From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
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Li abundance evolution as probe of extra-mixing in 47 Tuc RGB stars

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Abstract. Fundamental parameters and lithium abundances, A_{Li}, have been derived for a sample of evolved stars in the globular cluster 47 Tuc (from GIRAFFE spectra and MARCS models of atmosphere). These data sample a complete evolutionary sequence from subgiant stage to the tip of the Asymptotic Giant Branch. With this unique observational data set we have analyzed the evolution of A_{Li} along the Red Giant Branch (RGB) using non-standard stellar evolution models, so as to explore the occurence and the efficiency of extra-mixing processes in low mass stars at the so-called Red Giant bump.

Keywords. Stars: abundances, stars: evolution, stars: interiors, stars: rotation

1. Observations and Data Reduction

In October 2003, at VLT/UT2+GIRAFFE (in Medusa mode and high resolution set up centered at 679.7nm) we have sampled the HR diagram of 47 Tuc, with 123 spectra of stars located from the bottom of the RGB to the RGB Bump area and the HB (see the sample description in Lèbre et al. 2004). We have used photometry (V, I) and astrometry from Momany (2004, private communication), neglecting the low interstellar extinction (≃0.024, cf. Gratton et al. 2003). From (V-I) colors and data from Houdashelt *et al.* (2000), we have derived $T_{\rm eff}$ (±150 K) and M_{bol} (±0.1). The distance modulus $(m-M)_V = 13.52 \pm 0.03$ of 47 Tuc is from Gratton et al. 2003. To derive A_{Li} (with uncertainties ≃0.2 dex), we have computed synthetic spectra from MARCS models and linelists from Lèbre *et al.* (1999) with [Fe/H]=-0.67, $\log g = 3.0$ and $T_{\rm eff}$ from 4800 K to 5100 K.

2. Modeling the transport of chemical species

Models of $M_{ini} = 0.95 M_\odot$ have been computed from the PMS to the RGB tip using the STAREVOL code (Siess *et al.* 2000). Initial chemical composition is from Carretta *et al.* (2004) and Alves-Brito et al. (2005): $[Fe/H] = -0.67$, $[\alpha/Fe] = +0.3$, $[Na/Fe] = -0.23$, $Z = 0.0064$. For the computed models (see Fig. 1.), we find $L_{bump} \simeq 48 L_\odot$, i.e. $M_{bol} \simeq 0.56$, in good agreement with observations. The observed decline of A_{Li} around L_{bump} in 47 Tuc RGB stars provides evidence for an extra-mixing mechanism becoming efficient at this stage, that could be triggered by rotation as suggested by Charbonnel 1995. We have explored this possibility and computed the transport of chemical species and angular momentum (AM) by meridional circulation and shear-induced turbulence (Maeder & Zahn 1998) in our rotating models (M1 and M2). The transport is consistently treated

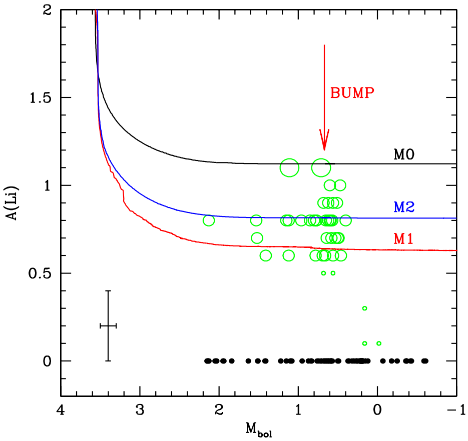

Figure 1. Black dots represent stars with $A_{Li} < 0$ dex. Predictions for models (M0, standard; M1 & M2, rotating) are superposed on our derived A_{Li}.

from the ZAMS to the RGB tip, under the assumption of uniform specific AM within the convective envelope at all phases (Palacios *et al.* 2005). Stars in 47 Tuc are assumed to be slow rotators with an initial rotation velocity $v_{ZAMS} = 10\ km\,s^{-1}$.

3. Results

(i) The standard model M0 leads to a post 1st dredge-up value of $A_{Li\ DUP} \simeq 1.13$. As expected, no further variation of A_{Li} is predicted. (ii) The rotating model M1 predicts a deeper dredge-up and $A_{Li\ DUP} \simeq 0.65$. On the other hand, the transport is not efficient enough to enable further decline of Li after the bump (see also Palacios et al. 2005). (iii) In the rotating model M2 we assume local conservation of the AM beyond the turnoff in the radiative interior of the star. This leads to shallower dredge-up than predicted for model M1, with $A_{Li\ DUP} \simeq 0.81$. As in model M1, the transport is not efficient enough to enable further decline of Li after the bump.

Rotational transport of AM and chemical species by meridional circulation and shear-induced turbulence allows deeper dredge-up than in standard models, and allows to reproduce the dispersion of lithium abundances observed before the bump in 47 Tuc. However, the efficiency of such a mixing remains too small to reproduce the decline of A_{Li} beyond the bump. This reveals the action of additional transport processes in RGB low-mass stars that need to be taken into account in order to reproduce the observations.

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