THE SUN'S PLACE IN NATURE.[1]

VI.

WE come now to the third new point of view. Many apparent stars are really centres of nebulæ, *i.e.* of meteoritic swarms.

In that very simple statement we have perhaps the very greatest and the most fundamental change which has been suggested by the new hypothesis. I am quite certain that all of you who have read text-books of astronomy will be perfectly familiar with the statement that all stars are distant suns. I have written that myself several times, but I now know that it is not true. Some stars, instead of being distant suns like our sun, a condensed mass of gas with a crust gradually forming on it, and a thick atmosphere over it, are simply the brighter condensations, the central condensations of nebulæ, whether they be like that of Andromeda, or planetary nebulæ, or such a nebula as that of Orion. You see the idea is perfectly new and completely different from the old one, which taught us that all stars were suns. Shortly after I made this assertion, photography came to our aid, and I am so fortunate as to be able to prove to you the absolute truth of it by an appeal to Nature herself; that is, I refer for demonstration to autobiographical records with which the heavens themselves have supplied us. Among the finest and most wonderful of the nebulæ is one which, unfortunately, we do not see here, because it is in the southern hemisphere; it is that surrounding the star η in a wonderful constellation, Argo, which it is quite worth while to go south to see, were there no other reasons. From the photograph you see that there is such an intimate connection, such an obvious relation, between star and nebula, that it is impossible for us to imagine for one moment that they are not most closely and intimately connected.

FIG. 24.—Nebula round η Argus (Dr. Gill).

I will now bring before you another case which we can, all of us, see, so far as a certain part of the phenomena is concerned, and especially at this time of the year. I refer to those "stars," the six Pleiads, which you will remember once lost a sister, that one sees in the constellation of the Bull. Here they are, photographed by Dr. Roberts. You see they are not stars; they are nebulæ. What we see in this photograph (see Fig. 25), in the case of each so-called "star," is obvious; we see the centre of condensation, and more than that, it is not a simple condensation, but there are stream-lines going in all directions, and the maximum luminosity, where we locate the "star," is just at the place where, according to this photograph, the greatest number of these streams cut each other, and where, therefore, we should get the greatest possible number of collisions per second of time. The main point demonstrated by this photograph, then, is that we are not dealing with stars anything like our sun; we are simply dealing with nebulous condensations. I can show you the spectra of the brighter parts of these condensations, and you will see that they resemble the spectra of ordinary stars. Broad dark lines of hydrogen are represented in every one; hence, although we are dealing not with a star like the sun, but a meteoric condensation—a place of intersection of streams of nebulous matter—we get a spectrum such as is generally associated with the spectrum of a star. And for this there is very good reason.

Here an interesting point comes in. Suppose that we wished to observe spectroscopically what was going on in these condensations, and that I allow the image of one of them to fall on the slit of the spectroscope, so that we have the condensation at the centre, and the ends of the slit of the spectroscope beyond the condensation. At the centre, where the slit crosses the condensation, of course we should have the spectrum which you have already seen on the screen, a spectrum indicating that there is something there which gives us a continuous spectrum, *i.e.* one rich in all the colours of the rainbow; but that some of the light is absorbed here and there in consequence of the surrounding atmosphere of hydrogen gas. So much for the centre. Next consider what will happen when I observe, for instance, this or that part of the nebula where the condensation is absent; we shall not get absorption phenomena, but we shall get radiation phenomena, and therefore a long bright line representing the radiation of hydrogen over a large area, and at the middle of it the ordinary spectrum of a star. Prof. Campbell, at the Lick Observatory, has recently subjected another star to a similar treatment, and you will see (Fig. 26) what he has found. By putting the slit of the spectroscope upon the image of the star, he finds that he gets the spectrum from one end to the other; but you see that at the place occupied by one of the hydrogen lines he gets a much longer image of the slit, showing that he had to deal there with a star immersed in something which was competent to give a spectrum of hydrogen. What was that something? You can understand perfectly well that, if one of the Pleiads had been examined in the same way, it would be quite possible that we should get just such an appearance as Prof. Campbell was fortunate enough to obtain. This raises an interesting question, in which astronomic thought has been going up and down now for the last fourteen or fifteen years, and I think I can show you exactly how the matter lies. The diameter of the sun is very nearly a million miles. Now, suppose that the diameter of the solar atmosphere was ten million miles; then if we were by any means whatever to spectroscopically examine the image of the sun under such conditions that all the light coming from these different regions could enter the slit of the spectroscope at the same time, and give us, added together, the whole light, we should be able to determine practically what we might be able to see under these conditions by some such considerations as these:—

Diameter of the sun, one million miles.

Diameter of the sun's atmosphere, ten million miles.

We should therefore get the light from the sun in the ratio of 1 to 99 of the light from the atmosphere. Now suppose that there is any chemical connection between the absorption in the light of the sun and the radiation in the light of the sun's atmosphere, if we sweep the slit of the spectroscope along the edge of the sun, the part of the spectrum which writes for us what is going on in the solar photosphere, gives us the spectrum crossed by dark lines; the effect of the atmosphere is to absorb the light of the more distant sun at which we look, and the result of the absorption is to give us dark lines.

But when we look at the atmosphere which is resting on the edge of the sun, and look at it where there is no brighter sun behind, absorption no longer comes into play, and we get bright lines. This is what happens when we look at the solar atmosphere above the sun's edge and the solar atmosphere between us and the sun. So long as we are telling the story of the sun, we get

[1] Revised from shorthand notes of a course of Lectures to Working Men at the Museum of Practical Geology during November and December, 1894. (Continued from page 14.)

the dark lines; so long as we are telling the story of the sun's atmosphere, we get bright lines.

We found that the area from which the sunlight comes to us is represented by 1, whereas the area from which the atmospheric light comes to us is represented by 99; so that if the light of the atmosphere is very much dimmer than the light of the central sun, in consequence of its enormous area we may get some light from it intermingled with the light of the sun itself in our spectroscopes.

Therefore, when we look at the complete spectrum, we may lose the dark hydrogen lines in the spectrum of the star, and we may get bright lines instead of dark ones for every line in the spectrum of a star which is filled up by the absorption of a substance the line of which may be seen bright in the spectrum of that star's atmosphere. Thus there is the possibility that when we have to deal with bright lines in the spectrum of an apparent star, we may be dealing with the atmosphere of the star. You will at once see that; if we are dealing with a pure meteoric agglomeration, then of course we shall get that appearance beyond all possible question.

Now, let me give you one or two cases showing you how this thing works out. The strongest case would be that we should get the bright hydrogen lines putting out the dark hydrogen lines, so that if we got a class of stars without any dark hydrogen lines, we should be justified in supposing that those stars had an enormous atmosphere of hydrogen, and that the fainter bright lines from the larger area just cancelled the effect of the other light from the very much smaller area. Another way that we might expect this thing to work would be that we should not get the bright hydrogen lines entirely putting out the dark hydrogen lines, but that we should get a thinner line in the centre of a broader dark one. Now, that really happens in several stars in the heavens.

FIG. 25.—The Pleiades (Dr. Roberts).

I give in Fig. 27 untouched photographs of a star in Orion, and a star in Cassiopeiæ. The latter is very like the star in Orion, because all the absorption lines are common to

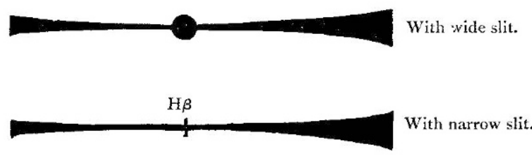

FIG. 26.—Prof. Campbell's observation of the F line of hydrogen in the spectrum of a bright line star.

the two stars; but I may point out to you that we get a bright hydrogen line running down the centre of the dark ones. We may have such an effect produced either by a star having an enormous atmosphere, or by the star with which we are dealing being simply the central condensation of an enormous nebula.

I am bound to say that when I began this work in 1876, I was under the impression that such phenomena were due only to the effects of the atmosphere. But one lives and learns, and since then I have come to the conclusion that that explanation is not the best one, and that when we get such phenomena as those you now see on the screen, we have really to deal with the central condensations of nebulous swarms. I do not hesitate to bring these facts before you, because it is particularly in this connection of thought and experiment and comparison that whatever progress which is now being made in astronomical science is being secured.

Associated with this view we have the statement that stars with bright lines are closely associated with nebulæ, as evidenced by their structure. You will see that there is one method which enables us to compare the bright lines in stars like γ Cassiopeiæ with the nebulæ, as it gives us an opportunity of determining whether or not the bright lines seen in the so-called bright-line stars are or are not the same as the bright lines seen in nebulæ. In the first inquiry in this direction, which consisted of a statistical statement of the number of times certain lines were seen in the spectra, both of nebulæ and of bright-line stars, it was stated that nine lines were coincident, and that and other work done about that time was of such a very trenchant nature that Prof. Pickering, who is one of our very highest authorities in all these matters, accepted at once the grouping together of stars having bright lines in their spectra with the nebulæ. That, you see, was another very definite step in advance indeed.

I can show you a map giving you the evidence of this kind which has been brought into court. We have in it the lines seen in the spectrum of the nebula of Orion, and the longer the line is the stronger it is in the photograph. Then we have underneath the lines recorded in the Orion stars, in the bright line stars, and in the planetary nebulæ; and if you will cast your eyes down these chief lines, you will see that there is a considerable number of lines common to all these bodies.

That is the kind of evidence on which we have been compelled to rely to answer the question: Is there any chemical relationship, and therefore physical relationship, between the bright line stars and the nebula of Orion? And you see the evidence is very strongly in favour of an affirmative statement. Not only does Prof. Pickering accept it, but Prof. Keeler also confirms it. He says the spectra of the planetary nebulæ have a remarkable resemblance to the bright line stars.

But even more fortunate for us than all this is the fact that Prof. Campbell has just finished a most important and laborious study of these stars at the Lick Observatory, and has observed all the lines in the spectra of a much greater number of stars than was available when I began the inquiry; his measurements are very much more accurate than any that were possible then to me. What happens when we come to deal with his results? The thing is a thousand times more convincing than it ever was. When we take Campbell's list, we get very many more coincidences than we had when we dealt with Pickering's. So that, the further we go in this inquiry, the greater is the number of coincidences. I told you that in the first inquiry there were nine coincidences observed; now we get nineteen coincidences out of thirty-three. We are therefore justified in saying that the more these phenomena are observed, the more closely associated are they seen to be.

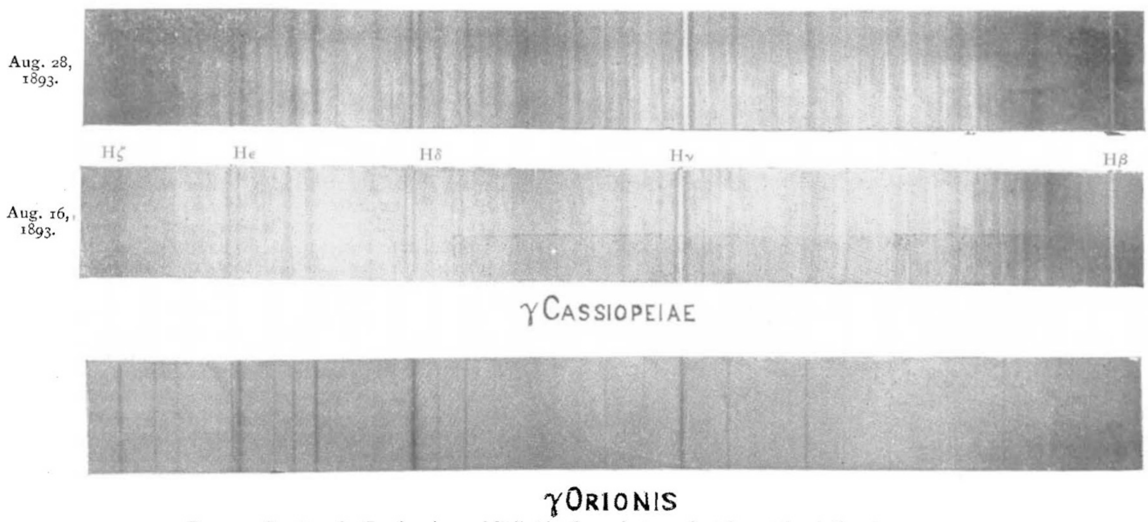

FIG. 27.—Spectra of γ Cassiopeiae and Bellatrix, from photographs taken at South Kensington.

Let us take the case of one of the brightest stars of this class in Argo, the spectrum of a star which my friend Respighi and myself were the first to see on a very hot night in Madras in 1871, a beautiful spectrum with many bright lines. Now, here these bright lines are indicated in the diagram, and we find by attempting to study their real positions that some of them are due to carbon, and some of them to iron, and some of them to sodium. Prof. Campbell has recently included the study of this star in his work at Lick, and everything that he has done there seems to confirm the idea. The great question is the question of carbon. You know the importance of carbon in a star like this, because we have had carbon differentiating comets from nebulæ, and finally the discovery of carbon in the nebulæ.

I have some apparatus here to show you, which illustrates what one has to do in studying the spectrum of carbon; we must not only deal with it in its ordinary form, and observe the spectrum as seen in the Bunsen flame, and so on, but we must get different compounds of carbon, and expose them to different temperatures and different pressures. That has been done by myself and others; during the last twenty years I suppose I have made thousands of observations on the spectrum of carbon in different forms and conditions.

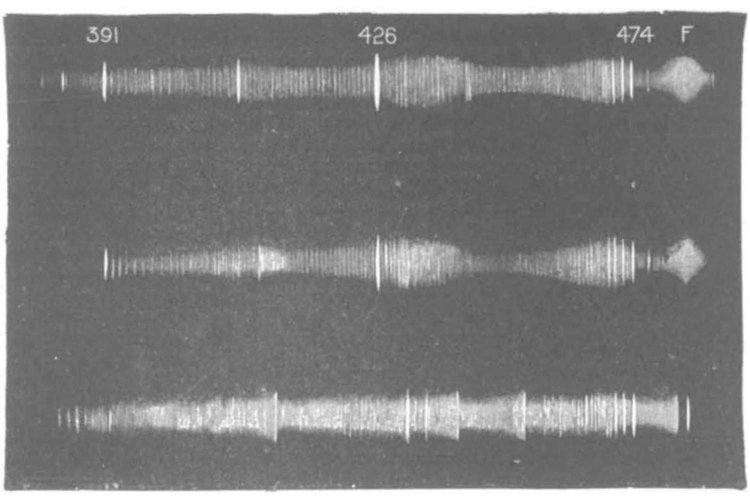

FIG. 28.—Spectrum of carbon at different temperatures.

Fig. 28 shows a series of photographs of the same carbon compound in the same tube, taken under different conditions; you will see that there is a very considerable difference in the intensity of the same bands, as the pressure of the gas has been changed; the particular part of one of the bands which you see enhanced seems to be playing a rôle of considerable importance in the spectra of some of these stars.

This is shown merely as an indication of the kind of minute work which is absolutely essential to determine what is happening in the chemical elements in these bodies.

J. NORMAN LOCKYER.

(*To be continued.*)

THE MANAGEMENT OF EPPING FOREST.

AS a sequel to the continued agitation in the newspapers about Epping Forest, a deputation was received by the Committee at their meeting on Tuesday last at the Guildhall. The object of the deputation was to present the following memorial:—

"Your memorialists have heard with grave concern that your Committee have been urged to put a stop to all further removals of trees in Epping Forest for a period of years. The undersigned have examined the area in question and are of opinion that such a resolution, if sanctioned by your Committee, would be productive of undoubted injury to the Forest, especially as regards those portions of Loughton, Epping, Waltham and Sewardstone Manors which are covered with a dense growth of pollarded trees.

"Those who have approached you with the request to which we have referred do not appear to have apprehended the altered