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On the Presence of Highly Stripped Atoms in the Solar Corona

In the November issue of SCIENCE AND CULTURE, Prof. M. N. Saha has announced a most important discovery made by Dr B.Edlen of Upsala, namely, the identificaton of the hitherto mysterious emission lines observed in the spectrum of the solar corona. According to Edlen these coronal lines are due to certain forbidden transitions of the familiar atoms of iron, nickel and calcium which have lost a large number of electrons. For instance, the green coronal line λ 5303 is produced by a forbidden transition of an iron atom which has only half of its normal complement of 26 electrons left. The obvious question now is, "How do such highly stripped atoms appear in the solar envelope?"

The theory which attributes coronal light to a sort of large-scale "meteor flash" in the solar envelope has always been of a *faute de mieux* character and Edlen's discovery practically rules it out, even as a possibility. Prof. Saha has suggested an alternative view according to which "it is quite possible that stripped iron and nickel atoms are produced in the chromosphere, or somewhat lower, as a result of some type of nuclear reaction analogous to uranium fission". But there are difficulties in this view as well, as he himself recognises. This is my justification for presenting yet another alternative view, which seems to have possibilities.

There are many phenomena of the solar envelope which indicate that matter is being ejected continuously, or at least quite frequently, from the deep interior of the sun. From a study of a variety of such problems (some of the results of which have been published in recent papers in the *Indian Journal of Physics*) I have found that many of the major peculiarities of prominences, dark markings, the chromosphere, the reversing layer etc., can be quantitatively explained on the assumption that the matter taking part in these phenomena has its origin in the core of the sun which roughly corresponds to a sphere of ⅓ the radius of the sun. At a distance of ⅓ radius from the centre of the sun the temperature, according to the current theories of the internal constitution of stars, is of the order of 20×10^6 degrees. At this temperature and under the conditions of pressure and density at this depth of the sun the degree of ionisation of the iron atom is so extreme that 95% of the iron atoms must have lost between 24 and 26 electrons. Now let us suppose that a mass of such practically bare iron nuclei is ejected outwards from its normal place of occurrence. Clearly such nuclei will penetrate eventually into the envelope, provided the velocity of ejection is sufficient, and they will reach different levels in the envelope depending upon the velocities with which they come out of the photosphere. From the papers mentioned above, it is evident that the velocities actually observed in the quiescent prominences of the average type and in the chromosphere and the reversing layer, are of the order necessary for the constituent atoms to reach the observed heights of these phenomena. The calculations that have been made for these cases are not strictly applicable to the outer corona, but a rough estimate based on the same method of calculation shows that a particle ejected from the core would have to issue from the photosphere with a velocity of the order of 50 km./sec. in order that it may reach the outer corona. This velocity is quite consistent with the velocity of expansion of the solar corona as derived from the Doppler displacements of the Fraunhofer lines of the corona. From his observations of the 1922 eclipse Moore derives a velocity of expansion of the corona which amounts to 26 km./sec. at 20′ from the limb, and from the 1932 eclipse Grotrian gets a value of the order of 20 km./sec. on the average with an indication that the velocity is less at 20′ than at 10′ from the limb. Naturally these values do not nearly possess the accuracy of the velocities available for the reversing layer and the chromosphere, but they seem to be consistent with the ideas I have put forward in the above papers. It seems, therefore, a fair supposition that the corona is being supplied with matter from the deep interior in the same way as the other strata of the solar envelope, the stratification of the envelope being due to the occurrence of particles with different ranges of velocity.

Now the important question is, "Would the stripped atoms originating in the deep interior of the sun retain their extreme degree of ionisation on reaching the corona?" Most certainly they should not, if we go by the current theories of ionisation which are based on the assumption of convective and thermodynamic equilibrium. But convective equilibrium presupposes that the convecting matter is moving so slowly that there is free exchange of energy between it and its surroundings at every moment. If the velocity of convection exceeds a certain limiting value, the degree of ionisation calculated on the basis of convective equilibrium will be unreliable. It is not possible to estimate off hand what this limiting velocity should be for the interior of the sun. In a paper in the *M. N. R. A. S.* which has just been received, Sir A. S. Eddington estimates that hydrogen atoms descending from the top of the layer of convective instability in the sun (a shallow layer of about 300 km. extending from the level where the temperature is 6500° to a level of about 18000°) to the bottom with a velocity of the order of 1 km/sec. should be mostly neutral and conversely hydrogen atoms ascending from the bottom of this layer with the same velocity would reach the top in a mostly ionised condition. Incidentally it may be mentioned that Eddington has shown in the above paper that one consequence of the failure of the state of ionisation of ascending matter to keep pace with the changing conditions is that the photosphere and the reversing layer will contain high frequency radiation in excess of that given by Planck's law. Undoubtedly in the deep interior also the same sort of thing will happen and the state of ionisation will lag behind the varying conditions of pressure and temperature, provided the speed of the convecting matter is sufficiently high. If almost depleted iron atoms are ejected from the core, as postulated in the present note, then they may very well reach the outer corona in a highly stripped condition if their speed is sufficient to cause a breakdown of ionisation equilibrium. Now the observed speed of the coronal particles seems to be of the order of 20 to 30 km./sec. and one may safely say that their velocity must have been many times more during their passage through the sun's interior, if they really started from the neighbourhood of the core. It would be surprising if the state of ionisation of matter ascending with such enormous velocities did not depart very greatly from what one would expect from theories of ionisation equilibrium. Even if the iron atoms lost about half the ionisation with which they started they would reach the outer corona with 13 out of their normal complement of 26 electrons missing. This will also imply that the radiation passing out of the solar envelope will contain a considerable proportion of very high frequency radiation, probably of the type of soft X-rays.

I do not pretend that the above view of the origin of highly stripped atoms of the corona is free from difficulties, but it appears to be well worth a closer examination.

A. K. Das

Solar Observatory,
Kodaikanal, 24-11-1941.