THE SUN AND STARS¹

IX.

LET us consider the case, then, on the supposition of small masses of matter. Where are we to find them? The answer is easy;—in those small meteoric masses which an ever-increasing mass of evidence tends to show occupy all the realms of space.

In connection with this, perhaps I may be permitted to quote the following from one of my "Manchester Lectures":—

"There is one point to which I think I may be permitted to draw your attention, although at present it rests merely upon an undorsed observation of my own. I thought it would be worth while to try what would happen if I inclosed specimens of meteorites, taken at random, in a tube from which I subsequently exhausted the air by a pump. After the pumping had gone on for some considerable time, of course we got an approach to a vacuum; and arrangements were made by means of which an electric spark could pass along this apparent vacuum, and give us the spectra of the gases evolved from the meteorites. Taking those precautions which are generally supposed to give us a spark of low temperature, and passing the current, we got a luminous effect which, on being analysed by the spectroscope, gave us that same spectrum of hydrocarbon which Mr. Huggins, Donati, and others have made us perfectly familiar with as the spectrum of the head of a comet. There, then, we get the atmosphere of meteorites, not necessarily carbonaceous meteorites, but meteorites taken at random; and this atmosphere is exactly what we get in the head of a comet.

"Now let me go one step further; and to take that step with advantage, allow me to refer to another point, . . . that whereas Schiaparelli has connected meteorites and falling stars with comets, Profs. Tait and Thomson, on the other hand, have connected comets with nebulae, both of them being, according to those physicists, clouds of stones. Now how has one to carry these spectroscopic observations into the region of the nebulae? A Leyden jar was included in the circuit, and we had what is generally supposed to be an electric current giving us a very much higher temperature than we had before. What, then, was the spectrum? The spectrum, so far as the known lines were concerned, was the spectrum which we get from the nebulae; for the hydrocarbon² spectrum, which we get from the atmospheric meteorites at a low temperature, was replaced by the spectrum of hydrogen; the spectrum of hydrogen coming, of course, from the decomposition of the hydrocarbon, with the curious, but at present unexplained, fact that we got the spectrum indications of hydrogen without indications of carbon. In my laboratory work I have come across other curious cases in which compound vapours, when dissociated, only gave us one spectrum at a time—by which I mean that in a vapour consisting of two well-known substances, under one condition we only get the spectrum of one substance, and under another condition we get the spectrum of the other substance alone; so in others, again, of both combined. The evidence seems, therefore—though I do not profess to speak with certainty—entirely in favour of the ideas of Sir William Thomson and Prof. Tait on the one hand, and of Schiaparelli on the other."

I have given the above extract to show that a mass of meteorites at a temperature higher than that found to exist in a comet's head could give us the hydrogen spectrum which was discovered with such richness in the *Nova*, which is represented in the spectra of most nebulae, and which remained in the spectra of the *Nova* after all the other lines had gone.

These considerations enhance the interest of the *Nova* to the spectroscopist if we accept the bright line observed in the star by Dr. Copeland and others to be veritably the chief nebula line.

This line brightened relatively with each decrease in the brilliancy of the hydrogen lines. On December 8, 1876, it was much fainter than F, while by March 2, 1877, F was a mere ghost by the side of it. On any probable supposition the temperature must have been higher at the former date.

Now it is well known that within certain limits the lines in the spectrum of a compound body get brighter with decrease of temperature, because at the higher one the compound almost entirely ceases to exist as such, and we get the lines of its constituents. It is a fair theory then to suggest that the famous

¹ A Course of Lectures to Working Men delivered by J. Norman Lockyer, F.R.S., at the Museum of Practical Geology. Revised from shorthand notes. Continued from p. 230.

² The Lectures from which I am quoting were delivered many years ago, before the spectrum was recognised to belong to carbon.

nebula line may belong to a compound. Nay the fact as it stands alone further points to the possibility that the compound in question contains hydrogen as one of its constituents.

At present we know very little indeed about these new stars. The star which appeared last year in the nebula in Andromeda is, if possible, still more difficult to understand, because, although it was so near the centre of the nebula in apparent position, we do not know that it was near the nebula locally, or whether it was simply in the line of sight. Therefore the views with regard to that star are much complicated by the fact that it is uncertain whether it was associated with a nebula. It may have had nothing to do with it. I have received this morning from Paris a photograph taken by the Brothers Henry, who are working now at the Paris Observatory, recording the very interesting discovery that apparently growing out of the side of one of the stars of the Pleiades is a real nebula. Those of you who remember the photographs of the corona during different eclipses will imagine that there may be some connection between this star and the surrounding nebula. Now it seems certain that there is some connection between this star and the nebula, and it may be that, in fact, what we call nebula in this case is a very considerable expansion of the star's coronal atmosphere. So obvious is that suggestion, that I spent last night in trying to observe its spectrum. The fog was too much for me, but still, although there was very little light, it did look very much as if there were some bright lines in the bright part of the spectrum of the star. And if that is so, it will not only show you the possible connection of the nebula in Andromeda with the new star in Andromeda, but it also shows you the importance of the question of area which I brought before you in the previous part of the lecture, if the bright lines we got are due, not to the star itself, but to the incandescent area which surrounds it.

Finally, then, with regard to the new stars generally. That they are stars in our sense is, I think, quite impossible. Some of them, you know, lose their brilliancy in a very few weeks. Now we know that any body like the star which we are most familiar with—our sun—if ever it got to a sufficient degree of temperature to increase its light ten or twenty times, would not lose its temperature in ten or twenty days, or ten or twenty years, or ten or twenty thousand years, so that the more rapidly any of these bodies cool down, the less likely is it that the bodies which cool down have any considerable mass.

So obvious was that that on the appearance of the star in 1866 I made the suggestion, as I have said, that the body which gave us this light might be quite close to us. Well that was negatived. It was found that it was not—that it was at a stellar distance—that it was no more possible to tell its distance than it was that of an ordinary star.

We are driven then to the conclusion that, as we must account for a tremendous increase of light, and we know that this light was produced at a very great distance, and that one very large mass cannot be in question, we must distribute the light among a great many masses—the idea of a collision between two stars must give way to the idea of some action of a meteor-swarm in the case of a star already existing, like T Coronæ, and of a collision between two meteor-swarms in the case of a new one like that of 1876; that seems a possible explanation of a great many of these "stars"—the components of meteor-streams driven to incandescence supplying that light in consequence of the innumerable multitude of their components, the light dying out very quickly because these innumerable components are small and far apart.

The next order of variable stars to which I shall refer you is very well represented by β Lyre. The curious point about this star is that it has a double minimum. Another star, η Argûs, with a bright line spectrum, is also remarkable from the fact that its maximum varies in the same sort of way.

In this star we get a number of differences. If you start from the maximum of the star you find it of three-and-a-quarter magnitude. It then in three-and-a-half days goes down to four-and-a-quarter. It then goes up so that in about six days it gets back again to its original brilliancy. It then goes down again, but does not stop where it did before, but goes half a magnitude lower, and then at last it ends the sequence of phenomena by getting up to its original brightness in thirteen days.

Now, although we cannot explain how it is, we have the fact that a curve of that kind is associated with a bright line spectrum. In η Argûs, one of the most remarkable stars in the heavens, we have very much the same conditions. This star is in the southern hemi-

sphere, and during the last twenty or thirty years a considerable discussion has been going on among astronomers as to whether the surrounding nebula is or is not changing its position with regard to the star. Now what happens to the star? I may tell you that the curve is only a rough one. But still you see the point fairly enough. This is, that this star, which has a bright

line spectrum like β Lyræ, has a period not of thirteen days, but of seventy years. We find that the star, which is at first possibly below a sixth magnitude star, rises up to the first magnitude, but then goes down to the second, and so on. The curve shows a period of seventy years, the curve being very irregular.

The third and fourth classes, so far as we can see, resemble

FIG. 27.—Light curve of β Lyræ.

our sun. The curves suggest that of the sun's spot period, when we can make anything out of them at all.

But when we come to another class, in which we get a large light change in one period, there is one star, the history of which is so extraordinary that it is quite worth while to throw its light curve on the screen. It is called Mira, or the Marvellous. It

is in the constellation of the Whale, and what happens to it in just a little less than a year is this. First it is of the second magnitude, and then in about eighty days it descends to the tenth magnitude, and then, so far as the observations have gone, it is invisible. In about another hundred days it again becomes visible as a star of the tenth magnitude. It then increases its

FIG. 28.—Light curve of Mira.

light to the second magnitude, and begins the story over again. But sometimes at the maximum its brilliancy is not quite constant. That is to say, sometimes it goes nearer the first magnitude than the second. What happens to the light of the star below the tenth magnitude it is impossible to say. Whether it follows more nearly either of the dotted curves in the diagram is not

known. Below the tenth magnitude no observations have been made, because it is very difficult to observe a star under those conditions. What one knows is that it remains invisible for about 140 days or something like that, and then it begins its cycle over again.

The next diagram illustrates the last conditions of variability,

the class of stars in which, if you remember, I told you that the variability probably did not depend upon the star itself, but upon its surroundings; and this is the famous star Algol, which is always visible in our latitudes. The history of the light changes of Algol is this. If we take the beginning of a cycle it is a star

of the second magnitude. Suddenly in three hours it goes down to the fourth, and then it comes up in another three hours to the second, and goes on again for very nearly three days; and then it goes down again, comes up again, and goes on again for another three days, and so on. The diagram shows the exact

FIG. 29.—Light curve of Algol.

hape of the light curve as it has been determined by Prof. Pickering, dividing the light into a thousand parts.

FIG. 30.—Plan and section of the orbit of the Companion of Algol.

There is another star very like this—a star which is in 81° N. declination, No. 25 in a well-known Catalogue. The difference

between Algol and this is that the rise and fall are a little more rapid. Its light is feeble for about the same time as the other one, but at the bottom the curve is flat, by which I mean that, instead of going suddenly down and coming suddenly up again, it stops at its least luminosity for some little time.

Prof. Pickering has shown, I think, beyond all reasonable doubt that what is happening is this. If we take this diagram to represent in plan a large star giving out light, and B, C, D, E, F represent also in plan different positions of a dark body revolving round that central star; and then if you take the thing in section, so that the star and its satellite are represented as they really are in the plane which joins the earth and the star, you will see that in one part of the revolution of the dark body it eclipses the light body. Now, a further investigation of those conditions in the case of the second star has shown that there must be a total eclipse, and therefore Prof. Pickering draws the conclusion that in the former case the light of the body which revolves round the central one may be considered as *nil*—that is to say, that it is a dark body; but that in the case of the star D. 25— 81° N.—there must be luminosity from the star which eclipses the other. And a very beautiful justification of that has recently been noted, because, although there is no change in the spectrum of Algol, there is a considerable change in the spectrum of that star the bottom curve of which is flat, showing that probably the companion has a large coronal atmosphere, and that the light of the central star has to pass through it. The light of the composite star practically changes from green to red very much as our sunlight would change if it had to pass through the atmosphere of another sun like itself coming between us.

I have prepared two or three other notes with regard to those special matters touching the stars which depend upon their distances, to show you that our sun, after all, is a small star—that there are several suns in the universe near enough to us to have had their distances already determined, which are considerably more brilliant and more imposing in every way than the star which is near us. But the clock tells me that I must leave all that to some other time, and I now end the course by thanking you very much for the indulgence that you have shown me in listening to what I have been able to tell you with regard to the constitution of our central body, and to the application of the knowledge which we have got in that way to an endeavour to cull some of the secrets of the physical construction of those suns which are very much farther removed from our ken.

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