From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
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Chemical pollution from AGB Stars

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Abstract. Low mass AGB Stars are the main contributors to the Galactic s-process enrichment. We present new theoretical results obtained by adopting a full network from H to Bi coupled with the physical evolution of the stellar structure. We describe the formation of a ^{13}C pocket as a consequence of H diffusion from the envelope into the He-rich intershell. Such ^{13}C is burnt during the interpulse phase and provides the main neutron source in these stars. We computed two models with the same total mass (that is 2 $M_{\odot}$) but two different initial chemical composition, namely (Y = 0.269 – Z = 0.015) and (Y = 0.245 – Z = 0.0001), representative of disk and halo stars respectively. We evaluate the differences in the final s-process surface composition and compare the results with the available observational data.

Keywords. Stars: AGB and post-AGB, nuclear reactions, nucleosynthesis, abundances

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During the thermally pulsing AGB phase (TP-AGB) a slow neutron flux is produced by the ^{13}C(α,n)^{16}O reaction occurring in a thin ^{13}C pocket located in the He- and C-rich region of these stars (He intershell). An exponential decay of the average velocity at the inner border of the convective envelope provides the diffusion of protons into the He intershell needed to allow the formation of such a pocket (Cristallo *et al.* 2001, Straniero *et al.* 2005). In Fig. 1 (panel a) we report the chemical profiles (disk stars case) in the region where the ^{13}C pocket forms, during the interpulse period between the 2nd and the 3rd thermal pulse with TDU. Starred line represents the hydrogen abundance, the dotted one is ^{12}C, the solid one is ^{13}C, the long-dashed one is ^{14}N, the short-dashed one is ^{22}Ne and the dot-dashed one is ^{23}Na. A tiny ^{13}C pocket (whose extension is $\Delta M \sim 7 \times 10^{-4}$ $M_{\odot}$) is left, partially overlapped with a ^{14}N pocket. The maximum neutron density is attained in the more internal layer of the ^{13}C pocket, where the ^{14}N (the strongest neutron poison) is less abundant. Note that proton diffusion is also responsible for the formation of a small ^{23}Na peak: this occurs in the region where proton capture on ^{22}Ne dominates over proton captures on lighter isotopes such as ^{12}C, ^{13}C and ^{14}N. In the solar-like model we obtain the formation of eleven ^{13}C pockets, the first two being partially engulfed in the following convective episodes generated by the 7th and 8th TPs. The effective mass fraction of ^{13}C in all the pockets are reported in Fig. 1 (panel b); the extension of the pocket decreases with time, the first one being the largest (each pocket has been shifted in mass in order to superimpose their external borders), while the obtained maximum ^{13}C mass fraction is constant within all pockets. In Fig. 2 (panel a) we show how the elemental surface composition changes pulse after pulse: the final carbon abundance is about a factor of 4 larger than the initial one, whilst the ls elements (Y, Zr) and the hs elements (Ba, La, Nd) are overproduced by a factor of 10. In order to investigate the effects of the metallicity over the s-process nucleosynthesis, we computed a 2 $M_{\odot}$ model at Z = 0.0001. As shown

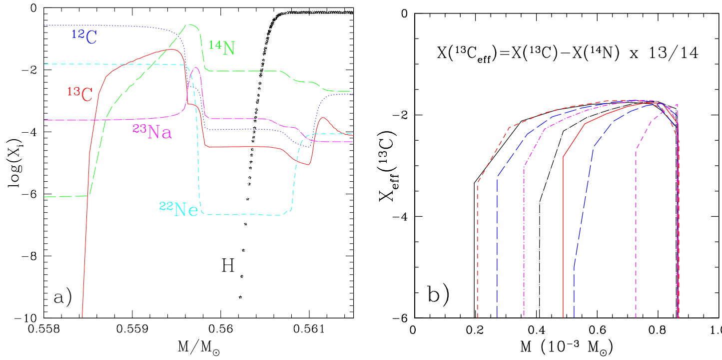

Figure 1. Panel a): Relevant chemical species (see text) in the region where the ^{13}C pocket forms after the occurrence of the third dredge up. Panel b): The *effective* mass fraction of ^{13}C within all pockets is reported.

in Fig. 2 (panel b), the production of heavier elements, in particular lead, is favoured with respect to the lighter ones (the ls elements and the hs elements). This behaviour is expected at low metallicities, where the large number of neutrons per Fe seed favours the production of the heaviest isotopes (Busso *et al.* 1999). Far from concluding that a single choice of the many model parameters (M, Z, convective efficiency, mass loss, etc.) can reproduce the observed abundance spread of low metallicity stars, in Fig. 2 (panel b) we tentatively compare our results with the abundances of HD196944 (Aoki *et al.* 2001). An overall agreement is found. Finally, let us stress the fact that ^{19}F is overproduced by about a factor of 200 with respect to the initial value: its production derives from α captures, occurring inside the thermal pulses, on the ^{15}N previously created in the ^{13}C pockets, when neutron are released by the ^{13}C(α,n)^{16}O reaction. This result confirms

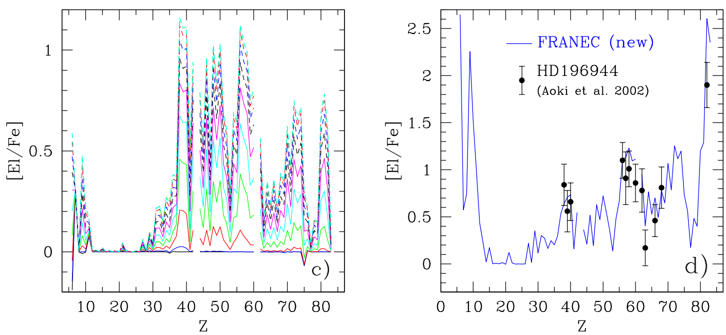

Figure 2. Panel a): The pulse by pulse surface composition of the disk-like model. Panel b): The final surface composition of the halo-like model; spectroscopic data of HD196944 are included for comparison.

that AGB stars are an important source for the Galactic fluorine (see Renda *et al.* 2004).

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