The Role of Z=0 AGB Stars on the Early Chemical Enrichment
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We present theoretical evolutionary models for \(Z=0\) stars in the mass range \(4 \leq M/M_\odot \leq 8\) from the pre-main sequence up to the AGB phase. Contrary to previous calculations we found that these stars develop normal thermal pulses and third dredge-up episodes. Special attention is devoted to analyze the chemical enrichment in the envelope due to the above mechanisms. As a consequence, we show that these stars become carbon and nitrogen rich. Using different IMFs proposed in the literature for the Population III stars, we study their contribution to the pre-galactic chemical enrichment. It is found that \(Z=0\) AGB stars could significantly contribute to \(^7\text{Li}, ^{12}\text{C}\) and \(^{14}\text{N}\) and produce extreme non-solar \(^{24}\text{Mg}/^{25}\text{Mg}/^{26}\text{Mg}\) ratios. However, the net contribution is very sensitive to the IMF adopted and to the fraction of primordial matter which goes into stars.

1. INTRODUCTION

The standard homogeneous Big Bang nucleosynthesis predicts that the material emerged from this epoch was mainly made by \(^1\text{H}\) and \(^4\text{He}\). The total mass fraction of heavier elements was lower than \(10^{-10}\), so that the first generation of stars, the so called Population III, was built from matter essentially deprived of metals. Such a peculiarity significantly affected the star formation phase. Yoshii and Saio \cite{5} found that the peak of the resulting IMF for Pop III stars ranges between 4 and 8 \(M_\odot\). Recently, Nakamura and Umemura \cite{3} have obtained that the typical mass of Pop III stars should be \(\sim 3 M_\odot\). Nevertheless, recent simulations of collapse and fragmentation of primordial clouds (see e.g. \cite{2}) obtain a Jean mass \(\sim 10^2 - 10^3 M_\odot\), although it is still not clear whether these clumps will further fragment down to stellar mass values. The key role in this process is played by molecular hydrogen rather than dust or heavy molecules cooling. Therefore, early star formation with a normal present-day IMF seems very unlikely. In this framework, intermediate and/or very massive stars were the dominant constituents of the first stellar population.

The simplest explanation for the absence of "zero metal" stars is that they have not survived up to the present epoch, which is compatible with the idea that primordial stars were not of low mass. Thus, the very metal poor stars presently observed were formed from matter already enriched by the ashes of massive \(Z=0\) stars. Consequently,
an indirect way to search for Pop III stars is to look for their nucleosynthetic imprint in the extremely metal poor objects now observed. As it is well known, the most important contribution of intermediate mass stars to the chemical enrichment of galaxies comes from the nucleosynthesis occurring during the AGB phase.

2. MODELS AND EVOLUTIONARY PROPERTIES

The evolutionary models of 4, 5, 6, 7 and 8 $M_\odot$ ($Z=0, Y=0.23$) stars have been computed by the latest version of the FRANEC code [1]. No mass loss has been assumed. Owing to the lack of metals the main differences in the evolution with respect to that of metallic AGB stars are: 1) H burning starts at high temperature through the pp chains. The convective cores are smaller but H-burning extends to the 80% of the stellar mass. The core contracts until the $3\alpha$ reaction starts; then the burning switches to the CNO, 2) during He-burning the star is at the blue side of the H-R diagram, therefore the 1st dredge-up does not occur, and 3) during the AGB phase the inward penetration of the envelope dredges-up He, C, N and O. For $M \geq 6 M_\odot$ the amount of CNO elements is enough to develop a normal TP phase. For $M < 6 M_\odot$ the normal TP phase starts after an episode of C ingestion during the first pulses. See [4] for more details.

Table 1
Important yields from $Z=0$ AGB stars.

| IMF | $\eta$ | $^4$He | $^7$Li | $^{12}$C | $^{14}$N |
|-----|-------|--------|--------|--------|--------|
| 1   | 0.1   | $2 \times 10^{-10}$ | $2 \times 10^{-3}$ | $4 \times 10^{-3}$ |
| (a) |       |        |        |        |        |
| 6   | 0.1   | $4 \times 10^{-10}$ | $9 \times 10^{-4}$ | $3 \times 10^{-4}$ |
| 1   | 0.14  | $3 \times 10^{-10}$ | $4 \times 10^{-3}$ | $6 \times 10^{-3}$ |
| (b) |       |        |        |        |        |
| 6   | 0.14  | $6 \times 10^{-10}$ | $1 \times 10^{-3}$ | $3 \times 10^{-4}$ |
| 1   | 0.02  | $4 \times 10^{-11}$ | $4 \times 10^{-4}$ | $7 \times 10^{-4}$ |
| Salpeter | |        |        |        |        |
| 6   | 0.02  | $7 \times 10^{-11}$ | $2 \times 10^{-4}$ | $3 \times 10^{-5}$ |

3. NUCLEOSYNTHESIS

As a consequence of the occurrence of normal TP, 3$^{th}$ dredge-up and hot bottom burning, the Pop III nucleosynthesis scenario is revised. The duration of the whole AGB phase has been determined by using the classical Reimers formula for the mass-loss rate for different values of the scaling factor $\eta$. The major products of these stars are $^4$He, $^7$Li, $^{12}$C and $^{14}$N. In Table 1 we report the most important (IMF weighted) yields provided by our $Z=0$ IMS models, namely: the abundance in mass fraction of a given element in the
Table 2
Abundance ratios from Z=0 objects using the IMF by Yoshii & Saio (1986).

| IMF | AGB | SNII |
|-----|-----|------|
|     | [C/Fe] | [N/Fe] | [C/Fe] | [N/Fe] |
| (a) | +0.2   | +0.8   | +0.2   | -0.45  |
| (b) | +0.6   | +1.4   | 0.0    | -0.6   |

material ejected into the interstellar medium at the end of the AGB phase. We have used the Population III IMF proposed by Yoshii and Saio [5] (cases a & b) and for comparison we also compute the yields from the Salpeter IMF. The [C,N/Fe] ratios are obtained from Z=0 AGB and SN II yields assuming an ejection of 0.05 M☉ of Fe per SNII (Table 2). The main results are:

- Li is produced by the Cameron-Fowler mechanism particularly efficient during the first part of the AGB phase. The maximum Li yield obtained is of the order of the standard Big-Bang nucleosynthesis predictions.

- C and N (primary) are built up during the AGB phase. However, the C and N yields significantly change along the AGB, thus the cumulative amount of these elements finally ejected depend on the mass loss history.

- Free neutrons are released from the operation of the 22Ne(α,n)25Mg reaction. The envelope is built up with extreme non-solar ratios 24Mg/25Mg/26Mg = 1/10/13.

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