spectrum, can be submitted to low conditions of tempera­ture so as to give fluted spectra. There can be little doubt, therefore, that a cooling of the sun would be followed by a change in its spectrum, which would cease to be one of lines and become one of flutings. While the sun was acquiring its present intensely heated state, it must at some period of its history have been in a condition of temperature in which its spectrum would consist of flut­ings, and similarly it must give a fluted spectrum at some future period when it has further cooled.

The ordinary Fraunhofer spectrum gives the sum total of the line absorptions of all the various layers in the sun’s atmosphere, but by examining individual layers just off the edge of the disk we can single out the absorption lines produced by the lower layers. Thus the absorption produced by the hottest layer, the chromosphere— hottest because nearest the photosphere—is indicated by its usually simple radiation spectrum when examined in this way. If the sun were made hotter, therefore, the gases which give the simple chromosphere spectrum would have a larger share in the absorp­tion, and the main features of the Fraunhofer spectrum would be the few dark lines corresponding to these bright ones. This being so, a star which gives practically the same absorption spectrum as the chromosphere of the sun must be hotter than the average temperature of the sun’s atmosphere,—as hot as the hottest part of it. The bright central part of the sun is not very much less than the whole volume, but it is so much hotter that it gives out thousands of times more light than the atmosphere. The cool vapours in the atmosphere give the dark Fraunhofer lines by their absorption, and even if they are hot enough to give bright lines when seen on the sun’s edge they can only reduce the intensity of the dark lines. Here the difference of area between the disk representing the cen­tral mass and that representing the sun’s atmosphere is very small, and, the light from the central mass being so much more intense, we do not ordinarily see the evidences of radiation, but, in place of it, the absorption of the atmosphere. If, however, we suppose the central mass to be very small compared with its atmosphere, the total radiation of the atmosphere may be sufficiently powerful to overcome the intensity of the light from the smaller central part, so that the spectrum of such a star would contain bright lines from the exterior mixed up with the dark lines from the interior. The spectrum of a star, therefore, does not always depend upon its total diameter, but upon the relative diameters of the central mass and the outer atmosphere. It is a question of sectional areas.

Observations of the spectra of a large number of stars show that, although there is a great difference between individual spectra, they still admit of arrangement in family groups. While some stars give line absorption spectra, others give fluted spectra, and others again give bright lines. They may be conveniently arranged as follows :—

|  |  |  |
| --- | --- | --- |
|  | *Example.* | |
| Class I. ... | Stars whose spectra consist of a few  thick absorption lines. | α Lyræ. |
| Class II. .. | Stars whose spectra consist of a large | Sun, Capella, |
| number of fine absorption lines. | &c. |
| Class III... | Stars with fluted spectra, the maxima of the flutings being towards the red. | 152 Schj. |
| Class IV. .. | Stars with fluted spectra, the maxima being towards the blue.  Stars whose spectra contain bright lines,—(*a*) of hydrogen, (*b*) of unknown substances. | α Orionis. |
| Class V. .. | *β* Lyræ. |
|  |  |

This classification probably represents the stars in order of tem­perature, class I. being the hottest.

Although different stars may contain lines of identical wave­lengths, the thickness of these lines is very liable to variation in passing from one star to another. The thickest lines in the solar spectrum are H and K in the ultra-violet, both of equal thickness ; on passing to some of the stars, however, we find H broad with K thin, and in others H without K. This is similar to what occurs in our laboratories when we study the spectrum of calcium, the substance which gives the lines H and K : at the temperature of the electric arc the blue line of calcium is very intense, while H and K are scarcely visible ; but on passing to a higher temperature, that of the induction spark, H and K appear. In those stars which give H without K, namely, those in class I., it is probable that there is a very high temperature competent to separate H and K, just as H and K were conjointly separated from the blue line. A further indication of high temperature in the stars belonging to class I. is that the few lines which do occur in their spectra are almost the exact counterparts of those which occur in the hottest layer of the sun, hydrogen lines being especially prominent. The passage from class I. to class II. is by no means sudden : there are stars with every gradation of broad and fine lines. It will readily be understood that the stars of class II. are probably not so hot as those belonging to class I., and the change in the spectrum is

supposed to be due to new combinations of the original substances, rendered possible by a reduction of temperature ; that is, new lines are formed at the expense of the old ones. The hydrogen lines are very prominent in class II., though not so intense as in class I. The stars of these two classes may be grouped together and called hydrogen stars. Stars belonging to class III. exhibit unmistakable evidence of carbon vapour. Sodium and iron are also often present. All the stars in this class, of which fifty-five are known, agree in having a reddish tint. They are usually faint, and seldom exceed the fourth magnitude. There is evidence of the existence of carbon vapour in the sun’s atmosphere, depending upon one solitary fluting, and hence stars of this class probably represent what the sun would become if it were cooled. Class III. therefore represents a lower temperature than classes II. and I. Class IV., containing 475 known members, includes the stars giving fluted spectra with the darkest edges of the flutings towards the violet. The origin of the substances of which they are mainly composed is not at present known. All the principal bands are absolutely unchanging in position, although there is considerable variation in the inten­sities. The bands in the spectrum appear to result from the rhythmical vibrations of the same substance, probably a complex one. Besides this unknown substance, there are also metallic lines in many of the stars, the complete spectrum consisting of the banded spectrum superposed upon the line spectrum. The metallic lines are generally seen in the spectra of sodium, iron, magnesium, or calcium ; the hydrogen lines are very inconspicuous.

These considerations suggest the question of stellar evolution. Comets and nebulæ are now supposed to consist of clouds of stones or small meteorites, and the difference between their spectra may be due to a difference of temperature, that of the nebulæ being highest. Comets ordinarily give the spectrum of carbon, and, if we imagine such cometary matter to surround a central bright nucleus, we have the spectrum of a star of the third class. On the nebular hypothesis, starting with ordinary cometary materials, the small masses resulting from the first condensations gravitate towards each other, and their energy becomes heat by the retardation of their motion on coming in contact. As soon as the condensed mass is hot enough, it gives a fluted spectrum, like stars of the third class. As the energy of condensation increases, the temperature is raised and the spectrum passes from that of a third class star to that of a second class star, and then to that of a first class star. On the subsequent cooling of what is then a star the successive stages will be again passed through in inverse order. According to this view, we ought to find fewer hydrogen stars than carbon stars, because every star is a carbon star at two periods of its existence, but a hydrogen star only once. On this point, however, nothing definite can be stated, as the stars of classes I. and II. have, in con­sequence of their greater brightness, received more attention than carbon stars.

In 1866 a star of the tenth magnitude in the constellation Corona suddenly flashed up iuto a star of nearly the first magni­tude ; its spectrum as a tenth magnitude star differed from its spectrum as a first or second,—the latter containing bright lines of hydrogen. In about a month it again became a tenth magni­tude star and appeared as if nothing had happened to it. There can be little doubt that here there was a sudden increase of tem­perature, as evidenced by the spectrum becoming like that of the chromosphere of the sun. Ten years afterwards a new star appeared in Cygnus ; it had never been seen before, but appeared suddenly as a third or fourth magnitude star. In about a year it gradually dwindled down to the tenth magnitude, and its spectrum became that of a nebula. This mass was at a stellar distance, but it cannot be considered to have been a large mass of incandescent material, for in that case it would have taken millions of years, instead of only one, to cool down to the tenth magnitude. A possible explanation of most of the new and variable stars is to be found in the meteorite theory : the innumerable components of one group of meteorites colliding with those of another group would be competent to give out light sufficient to make the whole appear as a star. Each meteorite gives only a little light, but the total must be very considerable. The new star in Corona, and similarly all new stars, may have been the result of a collision of two groups of meteorites. They die out quickly because the com­ponents are small and far apart. The sudden increase in the bril­liancy of the star in Cygnus would be produced by a collision of a meteor swarm with the star already existing. (J. N. L.)

SUN-BIRD, a name more or less in use for many years,1 and now generally accepted as that of a group of

1 Certainly since 1826 (*cf*. Stephens, *Gen. Zoology,* xiv. pt. 1, p. 229). Swainson (*Nat. Hist. and Classif. Birds,* i. p. 145) says they are “ so called by the natives of Asia in allusion to their splendid and shining plumage,” but gives uo hint as to the nation or language wherein the name originated. By the French they have been much longer known as “ Souimangas,” from the Madagascar name of one of the species given in 1658 by Flacourt as *Soumangha.*