s-PROCESS ELEMENTS AND GALACTIC EVOLUTION

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I. INTRODUCTION : Among the observations of heavy s-process elements at the surface of very metal poor stars (population II stars), Peterson 1976 and Spite and Spite 1977 recently showed that the ratio of the abundances of these elements against that of Fe increases with increasing [Fe/H].
These elements are supposed to be synthetized by slow neutron capture on iron peak nuclei inside red giant stars. For this reason, they are considered as secondary elements with respect to iron,(see eg. Audouze and Tinsley 1976) : they cannot be formed in first generation stars.

This observational increase of [s/Fe] with [Fe/H] can be interpreted in terms of galactic evolution. Schramm and Tinsley 1974 and more recently Butcher 1977 have built up some models to account for their evolution. In the present paper, the evolution of the s-elements is analyzed by taking into account the mass of the stars responsible of their formation and by considering the different possible mechanism which have been proposed to explain their nucleosynthesis (Ulrich and Scalo 1972, Ulrich 1973, Sackmann , Smith and Despain, 1973, Iben 1975).

II. THE EVOLUTION MODEL

The "simple" model of galactic evolution used here comes from Vigroux et al. 1976. The main parameters are the rate of star formation and the initial mass function which is given by the Salpeter relation.

The star lifetimes are specifically taken into account which means that we do not use the instant recycling approximation. Moreover the ejected mass is a continuous function of the stellar mass. The ejected mass has been calculated by using the recent analyses of Iben and Truran (1977) and of Arnett (1977). We have made two different assumptions regarding the s-process material : in case 1, we assume that the stars of any mass produce a constant number of s-elements relative to the

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https://doi.org/10.1017/S0252921100067555 Published online by Cambridge University Press

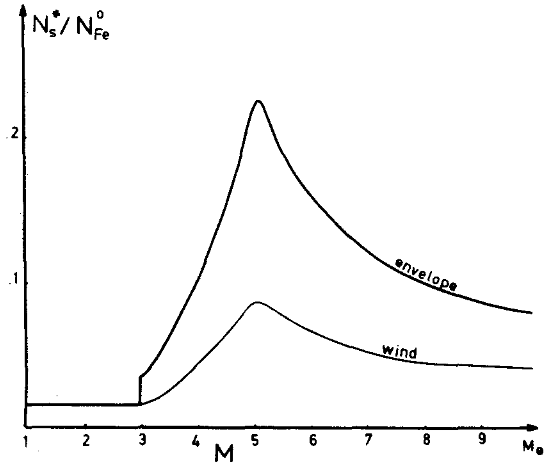

Figure 1 : The number N_s of s-process nuclei produced by a star of mass M and ejected by the stellar wind or with the envelope, respectively. This number is normalized to the number N_{Fe}^o of the iron-group progenitors present when the star was formed. The results are from Truran and Iben (1977) for star models of solar initial composition.

number of iron nuclei ; in the case 2, we assume after Iben and Truran (1977), that massive stars ($M \geq 3\ M_\odot$) are the main contributors to this process (fig. 1).

III - CONTRIBUTION OF MASSIVE STARS

The abundances of Fe and s-elements as a function of time have been calculated with our model, they are adjusted to the solar abundances compiled by Cameron (1973). We show in figure 2 the Z(s)/Z(Fe) ratios as a function of time in cases 1 and 2. The slopes are positive in both cases since the s-process is secondary. Moreover, the slope of case 2 (massive star production) decreases at large values. This variation is due to the short lifetimes of the massive stars and the birth rate function decreasing with time leading to more important contribution of the massive stars at early phases of the galactic evolution.

This effect is even more pronounced if, in case 1, we distinguish the contribution of very massive stars ($M \geq 9\ M_\odot$) and that of less massive stars ($M \leq 3\ M_\odot$). (fig. 3)

Therefore we conclude that if s-process elements are mainly produced in high mass stars, the production is important in the early phases of the galactic evolution but also that the Z(s)/Z(Fe) slope decreases

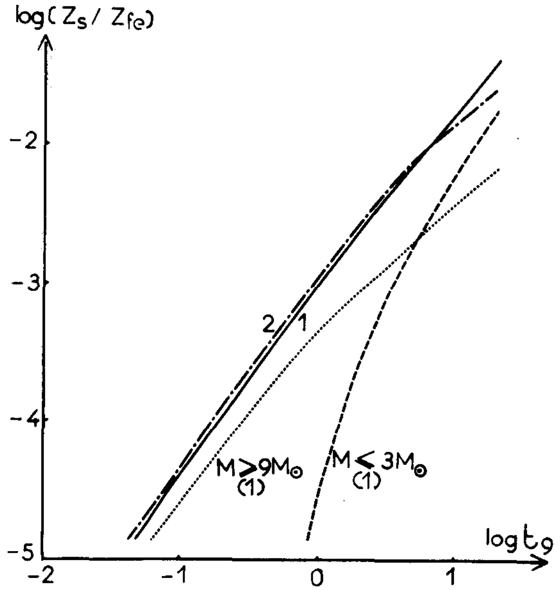

Figure 2 : The logarithm of Zs/ZFe ratio is plotted against the logarithm of time ($t_9 = 10^9$ years). In curve 1, any star is supposed to produce a number of s-elements constant relative to iron. In curve 2, the s-element number is generated according to the figure 1. In case 1, the contributions of very high massive stars ($M \geq 9$ M⊙) or less massive stars ($M \leq 3$ M⊙) are presented as a function of time.

in the later phases.

If s-process elements come mainly from low mass stars $M \lesssim 3$ M⊙ (fig. 2), the contribution begins later ($T \gtrsim 10^9$ years) but the Z(s)/Z(Fe) slope increases rapidly and continously.

IV - COMPARAISON WITH OBSERVATIONS

The important variation of [Ba/Fe] = f([Fe/H]), observed by Peterson (1976) and Spite and Spite (1977) can possibly be interpreted with our model : In our simple close model, the calculated Fe abundance is an increasing function of time (in agreement with the conclusions of Mayor 1977) In this condition, the observed Ba/Fe ratio is strongly increasing in the early stages of galactic evolution and the slope of Ba/Fe decreases later.

A first interpretation of our analysis would be to say that the s-process elements are mainly formed in massive stars. Consequently it would favour the nucleosynthetic process producing neutrons from ^{22}Ne (α , n)^{25} Mg and occuring in stars of M $\geq$ 3 Mo (Iben and Truran, 1977).

This interpretation is still provisional : much work is needed to perform more refined analysis on the observations of the s-elements in various evolved and non evolved stars in order to set up more definite conclusions on the evolution of s-process elements.

We would like to thank Drs François Spite and Laurent Vigroux for their various contributions which helped us to prepare this paper.

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