ACCRETION FROM AGB WINDS

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ABSTRACT. We have obtained very intriguing results for the correlations of r- and s-process elements with alpha elements in field metal-poor stars. We can separate the Population II stars into two subgroups, PopIIa and PopIIb, depending on the behavior of these correlations. We developed a scenario for the formation of these stars, linking their origin to globular clusters. We explain the PopIIb stars by assuming that while they belong to a globular cluster, they can accrete the s-process enriched gas ejected by the cluster's AGB stars.

1. Introduction

We have obtained accurate relative abundances for a homogeneous sample of 21 unevolved field mildly metal-poor ([Fe/H]$\sim$-1) stars from the analysis of high resolution, high signal-to-noise (S/N$\geq$200) spectra (Jehin et al. 1999). Looking for correlations between the element abundances, we found that the α-elements (Mg, Ca, Ti) and the iron-peak elements (Cr, Fe, Ni) are well correlated with each other, and the abundances of the rapid neutron-capture (r-process) elements (e.g. Eu) are well correlated with those of the α-elements, which is in agreement with the generally accepted idea that those elements are produced during the explosion of massive stars. For the slow neutron-capture elements (s-process elements Sr, Y, Zr, Ba, La, Ce), we find that the stars can be separated into two subpopulations. For those in PopIIa, the abundances of the s-process elements vary little while those of the α elements increase up to a maximum value. The stars in PopIIb show a large range in their s-process elements abundances, while they show a constant and maximum value for the abundances of the α elements. We called this behavior the "two-branches diagram". The mixed r- and s-process elements Nd and Sm exhibit an intermediate behavior. The two-branches behavior extends to more field stars, as shown in Figure 1, where we have added low-metallicity ([Fe/H]<-0.6) stars coming from other studies (Zhao and Magain (1991), Nissen and Schuster (1997)). As our metallicity range for (thick) disk stars is rather limited towards metal-poor stars (-1.3<[Fe/H]<-0.6), we have added in Figure 2 the data obtained by Edvardsson et al. (1993) for stars of various metallicities. We see immediately that the higher metallicity stars *do not* follow the relation obtained for metal-poor stars, but scatter mostly through the upper left part of the diagram.

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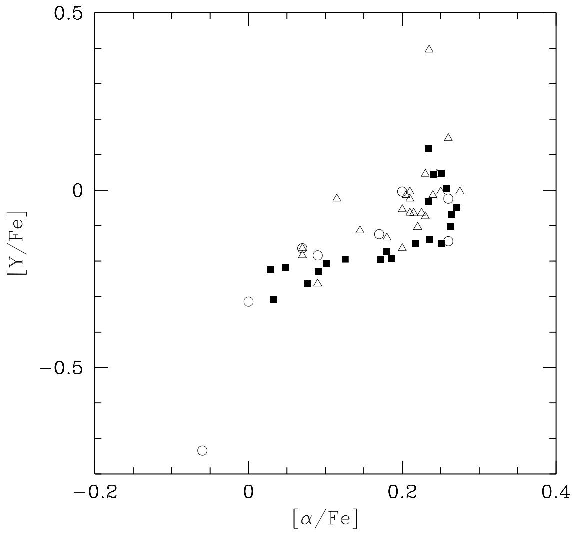

Fig. 1. Correlation diagram for [Y/Fe] versus [α/Fe] with our data (full squares), the data of Zhao and Magain (1991) (open circles) and the data of Nissen and Schuster (1997) (open triangles). Only stars with [Fe/H] < -0.6 are plotted.

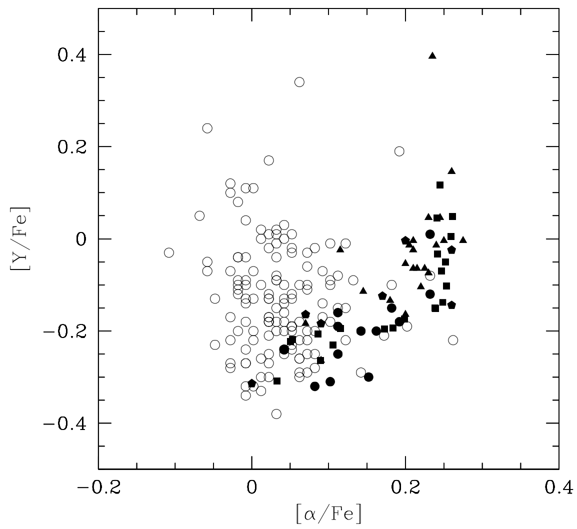

Fig. 2. Correlation diagram for [Y/Fe] versus [α/Fe] with our data (full squares), the data of Edvardsson et al. (1993) for [Fe/H] > -0.6 (open circles), for [Fe/H] < -0.6 (full circles), the data from Nissen and Schuster (1997) (full triangles), and the data from Zhao and Magain (1991) (full pentagons)

To explain these results we have developed the EASE scenario, which links the metal-poor field stars to the globular clusters. The observations and the EASE scenario are described in more details in Jehin et al. (1999).

One crucial piece of this scenario consists in explaining how unevolved stars (PopIIb) can get enriched in s-process elements while the α elements abundances remain constant. The s-process elements are mainly produced in asymptotic giant branch (AGB) stars, where they are brought to the surface through dredge-up processes. The AGB stars lose a large fraction of their mass through stellar winds or superwind events, releasing the s-process elements enriched gas in the interstellar medium. Main sequence stars can accrete this matter, thereby enriching their surface abundances in those elements. However, in order for accretion to be efficient, the density of the enriched gas should be large, the relative velocity of the accreting star with respect to the gas should be low, and the time during which the accretion takes place should be long. For these reasons, we postulate that the accretion process has to take place in globular clusters, since the stars we observe are not in binary systems. Later, those stars escaped from the cluster, either by evaporation or by the cluster's disruption.

The idea that the gas ejected by the AGB stars in globular clusters can be accreted by other stars in the cluster is not an entirely new one. Observations of globular clusters show that they contain much too little gas or dust, compared to what is lost by their AGB stars, and globular cluster stars also show many abundance anomalies. Many authors have been intrigued by the fate of the gas in globular clusters, and among them, Scott & Rose (1975), Faulkner & Freeman (1977), VandenBerg & Faulkner (1977), VandenBerg (1978), and Scott & Durisen (1978), and accretion has already been suggested as a plausible mechanism to explain abundance anomalies (D'Antona et al. 1983, Faulkner 1984, Faulkner & Coleman 1984, Smith 1996). It is interesting nonetheless to come back to this question and study it in more details in the light of the new observations.

2. Mass Lost by AGB Stars

When a star reaches the AGB phase it starts losing a large fraction of its mass. We show in Figure 3 the fraction of the cluster's initial mass which is re-injected in the cluster as gas. To obtain these results we have assumed a power-law initial mass spectrum of index α and lower and upper mass limits m_l and m_u, we used the fit by Bahcall & Piran (1983) for the stellar lifetime on the main sequence, and the Weidemann & Koester (1983) results for the final stellar masses. Details can be found in Thoul & al. (2000).

It is interesting to note that most of the gas is re-injected into the interstellar medium within the first 10^9 years. The choice of the power-law index is of course crucial to the results. For a Salpeter IMF ($\alpha = 2.35$) about 20% of the cluster's initial mass is re-injected into the ISM as gas in 10 Gyrs, while this fraction is as high as 60% if $\alpha = 1.5$.

3. Fate of the Gas

Smith (1996) has derived criteria for the fate of the gas ejected by AGB stars in globular clusters, by comparing the stellar-ejecta speed to the cluster's escape speed. He

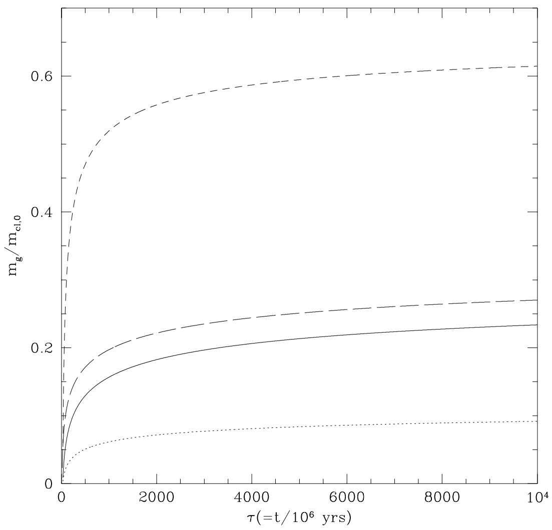

Fig. 3. Mass ejected by the AGB stars. We have used $\alpha = 2.35$, $m_l = 0.1$, and $m_u = 10$ (plain line); $\alpha = 1.5$, $m_l = 0.1$, and $m_u = 10$ (short-dashed line); $\alpha = 2.35$, $m_l = 0.01$, and $m_u = 10$ (dotted line); $\alpha = 2.35$, $m_l = 0.1$, and $m_u = 20$ (long-dashed line).

has shown that using present-day parameters, many Galactic globular clusters are sufficiantly bound to retain this gas in the cluster's central regions, forming a reservoir of gas. The gas will accumulate in the cluster's center between passages through the galactic plane, at which time the cluster will be swept clean of the gas.

4. Accretion of Gas in Globular Clusters

The gas in the cluster's core can be re-accreted by the cluster stars. The accretion rate can in principle be easily calculated using Bondi's (1952) formalism, as described in more details in Thoul & al. (2000). The main difficulty lies in the evaluation of the parameters entering the calculation, such as the initial mass spectrum, the globular cluster parameters (size, mass, concentration,...) and dynamical evolution, the energy sources (novae, hot stars,...), the stellar dynamics in the cluster (masses, orbits, velocity, mass segregation,...), the stellar composition, the AGB stellar mass loss rates, the AGB stars ejecta properties (gas versus dust, velocity, temperature, pressure, density) and chemical composition,...

Using "reasonable" values for these parameters, we were able to estimate the amount of gas accretion in tightly bound globular clusters. We found that in clusters such as 47Tuc and M15, the accretion can be very efficient, with up to about 90% of the gas being re-accreted. Most of the accretion takes place at early times, i.e., during the first 10^9 years.

5. Conclusions

A considerable fraction of the initial globular cluster's stellar mass is re-injected into the intracluster medium through AGB stellar mass loss. This gas can remain in the globular cluster's central regions, at least if the cluster is tightly bound. Some stars in the cluster will be able to accrete this gas. The total amount of accretion can be large in some cases. On the other hand, even a small amount of accretion will significantly affect the surface composition of main sequence stars. Observations of the chemical composition of those stars will reflect their surface composition, which can be different from their "real" chemical composition. This could explain the enrichment in s-process elements observed in mildly metal-poor field stars.

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