—OUTER CORONA OF 1878. (U. S. NAVAL OBSERVATORY.)

saw the last of the wonderful thing disappear and "fade into the light of common day."

There have been other eclipses since, the last being that visible in Oceanica in 1883, to observe which the United States Government sent an expedition to the Caroline Islands, under the charge of Professor Holden; but, in spite of all, our knowledge of the corona remains very incomplete, and if the most learned in such matters were asked what it was, he could probably answer truthfully, "I don't know."

This will not be wondered at when it is considered that as total eclipses come about every other year, and continue, one with another, hardly three minutes, an astronomer who should devote thirty years exclusively to the subject, never missing an eclipse in whatever quarter of the globe it occurred, would in that "The Sun" (the latter is most recent), will give the reader who desires to learn more of the little that is known, the fuller information which this is not the place for; but it may be said very briefly that it is certain that the corona is at times of enormous extent (the whole length of the longer beam seen on Pike's Peak must have been over fourteen million miles), that it almost certainly changes in its shape and dimensions from year to year (possibly much oftener, but this we cannot yet know), and that it shines partly by its own and partly by reflected light. When we come to ask whether it is a gas or not, the evidence is conflicting. The appearance of the green coronal line, and other testimony we have not alluded to, would make it seem almost certain that there must be a gas here of extreme tenuity, reaching the height of

some hundred thousand miles, at the least; while yet the fact that such light bodies as comets have been known to pass through it, close to the sun, without suffering any visible retardation, such as would come even from a gas far lighter than hydrogen, appears to throw doubt on evidence otherwise strong. It is possible to conceive of the corona, and especially of the outer portion, as very largely made up of minute particles such as form the scattered dust of meteoric trains, and this seems to be the most probable constitution of its outlying parts. It is even possible to conceive that it is in some degree a subjective phenomenon caused, as Professor Hastings has suggested, by diffraction upon the edge of the moon — the moon, that is, not merely serving as a screen to the sun to reveal the corona, but partly *making* the corona by diffracting the light, somewhat as we see the edge of any very distant object screening the sun gilded by its beams. This effect may be seen when the sun rises or sets unusually clear, for objects on the horizon partly hiding it are then fringed for a moment with a line of light; an appearance which has not escaped Shakspere, where he says:

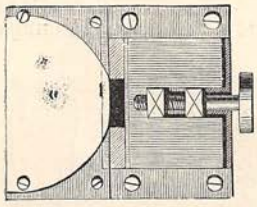

FIG. 13.—SPECTROSCOPE SLIT AND SOLAR IMAGE. (FROM "THE SUN," BY YOUNG.)

> "But when from under this terrestrial ball
> He fires the tall tops of the eastern pines."

Still, in admitting the possibility of some such contributory effect on the part of the moon, we must not, of course, be understood as meaning that the corona as a whole does not have a real existence, quite independent of the changes which the presence of the moon may bring; and in leaving the wonderful thing we must remember that it is, after all, a reality, and not a phantasm.

I have already described how, at the eclipse of 1870, I (with others) saw within the corona what seemed like rose and scarlet colored mountains rising from the sun's edge, an appearance which had first been particularly studied in the eclipse of 1868, two years before, and which, it might be added, Messrs. Lockyer and Janssen had succeeded in observing without an eclipse by the spectroscope. Besides the corona, it may be said, then, that the sun is surrounded by a thin envelope, rising here and there into prominences of a rose and scarlet color, invisible in the telescope, except at a total eclipse, but always visible through the spectroscope. It is within and quite distinct from the corona, and is usually called the "chromosphere," being a sort of sphere of colored fire surrounding the sun, but which we can usually see only on the edge. "The appearance," says Young, "is as if countless jets of heated gas were issuing through vents and spiracles over the whole surface, thus clothing it with flame, which heaves and tosses like the blaze of a conflagration." Out of this, then, somewhat like greater waves or larger swellings of the colored fires, rise the prominences, whose place, close to the sun's edge, has been indicated in many of the drawings and photographs just given of the corona, on whose background they are seen during eclipses; but as they can be studied at our leisure with the spectroscope, we have reserved a more particular description of them till now. They are at all times directly before us, as well as the corona; but, while both are yet invisible from the overpowering brightness of the sunlight reflected from the earth's atmosphere in front of them, these red flames are so far brighter than the coronal background, that if we could only weaken this "glare" a little, they, at least, might become visible, even if the corona were not. The difficulty is evidently to find some contrivance which will weaken the "glare" without enfeebling the prominences too; and this the spectroscope does by diffusing the white sunlight, while it lets the color pass nearly

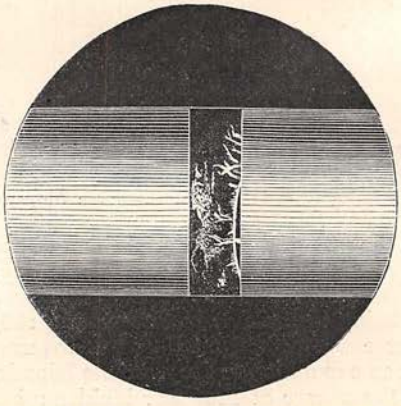

FIG. 14.—SLIT AND PROMINENCES. ("THE SUN," BY YOUNG.)

unimpaired. For the full understanding of its action the reader must be referred to such works as those on the sun already mentioned; but a general idea of it may be gathered, if we reflect that white light is composed of every possible variety of colors, and that the spectroscope, which consists essentially of a prism behind a very narrow slit through which the light enters, lets any single color pass freely, without weakening it or al-

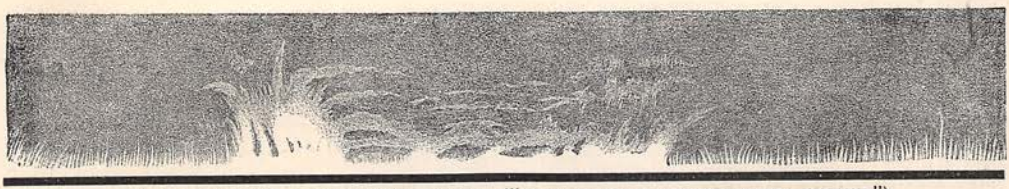

FIG. 15.—TACCHINI'S CHROMOSPHERIC CLOUDS. ("MEMORIE DEGLI SPETTROSCOPISTI ITALIANI.")

tering it in anything but its direction, but gives a different direction to each, and hence sorts out the tints, distributing them side by side, every one in its own place, upon the long colored band called the spectrum. If this distribution has spread the colors along a space a thousand times as wide as the original beam, the average light must be just so much weaker than the white light was, because this originally consisted of a thousand (let us say a thousand, but it is really an infinite number) mingled tints of blue, green, yellow, orange, and red, which have now been thus distributed. If, however, we look through the prism at a rose-leaf, and it has no blue, green, yellow or orange in it, and nothing but pure red, as each single color passes unchanged, this red will, according to what has been said, be as bright after it has passed as before. All depends, then, on the fact that these prominences do consist mainly of light of one color, like the rose-leaf, so that this monochromatic light will be seen through the spectroscope just as it is, while the luminous veil of glaring white before it will seem to be brushed away.

If a large telescope is directed toward the sun, the glass at the further end will, if the eye-piece be removed, form a little picture of the sun, as a picture is formed in a camera-obscura; and now, if the spectroscope be fastened to this eye-end, where the observer's head would be were he looking through, the edge of the solar image may be made to fall just *off* the slit, so that only the light from the prominences (and the white glare about them) shall pass in. To see this more clearly, let us turn our backs to the sun and the telescope and look at the place where the image falls by the spectroscope slit, which in Fig. 13 is drawn of its full size. This is a brass plate, having a minute rectangular window, the "slit," in it. The width of this slit is regulated by a screw, and any rays falling into the narrow aperture pass through the prism within, and finally fall on the observer's eye, but not till they have been sorted by the prism in the manner described. Formed on the brass plate, just as it would be formed on a sheet of paper, or anything else held in the focus, we see the bright solar image, a circle of light perhaps an inch and a half in diameter—a miniature of the sun with its spots. The whole of the sun (the photosphere) then is hidden to an observer who is looking up through the slit from the other side, for, as the sun's edge does not quite touch the slit, none of its rays can enter it; but if there be also the image here of a prominence, projecting beyond the edge, and really overhanging the slit (though to us invisible on account of the glare about it), these rays will fall into the slit and pass down to the prism, which will dispose of it in the way already stated.

And now let us get to the other side, and, looking up through the prism with the aid of a magnifying-glass, see what it has done for us (Fig. 14). The large rectangular opening here is the same as the small one which was visible from the outside, only that it is now magnified, and what was before invisible is seen; the edge of the sun itself is just hidden, but the scarlet flames of the chromosphere have become visible, with a cloudy promi-

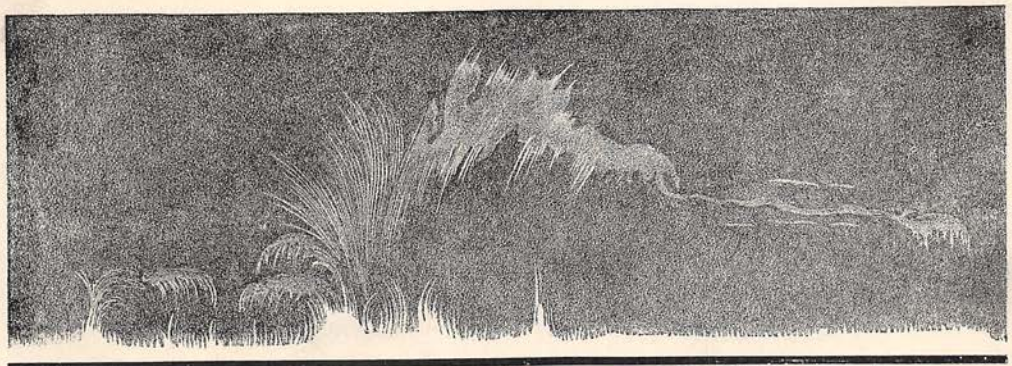

FIG. 16.—TACCHINI'S CHROMOSPHERIC CLOUDS. ("MEMORIE DEGLI SPETTROSCOPISTI ITALIANI.")

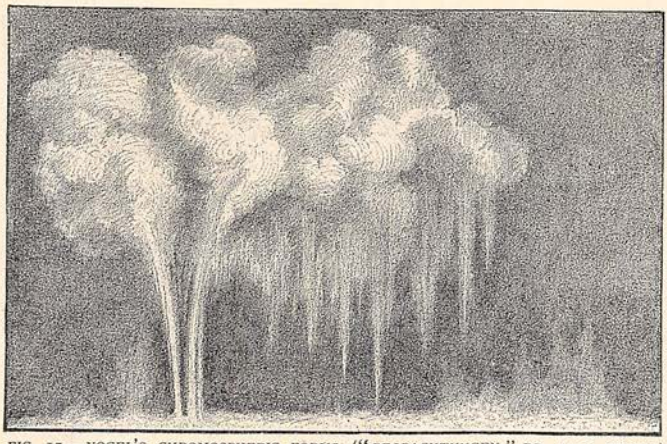

FIG. 17.—VOGEL'S CHROMOSPHERIC FORMS. ("BEOBACHTUNGEN," DR. H. C. VOGEL.)

nence rising above them. The "flames" are flame-like only in form, for their light is probably due not to any combustion, but to the glow of intensely heated matter, and as its light is not quite pure red, we can, by going to another part of the spectrum, see the same thing repeated in orange, the effect being as though we had a number of long narrow windows, some glazed with red, some with orange, and other colors, through which we could look out at the same clouds. I have looked at these prominences often in this way, but I prefer, in the reader's interest, to borrow from the description by Professor Young, who has made these most interesting and wonderful forms a special study.

Let us premise that the depth of the crimson shell out of which they rise is usually less than five thousand miles, and that though the prominences vary greatly, the majority reach a height of nearly twenty thousand miles, while in exceptional cases this is immensely exceeded. Professor Young has seen one which grew to a height of three hundred and fifty thousand miles in an hour and a half, and in half an hour more had faded away.

These forms fall into two main classes: that of the quiet and cloud-like, and that of the eruptive, the first being almost exactly in form like the clouds of our own sky, sometimes appearing to lie on the limb of the sun like a bank of clouds on the horizon, sometimes floating entirely free; while sometimes "the whole under surface is fringed with down-hanging filaments, which remind one of a summer shower hanging from a heavy thunder-cloud."

Here are some of the typical forms of the quieter ones:

Fig. 15, by Tacchini, the Director of the Roman Observatory, represents an ordinary prominence or cloud-group in the chromosphere whose height is about twenty-five thousand miles. The little spires of flame which rise, thick as grass-blades, everywhere from the surface are seen on its right and left.

Fig. 16 (Tacchini) is one where the agitation is greater and the "filamentary" type is more marked. Besides the curiously thread-

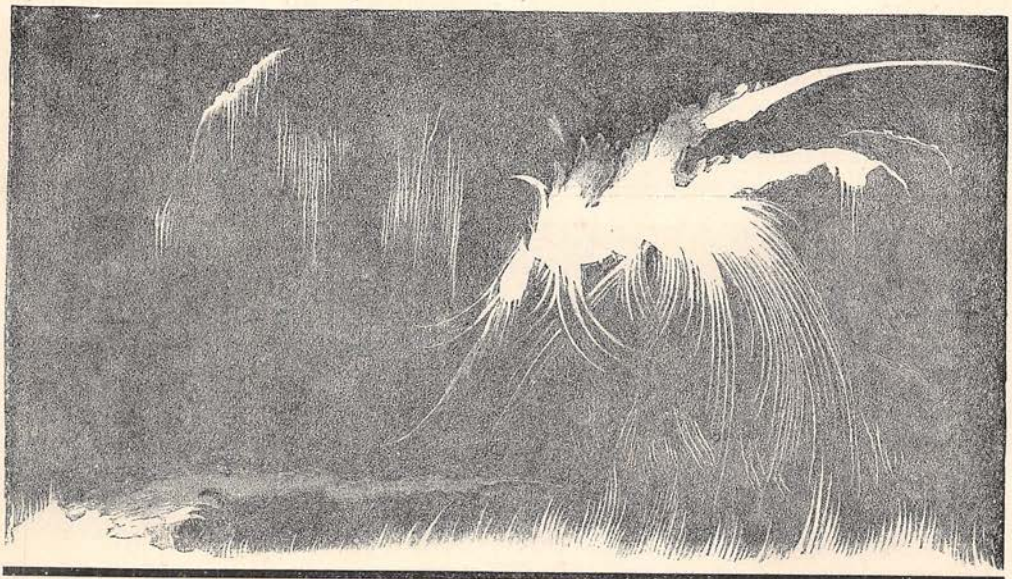

FIG. 18.—TACCHINI'S CHROMOSPHERIC FORMS. ("MEMORIE DEGLI SPETTROSCOPISTI ITALIANI.")

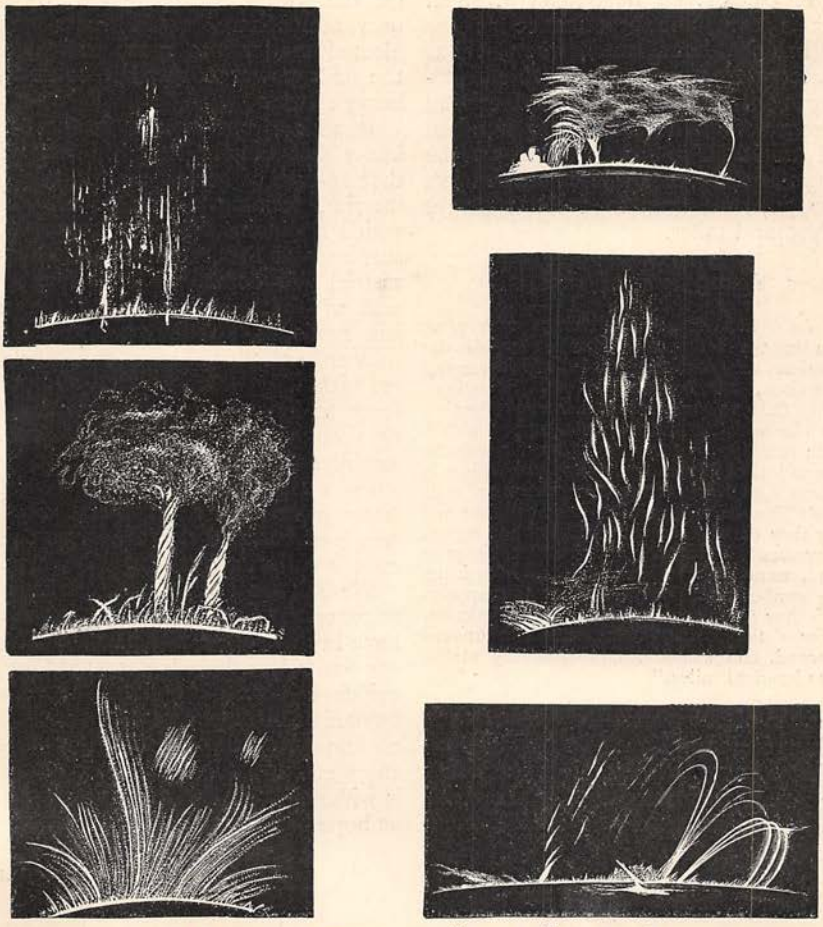

FIG. 19.— ERUPTIVE PROMINENCES. ("THE SUN," BY YOUNG.)

like forms (so suggestive of what we have already seen in the photosphere, we have here what looks like an extended cloudy mass, drawn out by a horizontally moving wind.

Fig. 17 (by Vogel, at Bothkamp) represents another of these numerous types.

The extraordinary Fig. 18 is from another drawing, by Tacchini, of a protuberance seen in 1871 (a time of great solar disturbance), and it belongs to the more energetic of its class.

The fantastic cloud-shape, "if shape it might be called that shape had none," looking like some nightmare vision, was about fifty thousand miles long and sixty thousand high above the surface. The reader will notice also the fiery rain, like the drops from a falling rocket, and may add to it all, in imagination, the actual color, which is of a deep scarlet.

It may add to the interest such things excite to know that they have some mysterious connection with a terrestrial one,—the aurora,—for the northern lights have been again and again noticed to dance in company with these solar displays.

The eruptive prominences are very different in appearance, as will be seen by the next illustration, for which we are indebted to Professor Young.

In Fig. 19 we have a group of most interesting views by him (drawn here on the common scale of seventy-five thousand miles to an inch), illustrating the more eruptive types, of which we will let him speak directly. The first shows a case of the vertical filaments like those rocket-drops we saw just now in Tacchini's drawing, but here more marked; while the second (left side) is a cyclone-form, where the twisted stems suggest what we have seen before in the "bridges" of sun-spots, and below this is another example of filamentary forms.

The upper one, on the right, is the view of a cloud prominence as it appeared at *half-*

past twelve o'clock, on September 7, 1871. Below it is the same prominence at *one* o'clock (half an hour later), when it has been shattered by some inconceivable explosion, blowing it into fragments and driving the hydrogen to a height of two hundred thousand miles. The lowest figure on the right shows another case where inclined jets (of hydrogen) were seen to rise to a height of fifty thousand miles.

Professor Young says of these:

"Their form and appearance change with great rapidity, so that the motion can almost be seen with the eye. Sometimes they consist of pointed rays, diverging in all directions, like hedgehog-spines. Sometimes they look like flames; sometimes like sheaves of grain; sometimes like whirling water-spouts, capped with a great cloud; occasionally they present most exactly the appearance of jets of liquid fire, rising and falling in graceful parabolas; frequently they carry on their edges spirals like the volutes of an Ionic column; and continually they detach filaments which rise to a great elevation, gradually expanding and growing fainter as they ascend, until the eye loses them. There is no end to the number of curious and interesting appearances which they exhibit under varying circumstances. The velocity of the motions often exceeds a hundred miles a second, and sometimes, though very rarely, reaches two hundred miles."

In the case of the particular phenomenon recorded by Professor Young in the last illustration, Mr. Proctor, however, has calculated that the initial velocity probably exceeded five hundred miles a second, which, except for the resistance experienced by the sun's own atmosphere, would have hurled the ejected matter into space entirely clear of the sun's power to recall it, so that it would never return.

It adds to our interest in these flames to know that they at least are connected with that up-rush of heated matter from the sun's interior, forming a part of the circulation which maintains both the temperature of its surface and that radiation on which all terrestrial life depends. The flames, indeed, add of themselves little to the heat the sun sends us, but they are in this way the outward and visible signs of a constant process within, by which we live, and so far they seem to have a more immediate interest to us, though invisible, than the corona which surrounds them. But we must remember when we lift our eyes to the sun that this latter wonder is really there, whether man sees it or not, and that the cause of its existence is still unknown.

We ask for its "object" perhaps with an unconscious assumption that the whole must have been in some way provided to subserve *our* wants, but there is not as yet the slightest evidence connecting its existence with any human need or purpose, and as yet we have no knowledge that, in this sense, it exists to any "end" at all. "As the thought of man is widened with the process of the suns," let us hope that we shall one day know more.

S. P. Langley.

THE HEART OF THE CITY.

CAN you not feel the pulse of traffic beat,
Here where shrewd Commerce rears the gilded dome
Of her vast temple, and men's footsteps roam
Amid the bustling but inconstant street?
Here honest barter and keen avarice meet
And speculative passion seeks a home,
Frail as the glittering and unstable foam,
Borne from wan billows when the winds are fleet!
In scenes like these men find no sweet repose,
Through sordid nights and long tumultuous days,
With strained nerves battling for the love of gain:
For them no gracious flower of slumber grows,
With restful rapture past the meed of praise,
In Thought's grim citadel — a burdened brain.

William H. Hayne.