ON THE DISTRIBUTION OF THE VARIOUS CHEMICAL GROUPS OF STARS.[1]

II.

THE results so far referred to have regard to the stars with dark lines in their spectra, but besides these there are many so-called bright-line stars.

I should state that there has necessarily been a change of front in our views with regard to these bright-line stars since they were first classified with nebulæ by Pickering and myself.

The nebulæ are separated from stars by the fact that in their case we have to deal with bright lines, that is to say, we are dealing with radiation phenomena, and not with absorption phenomena, as in the case of the stars so far considered; and in the first instance it was imagined that the bright-line stars were, from the chemical point of view, practically nebulæ, although they appeared as stars, because the brightest condensations of them were so limited or so far away that they gave a star-like appearance in the telescope.

Since that first grouping of bright-line stars, by the work chiefly of the American astronomers it has been found that in a large number of cases *they have also dark lines in their spectra*, and that being so we must classify them by their dark lines instead of by their bright ones; and the bright-line stars thus considered chiefly turn out to be gaseous stars, *with a difference*. What is that difference? It is this, I think: in the case of the bright-line stars we are dealing with the condensations of the most disturbed nebulæ in the heavens; together with the light which we get from the nucleus of that nebula which appears as a star and can be spectroscopically classified with the other dark-line stars, inasmuch as the surrounding vapours close to the star produce absorption, and therefore give us dark lines; other parts of the nebulæ, probably those further afield, give us bright lines which mix with the dark ones. Therefore we get both bright lines and dark lines under these conditions. So far as the result goes up to the present moment, it looks as we have now to consider that these bright-line stars, instead of being nebulæ merely, are gaseous stars at a very high temperature, in consequence of the fact that the nebula which is surrounding them, which is falling upon them, is increasing the temperature of the central mass by the change of *vis viva* into heat. Pickering,[2] in his discussion of these stars, had thirty-three to deal with, and he found that there was a wonderful tendency among these to group themselves along the Milky Way; that very few of them, in fact, lay outside its central plane; that is to say, the galactic latitude, as it is called, the distance in degrees from the plane was limited in the generality to only two degrees, and the greatest departure, the greatest galactic latitude, was something within nine degrees. That was the story in 1891. Two years afterwards Campbell, another distinguished American astronomer, also interested himself in this question of the bright-line stars, and he discussed them, his catalogue containing fifty-five as opposed to Pickering's thirty-three. He found also that they were collected almost exclusively in the Milky Way, and that outside the Milky Way practically none had ever been observed. The importance of this result I will indicate by and by, but in the meantime I can throw on the screen a very useful map which Campbell prepared. The central line of that map represents the galactic zone, the plane of the Milky Way, and he marks along it the different galactic longitudes, showing above and below the plane just a few degrees of galactic latitude north and south, sufficient to enable him to plot upon it all the bright-line stars which he discussed. The diagram shows that all these bright-line stars really are close to the central plane of the Milky Way. Only one out of the fifty-five is more than nine degrees from it, and this lies in a projecting spur, so that we cannot really say that that is out of the Milky Way. It is remarkable that these bright-line stars are not equally distributed along the Milky Way. They are chiefly condensed in two opposite regions, and there is one region in which they are markedly absent. The glass globe will show how the matter stands, I think, rather conveniently. We have the Milky Way represented by red tape. The secondary Milky Way, which starts from it at one point of the heavens and meets it again, is also indicated. Dark wafers mark the galactic longitudes and latitudes of the bright-line stars. We find that these stars begin just before the doubling commences. They go on, and are sometimes very numerous, and they end just after the doubling ends; and we notice there is a long range of the Milky Way where it is single in which there is absolutely no bright-line star at all. It looks, therefore, very much as if there is a something connected with this doubling of the Milky Way which produces the conditions which generate these bright-line stars.

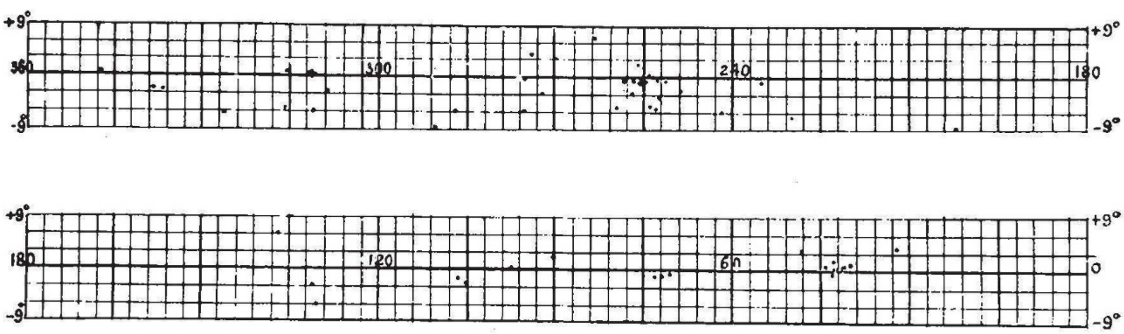

FIG. 3.—Distribution of the Wolf-Rayet stars in the Milky Way.

By the labours of Dunér, Pickering, McClean and Campbell, we are beginning to get very definite notions as to the distribution of the various chemically different stars in relation to the Milky Way. How about the nebulæ from the point of view of chemical distribution? Here we are in difficulties.

I have already stated that with regard to the general question of the nebulæ it is impossible to speak with certainty, because at present there has not been sufficient time and there has not been a sufficient number of observers at work to classify the thousands of "nebulæ" which we now know of into those which give us the gaseous spectrum, and those which are entirely different, apparently, in their constitution, and only give us what is called a continuous spectrum; but still we can go a

[1] A Lecture to Working Men, delivered at the Museum of Practical Geology, on April 10, by Prof. Sir Norman Lockyer, K.C.B., F.R.S. (Continued from vol. lx., p. 620.)

[2] *Astr. Nach.*, No. 2025.

little way in this direction by means of some figures which I have noted. The point is to see whether there is any difference in the distribution of those nebulæ, which are undoubtedly masses of gas, and give us the so-called nebulous spectrum, and those other nebulæ about which at present we know very little, but give us so-called continuous spectra. It is clear that on this point, undoubtedly at some future time, even if we cannot do it now, a great deal will be learned. The table I give brings the results up to the year 1894. If we take the region near the Milky Way, the region bounded by 10° galactic latitude north and south, and consider the planetary nebulæ distinguished by bright-line spectra, we find that there are forty-two; but if we deal with those which are further than 10° from the Milky Way, that number drops to five. If we take other nebulæ, not necessarily planetary, but gaseous like planetary nebulæ, inasmuch as they give us a spectrum of bright lines, we find that there are twenty-two in or near the Milky Way, and only six outside. If we take the so-called nebulæ known to have continuous spectra, which need not be nebulæ at all—we only imagine them to be nebulæ because they are so far away that we cannot get a really true account of them—we find that the conditions are absolutely reversed. There are only fourteen of them in the plane of the Milky Way, but there are forty-three lying outside it; so that the percentage within 10° of the Milky Way comes out to be eighty-four in the case of the planetary and the other nebulæ which give us bright lines, and in nebulæ with continuous spectra only 25. Therefore we get an absolute identity of result with regard to the bright-line stars and the other objects which give us bright-line spectra.

There is another class of bodies of extreme interest. In fact, to some they are more interesting than all the other stars in the heavens put together (because they are "new stars"); each new star being supposed to be a new creation, so that for this reason everybody is very much agog to find out what they are like. When we come to examine these so-called new stars we find that they also are almost absolutely limited to the Milky Way, as shown in the table which gives the number of new stars, so-called, which have been observed in historic times. It begins at 134 years before Christ, and it ends last year. The number of stars thus reported as new stars is thirty-one, and of these only three have been seen outside the Milky Way. The glass globe will show in a convenient way what the facts are with regard to the new stars. The bright line stars being distinguished by dark wafers, the new stars are shown by white wafers. We notice that where we get practically the greatest number of dark wafers we get a considerable number of white ones. That means that these new stars take their origin in the same part of space as that occupied by the bright-line stars, and it is also interesting to point out that the void which I indicated where the Milky Way is single, where there were no bright-line stars, is equally true for the new stars; only one new star has been recorded in this region.

As I have said, a great deal of interest has been attached by many people to the question of the new stars, for the reason that whenever a new star appeared in a part of the heavens where no star was seen before, it was imagined that something miraculous and wonderful had happened. That was justifiable while we were ignorant, but recent work has shown, I think almost to a certainty, that the real genesis of a new star is simply this. We have near the Milky Way a great number of nebulæ, planetary or otherwise; we have more planetary nebulæ near the Milky Way than in any other part of the heavens; the nebulous patches also observed in it may include streams of meteorites rushing about under the influence of gravity; the origin of a new star is due to the circumstance that one of these unchronicled nebulæ suddenly finds itself invaded by one of these streams of meteorites. There is a clash. These meteorites we know enter our own atmosphere at the rate of thirty-three miles a second, and we may therefore be justified in assuming that any meteoritic stream in space, even in the Milky Way, would not be going very much more slowly. If we get this rapidly-moving stream passing through a nebula, which is supposed to be a mass of meteorites more or less at rest, of course we must get collisions; of course, also, we shall get heat, and therefore light. When the stream has passed through the nebula the luminosity will dim and ultimately, attention having been called by this cataclysm to that particular part of space, we shall find that there is a

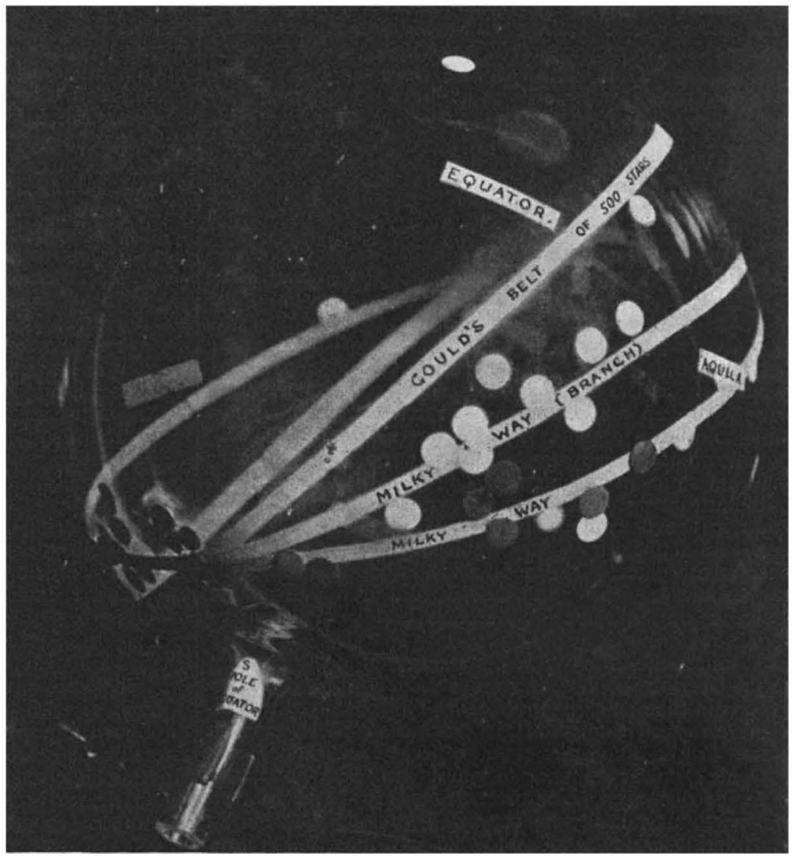

FIG. 4.—The Milky Way, where double in relation to the Equator and Gould's belt of stars, showing that the bright-line stars (dark wafers) and new stars (white wafers) are limited to the Milky Way.

nebula there. This has always been so; and therefore in the case of new stars we must always expect to get indications of the existence of two bodies, the intruder and the body intruded upon.

We must also expect, if we are dealing with small particles of meteoritic dust, that the action will be very quick, and that the war will be soon over. All this really agrees with the facts. I will, just in order to point my remarks, show what happened in the case of the new star we were fortunate enough to have the opportunity of observing in the northern hemisphere not very long ago, the new star in the constellation Auriga. We have in the diagram the stars in the region in question; a black arrow indicates a dark space in the heavens where there is no star. The next drawing shows the same stars and the same region of the heavens; but we observe that in the centre is a star, which is the new star. In the spectrum of it we obtained undoubted indications of the fact that we were dealing with two different masses of matter; for the reason that if you take the chief spectral lines marked G, *h*, H and K, that is to say, the lines of hydrogen and of calcium, we find both bright lines and dark lines, which being interpreted means that hydrogen and calcium were both giving out light and stopping light. We cannot imagine that the *same* particles of calcium and of hydrogen were both giving out light and stopping light; there must have been different particles of hydrogen and calcium giving light and different particles of hydrogen and calcium stopping light; and if we look at the photograph carefully we find that the bright lines and the dark lines are side by side, and we know that that means a change of wave-length in consequence of movement, and we also know from the change of wave-length indicated that the differential velocity of the particles which gave us the bright hydrogen and calcium, and the dark hydrogen and calcium, must have been something like 500 miles a second. In that way we obtained indisputable proof that we were really dealing with two perfectly different series of particles moving in opposite directions, and that that was the reason we got that sudden illumination in the heavens which as suddenly died out until finally a nebula previously undiscovered was found to occupy the place. The nebula is really not the result, the nebula was the cause, but we did not know of its existence until our special attention had been drawn to that part of the heavens.

So much then for the first statement of facts relating to the distribution of the various star groups and nebular groups in the most general form. The next question is, Can we say anything about the distances of these gaseous stars, bright line stars, and other types? The way in which an astronomer attempts to determine the different distances which the stars occupy in relation to the earth may really be very well grasped, I think, by considering what happens to one when travelling in a railway train. If the train is going fairly quickly, and we look at the near objects, we find that they appear to rush by so rapidly that they tire the eye, and one naturally looks at the objects which are more distant; the more distant the object we look at is the more slowly it appears to move, and the less the eye is fatigued. Now, suppose that instead of the train rushing through the country and passing the objects which we regard under these different conditions, the different objects are rushing past us at rest. Then, obviously, those things which appear to be moving most quickly will be those nearest, and the more distant objects, just because they are distant, will appear to move more slowly; that is to say, we shall get what is called a large "proper motion"—in the case of the objects nearest to us—and a small "proper motion"—in the case of the bodies which are further away.

This question has been attacked with regard to the stars in magnificent fashion by a great number of astronomers. A photograph will show in a diagrammatic form the very various rates of proper motion which have been assigned by careful observation to a very great number of the stars. In the chart the amount of proper motion of the various stars is indicated by the lengths of the lines which proceed from them, and the direction in which the various stars appear to be moving is also indicated by the direction which these lines take. Some of the lines are extremely long; they seem to stretch over a large part of the sky. Of course the scale is an exaggerated one, but it is the *relative* motion that we have chiefly to deal with, and we find that on the same scale in some cases the lines are extremely short; so that the diagram tells us that the amount of proper motion is apt to vary very considerably. We have large proper motions and small proper motions among the stars.

It was Mr. Monck who was the first to show in 1892[1] that the gaseous stars had the smallest proper motion; that is to say, that the hottest stars were further away from us than the cooler ones. That is a good, definite statement, and one which everybody can understand. He next found that the proto-metallic stars—that is to say, the stars not so hot as the gaseous ones, but hotter than the metallic ones—had the next smaller proper motion. This, of course, indicates that the metallic stars are the nearest to us unless proper motion does not depend upon distance, but rather upon a greater average velocity in space. It has been shown, however, by considering the sun's movement in space, that this view probably may be neglected. The first discussion of proper motion then went to show, roughly, that the hotter a star is the further away from us it is; and it made out a fair case for the conclusion that the sun forms one of a group or cluster of stars in which the predominating type of spectrum is similar to its own.

Kapteyn carried the inquiry a stage further.[2] Working upon the idea that stars with the greatest proper motion are on the average the nearest, the part of the proper motion due to the sun's translation in space he considered must depend strictly upon the distance, and he determined this by resolving the observed proper motion along a great circle passing through the point of space towards which the sun is moving, which is called the apex of the sun's way, and reducing to a point 90° from the apex. His results were practically the same as those obtained by taking the individual proper motions. He also found that stars with the greatest proper motion are mainly metallic, and have no regard at all to the Milky Way; that stars with the smallest and no observable proper motion are gaseous and proto-metallic, including a few metallic ones which have collected in the galactic plane. In this he agrees with the prior observations to which I have drawn attention. In the table which I now give the mean proper motion is shown.

Relation between Spectra and Proper Motions of Stars (Kapteyn).

Mean proper motion.	Gaseous and proto-metallic stars.	Metallic stars.	Metallic flutings.	Ratio, metallic to gaseous.
″ 1·39	3	51	—	17·0
0·52	12	66	1	5·5
0·35	14	66	—	4·7
0·24	34	124	—	3·6
0·18	35	67	3	1·9
Inappreciable	79	35	1	0·44

The table deals with something over a second, which may be looked upon as a great proper motion, down to the tenth of a second, which may be regarded as a small one;

1 "Astronomy and Astro-Physics," xviii., 2, p. 876.
2 Amsterdam Academy of Science, 1893.

and we find that the gaseous and proto-metallic stars increase in number as the proper motion decreases. We find also the ratio of the metallic to the gaseous and the proto-metallic. We begin with a ratio of 17, and end with something like a ratio of half, so that the results may be considered to be pretty definite. These results were obtained by Kapteyn with 591 stars which were common to Stumpe's catalogue of proper motions and the Draper catalogue dealing with spectra. The general result may, therefore, be stated that at the nearest distance the metallic stars are seventeen times more numerous than gaseous stars, and at the greatest distance they are not half the number. Here again the question arises, how far the intrinsic brightness of these bodies, in relation to their distance from us and the possible greater or less extinction of light in space, has to be taken into consideration. That is a problem which will require a considerable amount of work in the future. It is rather remarkable that if we take the stars with very great proper motion, very much greater than the average, we find with regard to four that three of them are undoubtedly metallic, but it is possible that the star 1830 Groombridge, which is always looked upon as the star which beats the record in velocity seeing that it would travel from London to Pekin in about two minutes, is not a metallic star.[1]

We are now in a position to make a general summary of the stellar distribution not only in relation to chemistry, but in relation to distance. Taking the chemistry as the basis, we can see what happens to the gaseous, proto-metallic stars and so on, with regard not only to their proper motions, but in regard to the Milky Way.

Summary of Stellar Distribution.

Group.	Proper motion.	Relation to Milky Way.
Gaseous stars	Smallest[2] (Monck)... ...	Condensed in Milky Way (Pickering and McClean)
Proto-metallic	Intermediate (Monck) ...	Brighter ones not notably condensed in Milky Way (McClean)
		Tend to collect in Milky Way, more especially the fainter stars (Pickering)
Metallic ...	Div. 1. Greatest (Kapteyn)	Not condensed in Milky Way (Pickering and McClean)
	Div. 2. Small (Kapteyn)	Collected in Milky Way (Kapteyn)
Mixed flutings.	?	?
Carbon ...	?	?

The gaseous stars, which we have seen have the smallest proper motion, are condensed in the Milky Way. The proto-metallic stars, which have but intermediate proper motion, are notably condensed in the Milky Way according to McClean, and tend to collect in the Milky Way more especially with the fainter stars according to Pickering. When we come to deal with the metallic stars, we find that there is no special condensation in the Milky Way. The greater number are not condensed in the Milky Way.

That being so, then, we may take a still further general view. We find that the bright-line stars, the new stars, are almost exclusively in the Milky Way and are far away from us; that the gaseous stars are chiefly in the Milky Way and are far away from us; that the proto-metallic stars are not so confined to the Milky Way, and they are not so far away from us. But when we come to the metallic stars and the carbon stars they have not much obvious connection with the Milky Way, and they are close to us. Unfortunately, with regard to the metallic fluting stars the information is not certain, so that it is best not to say anything about it. Mr. McClean has dealt with a very small number, and he shows that they, like Dunér's stars, the carbon stars, have very little relation to the Milky Way. We thus obtain a tremendous separation between the hot stars with their great distance and the cooler stars with their smaller distance.

But we can go further. As the stars become hot in consequence of meteoritic collisions, we should expect to find nebulous conditions following suit; seeing that nebulæ are masses of meteorites, we should expect to find especially the gaseous nebulæ and results depending upon their presence in the region where the hottest stars exist.

The planetary nebulæ consist of streams of meteorites moving generally in spirals or in circular paths. There is no very great disturbance. We get a bright line spectrum from them, and we know they are practically limited to the Milky Way. We have found that the bright-line stars are limited to the Milky Way; they are simply stars involved in nebulæ. There again we get a connection between the Milky Way and nebulæ. The new stars are due to fixed nebulæ driven into by moving nebulæ, and they are also limited practically to the Milky Way; there again we have the nebulous touch. A piece of work which has not been done, but which badly wants doing, is to see whether those nebulous regions which Sir William Herschel was the first to chronicle have or have not a strict relation with the Milky Way. I have, in fact, made a preliminary inquiry into this matter, and it suggests that these nebulosities are most profusely distributed in the vicinity of the Milky Way just as is the case with the gaseous nebulæ.

(*To be continued.*)

[1] These stars are—

1830 Groombridge	7″·04 ...	Gaseous or proto-metallic.
Σ 2758...	5·196 ...	Metallic.
Σ 578...	4·049 ...	Probably metallic.
D.C. 583	3·7 ...	Metallic.

[2] Kapteyn finds small proper motions for gaseous and proto-metallic stars, but does not separate them into two groups.

SOME REMARKS ON RADIATION PHENOMENA IN A MAGNETIC FIELD.[1]

IN many articles which have recently appeared concerning the work which has been done in the study of radiation phenomena in a magnetic field, I find that, from the historical point of view, there are some statements which are not quite correct, and to which I now desire to attract attention. This appears to me desirable, as it is much easier, and much better, to test and correct errors of statement at the outset than after a lapse of time.

In the first place, it has been very generally accepted that the quartet form which occurs in the magnetic effect was first observed by M. Cornu; but on reference to the enclosed paper (*Trans. Roy. Dublin Society*, vol. vi., series ii., p. 385, read December 22, 1897), you will see that the quartet form,[2] the sextet, and other variations of the magnetic triplet were not only observed, but were photographed and exhibited to an audience in Dublin in the latter end of the year 1897. On the other hand, it was not until the following year (1898) that M. Cornu (working quite independently) announced in the *Comptes rendus* that he had observed the quartet form. Now the *Comptes rendus* being a weekly journal which is widely read, lends itself admirably to the rapid diffusion and circulation of new results, whereas the scientific *Transactions* of a local learned society are slow in appearing and little read or known outside their immediate place of publication. For this reason, the observations of M. Cornu became generally known, while mine remained unknown outside Dublin.

It is true, however, that I endeavoured to have them

[1] These remarks were addressed to Sir Norman Lockyer in the course of a correspondence, and have been thought of sufficient interest for publication.

[2] The quartets are clearly shown, as well as the triplet form, in the plate attached to the paper, and reproduced from the photographs shown at the meeting when the paper was read.