mechanism of particle acceleration in such stars is not quite clear, for variable magnetic fields of the kind observed on the Sun arise in all probability as a result of interaction of external convective zones with the general magnetic field of the star. It is possible that the acceleration occurs as a result of divergence of the directions of magnetic and angular momenta.

In stars similar to the Sun, where the external convective zone destroys the magnetic field near the surface and carries the reaction products into the deeper layers, a too large flux of fast particles would be required (at least 100,000 times more than the existing) for producing the observed concentration of Li and Be.

It follows that some other mechanism for the formation of these elements has to be introduced. If it should turn out that D, Li, Be and B are equally abundant in all cosmic objects, including interstellar matter, one should assume evidently that the theories considering the element formation in terms of general cosmology possess a certain amount of truth.

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10. GENERAL DISCUSSION

I. P. SELINOV: Anomalous abundances of Te and Xe isotopes in meteorites and in the Earth permit us to draw some conclusions concerning the age of uranium and the processes of nucleogenesis. According to the estimate by Hoyle the amount of ^{254}Cf disintegrated during a super-nova outburst is of the order of 10^{29} g or 10^{-4} of the stellar mass. According to the fission-yield curve the isotopes of Te comprise about 1% of the mass of fission products. The abundances of Te 128–131 are anomalously high, due to the fission of heavy nuclei. The element abundances do not permit us to draw any conclusions about the *r*-process. The isotopes of Te and Xe with even mass numbers give evidence in favour of the *r*-process (anomalously high abundances). But the amount of Te in meteorites and in Earth is about 1000 times less than it should be if formed during the outburst. The Sikhote-Alin meteorite shows the same anomaly. We may conclude that the heavy elements of the solar system have been formed not in a single super-nova outburst, but as a result of mixing from the totality of outbursts. According to Hoyle, this gives a definite estimate for the age of uranium.

L. H. ALLER: Studies of the abundances of elements in the first two rows of the periodic table in B stars and in the Sun, as carried out by model atmosphere methods, have shown:

1. The more precise the method of analysis, the less the difference between the Sun and the young stars.

2. Uncertainties in the atmospheric models, *f*-values and damping constants limit the accuracy attainable, so that small differences would not be detected.

J. C. PECKER (comment on Mrs Burbidge's paper): Les données sur les abondances citées par Mrs Burbidge sont issues de calculs d'un type 'classique' (courbes de croissance...) qui supposent l'équilibre thermodynamique local (E.T.L.) réalisé dans les atmosphères stellaires. En réalité, il n'en est rien; et le fait de tenir compte des écarts à l'E.T.L. peut entraîner des modifications sensibles: ainsi, dans le cas du Titane, dans la photosphère solaire, il faudrait multiplier l'abondance 'classique' par un facteur de l'ordre de 8 à 10. Les valeurs citées par Mrs Burbidge doivent donc être considérées comme provisoires.

W. P. BIDELMAN: The existence of the horizontal branch and RR Lyrae stars is an observed fact for population II stars. Presumably these objects have all been through the

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red giant stage of their evolution, and it may be expected that the abundances of the elements in their central regions, at least, should be anomalous.

I would like to ask whether we should not also expect such 'horizontal branch' stars in population I. In the absence of any definite theoretical argument against this hypothesis, I would like to suggest that several types of unusual stars of the early spectral classes, especially the peculiar A stars and the metallic-line stars, both of which seem to have quite abnormal abundances of the elements, may in fact be such stars of population I analogous to the horizontal branch stars found in globular clusters and elsewhere in population II. A similar suggestion was made several years ago by Dr O. J. Eggen in the case of several F-type short-period variables of small range, such as δ Delphini and ρ Puppis.

Other objects which may be 'returning' stars in the early spectral classes include the β Canis Majoris stars and the cepheid variables. Also some of the sharp-line, apparently non-rotating, stars of classes O, B and A may belong to this class. It is a curious fact that such stars are found to be the earliest-type members of several galactic clusters and stellar associations, i.e. Praesepe, the Hyades, the Coma and Ursa Major clusters, the Scorpio-Centaurus cluster, and the 10 Lacertae group. Some characteristics of these 'returning' stars would be a lack of rotation, a tendency to pulsation of some type, and in some cases at least, peculiar abundances of the elements and an observable magnetic field.

J. L. GREENSTEIN: Since part of the philosophical attractiveness of the theory that elements are formed largely in stars have now begun to disappear with the increased complexity of the processes required, I would like, as one who helped to revive interest in observational aspects of this field in 1951, to make some critical remarks. Except for the case of technetium, which has no stable isotopes, we really are unable to point to stars in which element synthesis, beyond helium, is now occurring. Martin Schmidt, in a paper presented at the Symposium on the H-R diagram reaches the conclusion that the major part of the synthesis of the heavy elements and of iron occurred in the first 20% of the life of the Galaxy. The measurements of relative abundances in the Sun (which is more than four billion years old) and in young stars in galactic clusters (less than a billion years old) show that the metal abundances are substantially unchanged. Only a few stars may show higher metal abundances, than the Sun. The only plausible conclusion is that the Galaxy is twice as old as the Sun and that quantitatively trivial amounts of metal synthesis have occurred in the last five billion years. The number of super-novae will have been much greater and even their mass and type will have been different in the early years of our Galaxy, and the rate of metal synthesis very much greater.

We should be prepared to find evidence not only of some systematic change of abundances with time, but of differences dependent on location in the Galaxy.

F. HOYLE: There is no reason to speak about the first 20% of the life of the Galaxy, because the Sun is much younger than the Galaxy. The age of Sun is about 5×10^9 years, that of Galaxy about 9×10^9 years.

JA. B. ZELDOVICH: If, as pointed out by Greenstein, the bulk of heavy elements has been formed early in the life of the Galaxy—then the formation processes had to proceed very fast in massive stars, which have finished their evolutionary path by gravitational formation of neutrons. It follows that per unit mass of ejected heavy elements, ninety-nine units had to remain in a condensed state. The total mass of extinct stars ought to be far larger than the mass of hot stars formed from the ejected matter. The crucial question is: whether such extinct stars do actually exist?

J. L. GREENSTEIN: The question of the ultimate fate of extinct stars is yet unsolved. White dwarfs comprise only some few per cent of the total stellar mass. But a final explosion is energetically possible since gravitational energy is large.

E. SCHATZMAN: L'accrétion d'une petite quantité de matier par une naine blanche peut entraîner une augmentation suffisante de sa densité centrale pour que les phénomènes de capture béta se produisent et abaissent la compressibilité adiabatique au dessous de la valeur 4/3 dans une région étendue de l'étoile. L'étoile peut alors devenir dynamiquement instable et exploser. Il est possible que la matière des étoiles dégenérés puisse ainsi être rejetée dans la Galaxie.

M. SCHMIDT: An important problem in the application of theories of nucleogenesis to the concept of metal enrichment of the interstellar gas is the rate of diffusion throughout the galactic system. As has been mentioned before, most of the metal enrichment seems to have taken place more than 5×10^9 years ago. If most of the enrichment took place in the earliest epoch, when the gas in the system was distributed throughout the halo, the diffusion problem is reduced because the combination of rotational motion of the gas with high z-velocities may have led to rapid mixing.

Miss Roman has found that a good correlation exists between the U–B excess and the z-velocities of F stars. This suggests that a stratification of metal enrichment in the halo exists.

I am tempted, then, to believe that an important phase of metal enrichment took place in the halo in the earliest epoch, while the gas was contracting into the disk.

I. M. GORDON spoke briefly on 'The physical nature of non-thermal ultra-violet emission in the spectra of T Tau stars and the origin of cosmic rays'.

The conclusion about the non-thermal nature of the peculiar ultra-violet continuous emission in the spectra of T Tau stars made independently by V. A. Ambartsumian and the author was fully confirmed by the spectrophotometric investigations by K. H. Böhm. All the peculiar features of radiation in question can be interpreted by the theory of excitation of emission lines in the atmospheres of non-stationary stars by synchrotron radiation of relativistic electrons.

The results give strong support to the suggestion made earlier that the T Tau stars, and the unstable stars of some other types, are an important cosmic-ray source in the Galaxy. From this point of view the peculiar anomalies of Balmer decrement and the ultra-violet emission in the cold unstable stars are due to the synchrotron emission and are connected with the creation of cosmic rays in the atmospheres of these stars. The full account of this work was published in the *Astr. J., Moscow*, **35**, 458, 1958.

W. A. FOWLER (concluding remarks): No one has successfully produced a thermonuclear chain reaction in the laboratory. However, all experiments have been carried out at low density in apparatus of relatively small dimensions. This situation may soon be rectified in several countries. At the same time, we know that thermonuclear explosions have synthesized ^{254}Cf. Thus, one of the processes under consideration in this joint discussion has already been reproduced here on our Earth.

Thank you and good day.