THE SUN'S PLACE IN NATURE.[1]

III.

THE next question that we have now to consider has to do with the connection between nebulæ and stars, and I shall show that the more the facts are studied the closer does this connection prove to be. You remember that that was the idea which lay at the bottom of the hypotheses both of Kant and of Laplace. In the last lecture I referred to some of the earliest observations which had been made of the nebulæ by means of the spectroscope, and it so happened that Dr. Huggins, to whom we owe this work, came to the conclusion that the result of his inquiries was rather to show that this connection, which had been asserted both by Kant and Laplace, and which had been accepted by everybody up to then, really did not exist. In a paper which detailed these spectroscopic observations, published in 1865, Dr. Huggins stated his conclusion that the nebulæ, instead of having anything whatever to do with any evolutionary line along which both nebulæ and stars might be traced, possessed a structure and a purpose in relation to the universe altogether distinct and of another order. So that you see the first apparent teaching which we got from the spectroscope practically put us in a very considerable difficulty; if it had to be accepted, of course the views of Kant and Laplace would have to be rejected.

When I commenced my general survey in 1887, this view held the field, and further, it was imagined that the observations of Dr. Huggins justified the idea that the nebulæ were masses of of these singular bodies, the nebulæ, and the simplicity of their composition, one is led to see in them only the residuum of the primitive matter after condensation into suns and into planets has extracted the greater part of the simple elements which we find on the earth and chemically in some of the stars."

It was perfectly clear then to Dr. Wolf that, if the constitution of the nebulæ was anything like what was supposed to have been revealed by early spectroscopic observation, we were dealing with a residuum. There was one kind of action in space, bringing together one class of elements with which we are familiar here, and forming them into stars, suns, and planets; but there was another kind of matter which declined to form part of these aggregations, which remained by itself, and finally put on the appearance of the so called nebulæ.

The first thing I have to say concerning this view is, that the discussion of the spectroscopic observations which I told you, in the last lecture, had been undertaken with a view of seeing what really could be determined in relation to this question, showed, beyond all question, that there was no ground whatever for it; that there was no real ground for supposing that there was this enormous difference between the nebulæ and the stars. In the year 1887, the year following the course of lectures to which I have already referred, after testing the views on this question by an appeal to all the available observations, I stated that the facts taken in all their generality showed that the nebulæ simply represent early stages of evolution; that is to say, that we have a continuous and orderly progression from the nebulæ to the oldest star, and

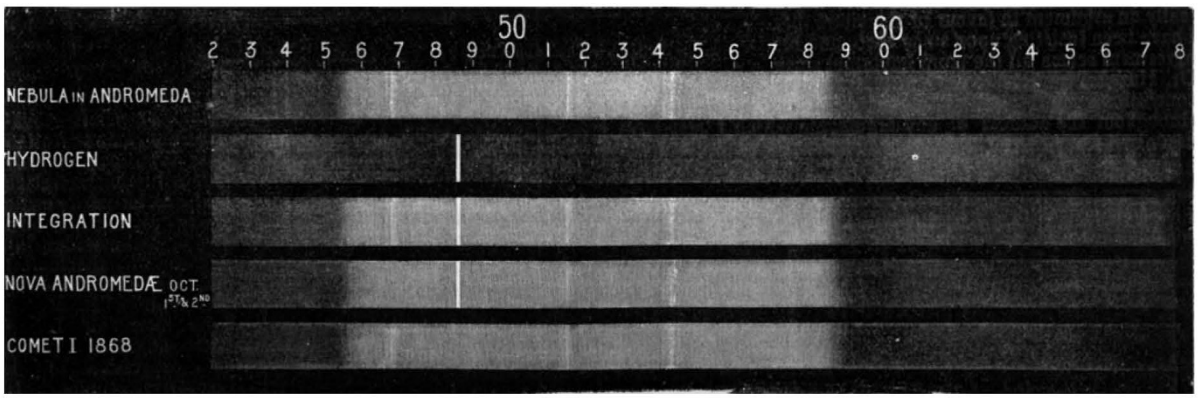

FIG. 12.—Spectrum of the nebula in Andromeda compared with Nova Andromedæ and comet. The flutings common to all are those of carbon.

gas; what particular gas will concern us a little later on, but for the moment I need only say that these statements announcing the nebulæ to consist of one or two gases, at once led to several most remarkable views of the general constitution of the heavens.

Near the end of this nineteenth century chemists claim to know something of the materials which have built up the planet on which we dwell, and if you consult any of the books which have been written about spectrum analysis, giving the results of the work during the last thirty years or so, you will find it stated over and over again that the spectroscope has put it for ever beyond doubt that the chemistry of the skies, *i.e.* the chemistry of the various bodies which people space, and which are at a sufficiently high temperature to enable us to examine them spectroscopically, exactly resembles the chemistry of the earth. So that, if this were true, we should have a common chemistry of the earth, of the stars, and among the stars of course our own sun. On the other hand, we should have, according to Dr. Huggins, absolutely and completely distinct from these bodies another class, the nebulæ, in which the chemistry is absolutely and completely unique. This was so clearly the idea suggested to philosophical students of these questions, that Dr. Wolf, a famous French astronomer, who has written an all-important book for those who are interested in these inquiries, "Les hypotheses cosmogoniques," published in 1886, writes: "If we admit the data of spectrum analysis as to the gaseous state that the nebulæ represent the first stage, and the oldest star or planet represents the last. It seemed to be perfectly clear from the discussion that we were justified in stating that every nebula which is visible now will some time or other, owing to the condensation of its various parts, become a star of some order or another; and that it is equally true to say that every star which we see now in the heavens, knowing it to be a star, has really been a nebula at some time or another.

I told you that the first suggestion of a possible condition which would enable an evolution to take place from nebulæ to stars had been made by Prof. Tait, when he thought that probably cool meteoritic particles might have something to do with it. The complete inquiry shows that these meteoritic particles might account equally well both for the luminosity of comets and of nebulæ. This association is important because it is generally conceded that comets are swarms of meteorites.

It seemed so obvious that there was this close connection that in 1888 I predicted that, if the nebulæ were carefully observed, we should find in them sooner or later indications of that same substance which makes the comet's spectrum so very distinct and special. In almost every comet which has been observed, the spectrum of carbon, or of some compound of carbon, is the strongest and most obvious feature which is presented to us. In 1889, *i.e.* only the next year, matters were made very much clearer by the discovery, by Mr. Fowler and Mr. Taylor, of the spectrum of carbon in the nebula of Andromeda (Fig. 12), so that there, you see, was a prediction verified, and such verification is always a very precious

[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 399.)

test, since it helps us to know whether one is going right or wrong, and it seemed to strengthen very much the view under consideration. Further, not only do we find carbon both in comets and nebulæ but it is recognised by everybody that in some stars the same substance exists in enormous quantities. Here, then, we are in the presence of the fact that the statement that there is an enormous chemical difference in structure between nebulæ and stars is shown spectroscopically to be unfounded, while the evidence also goes to show that there is a close connection between nebulæ and comets. By this, of course, the argument is very much strengthened all round, because, as we have seen, nearly everybody agrees that comets most probably consist of meteoritic stones or particles.

I am glad to say that among the first to accept the new evidence proving that nebulæ are really early stages of evolution of stars was Dr. Huggins himself, the observer whose statement which I have quoted I had been fighting for years. That you see was a great victory. He says now not only that these bodies may represent early forms ; places them in the line of evolution where I had placed them, but he even adduces the same evidence which I had brought forward in several of the arguments which I had employed. Dr. Huggins made a reference to this question as President of the British Association in the year 1891, and if any of you read that you will see that it is really an argument in favour of the views that I have been insisting upon since 1886, and his agreement seems all the more important since Dr. Huggins appears to have arrived at these conclusions quite independently. Not one word is said throughout the address of any arguments which I may have used, or of any line of thought or observation on which I had founded the various statements which I had made ; and therefore it would be charitable to suppose that he was unacquainted with my work when that address was given to the world. Of course you will acknowledge that that was a very extraordinary change of opinion, so extraordinary indeed that it is clear that Dr. Huggins felt that it was of importance to himself that the change should be explained ; and he confesses in the address, to which I refer, that the communication he made to the Royal Society in 1864 was not entirely founded on scientific evidence, but partly made under, to use his own words, "the undue influence of theological opinions then widely prevalent."

FIG. 13.—The nebula near 52 Cygni, from a photograph by Dr. Roberts.

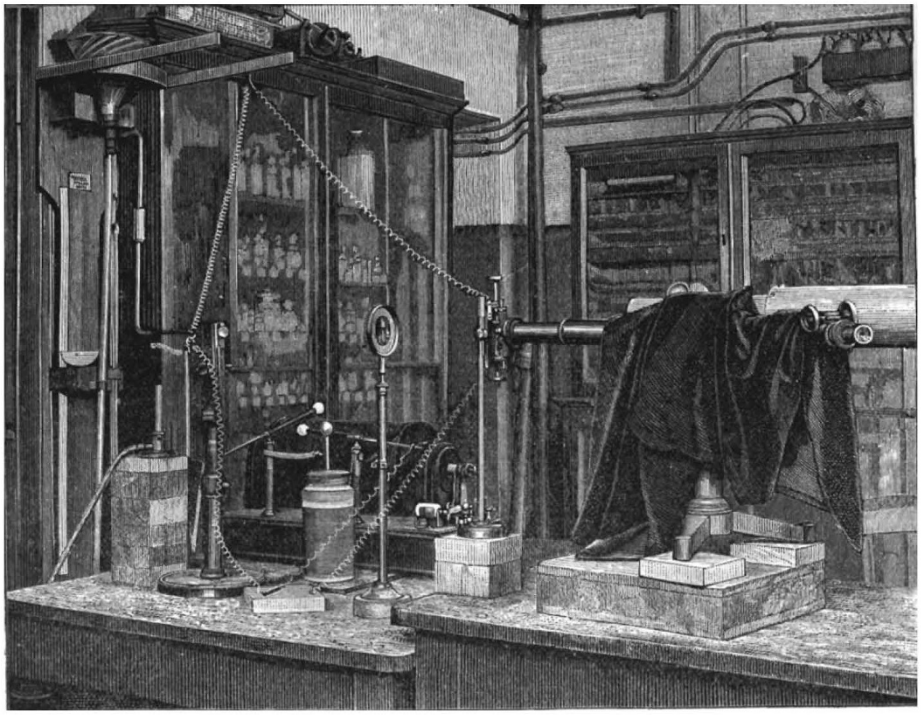

FIG. 14.—Observation of a meteoritic glow.

So after all I had been fighting partly an expression of a theological opinion. If we had known that before, probably some trouble might have been saved.

It is a very important thing to know that now, from east to west, those who dwell upon this planet are all perfectly convinced that nebulæ are early forms in the evolution of the heavenly bodies. The more one knows of the history of human thought, especially during the last two centuries, the more important does it seem that that result should be acknowledged as one of the most important truths established during the present century.

Before I go further, let me refer to two or three typical examples of these strange bodies, as I can do by the kindness of Dr. Roberts, whose method of work I described in the last lecture.

First of all we have a representation of a form of nebulæ

which is not very common, but the study of which is all important for our present purpose. It is called a spiral nebula, it is one of the nebulæ in the constellation of the Great Bear. I wish to point out that in the centre we have a condensation, and from the centre of the condensation the luminosity gradually gets less and less until at last we have no luminosity greater than that of the surrounding sky. In the nebula itself we find exquisite spirals, starting apparently from different points, and gradually coming towards the centre, and if you look along these spirals you will see that the star-like masses, which may not be stars, are in many cases located on the spirals, representing apparently minor condensations, each spiral itself being probably brighter than the other parts because it is more disturbed.

Next we have an absolutely untouched photograph of the famous Dumb-bell Nebula. I am certain that many here have studied the drawings of this nebula given in encyclopædias and in books of astronomy during the last forty years, and that it is a great comfort to you to see, as it is to me to be able to show you, the autobiographical account that it gives of itself, because if you refer to those drawings it will be very difficult to find any two alike, even if it is distinctly stated that one has been copied from the other. In this again we find a central condensation, and associated with it arcs in which the luminosity is greater than in the adjacent regions.

The other nebula that I have to exhibit is one remarkable for its difference from the other two, inasmuch as no condensation is suggested. This nebula, which you see stretching across the screen like a sort of celestial river (Fig. 13), seems to be careering through space, and I call your attention specially to this because it is well to remember that, if we have meteoritic swarms in space, *i.e.* swarms which are condensing, it is quite possible that we may have meteoritic streams. I think you will consider that it is not any misuse of words to say that we have there a possibility of a meteoritic *stream*.

So much then for some typical representations of some of the different forms of nebulæ.

While, however, Dr. Huggins in his presidential address, apparently from quite independent inquiry, announced my main contention, viz. that nebulæ and stars *do* belong to the same order of celestial bodies, and withdrew his unfortunate statement as having been made on theological grounds, I am compelled to say, but wish to say it with the utmost courtesy, that a complete study of the literature shows that he was quite familiar with my work all the time, and that while he thought fit to republish my main contention as his own on the one hand, on the other he was engaged in attempting to throw discredit on my work, and to conceal his retreat after the manner of the sepia by a great cloud of ink—printer's ink, referring to a minor point. He endeavoured to suggest to anybody who was not really completely acquainted with my work, that the methods employed by my assistants and myself for something like three years were inaccurate, and that the conclusion reached, which must have been right because he had come to agree with it, had been got at in the wrong way. Although the charges of inaccuracy which Dr. Huggins thought fit to make were general, in his printed papers the chief stress has been laid upon a statement I had made with regard to a matter of secondary importance in the general discussion, I refer to the possible origin of the chief line in the nebular spectrum.

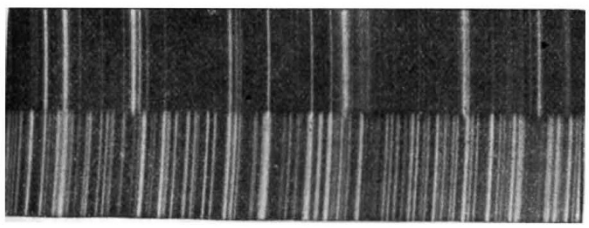

FIG. 15.—Line-spectra of barium and iron. 1, Barium. 2, Iron.

I propose to go into this matter in some detail, because it will enable me to indicate the closeness with which the skill of trained observers and the magnificent instruments of modern research that I have already referred to, enable us now to deal with facts, and to replace the imperfect observations of the past with others of which the accuracy may be relied upon.

Among the many lines of evidence which had been brought forward, it was stated by myself that in following up the suggestion of Prof. Tait and experimenting upon meteoritic dust, a line had been seen very near the position of the chief line which Dr. Huggins had discovered in the year 1864 in the spectrum of the nebulæ. In fact, after accumulating all the spectroscopic

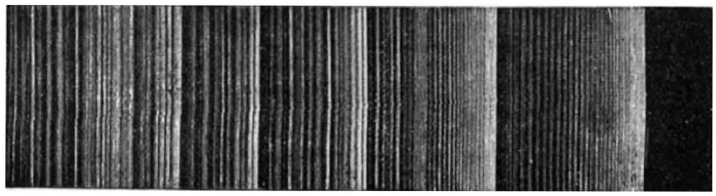

FIG. 16.—Flutings of carbon.

observations which I could lay my hands on, I went on to experiment myself, and I have here some apparatus which will give you an idea of the kind of experiment which was undertaken (Fig. 14.) Meteoritic dust is placed in a horizontal spectrum tube connected with a Sprengel air-pump, so that an electric spark can be passed through the dust; an image is formed on the slit of the spectroscope, and an arrangement for an ordinary electric spark in air serves for a comparison spectrum. The point was to see whether there was any probability that Prof. Tait's suggestion was right, by examining the spectrum of meteoritic dust. For this purpose some dust was placed in a tube resembling the one now on the table, and an electric current was sent through it. Now it had long been known that when one heats meteoritic dust, it gives out compounds of carbon, and also hydrogen gas; what I did was to observe the change in the spectrum of that tube under different conditions. For instance, if it were wished to expose the dust to a higher temperature, a Bunsen burner was placed underneath it.

You will be able to see that, in a little time, the heat will make a considerable difference in the phenomenon observed in the region which comes under its influence, and I think you will also see that in some parts we get a distinct indication of green colour. Now what I found was that in the spectrum of dust from several meteorites so examined, there was a line very near the position which had been stated by Dr. Huggins to represent the actual position of the chief line seen in the spectrum of the nebulæ. That line I was able to trace home by comparative work to olivine, a substance which occurs in almost all meteorites, even in iron meteorites. and not only to olivine, but to one of the constituents of it, which is magnesium. I have here a diagram of some of the results obtained in the green part of the spectrum, and it will be seen that we get in the nebula of Orion, and in the comets of 1866 and 1886, a bright line apparently in the same position. When I say line I should correct myself, this luminosity given out by magnesium does not take the form of a line as ordinarily so called. I will throw on the screen photographs of two spectra of the vapours of two metallic substances, barium and iron (Fig. 15), and you will then see what is meant by men of science when they talk about a line spectrum.

But besides what we call line spectra, there is another thoroughly well-recognised class, which we call fluted spectra, because it reminds one of the flutings of a column. Here, for instance, is a fluting of carbon (Fig. 16). In these flutings, instead of the lines being distributed irregularly, as in the case of iron and barium, we get a beautiful rhythm from one part where the light rapidly degrades to another where there is an enhancement of the light, followed by another degradation, and so on. Indeed, we not only get main flutings, but we get subsidiary flutings.

J. NORMAN LOCKYER.

(*To be continued.*)