NEWS AND VIEWS

Explaining the Deuterium in the Universe

THE recent detection of deuterium in the Orion Nebula and near the galactic centre has stimulated the interest of astronomers in the processes by which this isotope is produced. Previously the presence of deuterium was definitely established only in the solar system; other measurements merely gave upper limits. Now it seems that the abundance of deuterium relative to hydrogen near the galactic centre is comparable with the terrestrial values, and an even higher deuterium abundance is deduced from the relative strengths of HCN and DCN lines in the Orion Nebula. It is conceivable that some fractionation of D and H occurs in molecule formation, in which case it is not impossible that the terrestrial value, $D/H \sim 10^{-4}$, is fairly widespread in the Galaxy.

Astronomers study the chemical composition of objects in the Galaxy with the hope of discovering to what extent their composition is characteristic of the Galaxy at birth and to what extent it is determined by nuclear reactions which have occurred during the galactic lifetime. It is known that nuclear reactions in stars gradually change the chemical composition of the stellar material and that, if stars lose mass into the interstellar medium, newly formed stars will have a chemical composition different from that of earlier generations of stars. Normal processes of stellar nucleosynthesis do not, however, produce deuterium, which is very easily destroyed by nuclear reactions at the high temperatures in stellar interiors.

It has been known for some time that a relatively smooth abundance of deuterium in the Galaxy could be explained if the life history of the Universe is correctly described by a Big Bang cosmological theory. According to this theory, in which the Universe was initially very hot and very dense and subsequently expanded and cooled, the chemical composition after the initial stages was essentially a mixture of hydrogen and helium and a very small amount of deuterium. The theory also predicts that the Universe should now be filled with microwave radiation which is a highly redshifted relic of the radiation present in the hot early stages of the expansion. The discovery of a cosmic microwave background with a temperature of 2.7 K stimulated interest in the Big Bang theory, which further predicts a relation between the present mean density of the Universe, the microwave temperature and the proportion of helium produced. Although the present mean density of the Universe is not known accurately, all expected values give an initial helium production which is approximately in agreement with observations. By contrast, a deuterium abundance comparable with the terrestrial value is only obtained for the lowest allowable values of the mean density of the Universe; for higher values less deuterium is produced.

If there proves to be a deuterium abundance throughout the Galaxy which is comparable with the terrestrial abundance, the simplest explanation is that the deuterium was produced in a Big Bang. It is not quite as simple as this, for some deuterium must have been destroyed in matter that has passed through stars, but, given a model of galactic evolution, it should be possible to allow for this destruction. Even if it is plausible that the deuterium is primaeval, it is nevertheless necessary to ask whether there are any other processes that could produce a substantial amount of deuterium during the galactic lifetime.

There are two reasons for asking this question. The first is the obvious one that, if there are production processes as well as the destruction mechanisms just mentioned, they must both be studied along with the primaeval abundance in trying to understand the present observations. The second reason is that, although a Big Bang theory is capable of explaining the observed deuterium abundance, one is hesitant to believe that the mean density of the Universe is as low as this would require. To obtain the required primaeval helium abundance almost all the matter in the Universe has to be the matter which is known to be contained in galaxies, so that the intergalactic medium must be essentially non-existent. Although there is still no sure detection of a general intergalactic medium there are several pointers to its existence. For example, attempts to understand the formation of galaxies are much more difficult if it is demanded that most of the matter in the Universe went into galaxies than if the intergalactic medium is still the principal form of mass in the Universe.

For these reasons, Hoyle and Fowler consider on page 384 of this issue of *Nature* whether substantial amounts of deuterium can have been produced in the galactic lifetime. Although deuterium is destroyed efficiently by thermonuclear reactions inside stars, there is one obvious way in which it can be produced. This is by breakdown or spallation nuclear reactions in which α particles are hit by fast protons moving at a significant fraction of the speed of light. Various authors, including Hoyle and Fowler, have previously suggested that, as a result of such reactions during the formation of the solar system, the terrestrial value of D/H might be higher than the initial value for the solar system. Hoyle and Fowler now suggest that these spallation reactions may have occurred in outgoing shock waves from a supernova explosion, or as the result of the explosion of a more massive object, and they estimate that there may have been sufficient explosions to give a general galactic abundance of deuterium comparable with the abundance in the solar system.

It is clear that much more work needs to be done before the relative importance of primaeval and galactic production of deuterium is certain. It is also obvious that there will be continued interest in the subject that Hoyle and Fowler have previously named "deuteronomy".—R. J. T.