From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
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Lithium abundances in exoplanet host stars as a test for planetary formation scenarii

M. Castro[1], **O. Richard**[2] **and S. Vauclair**[1]

[1]Laboratoire d'Astrophysique de Toulouse et Tarbes,
email: mcastro@ast.obs-mip.fr, svcr@ast.obs-mip.fr

[2]Groupe de Recherche en Astronomie et Astrophysique du Languedoc,
email: richard@graal.univ-montp2.fr

Abstract. The observations of Israelian *et al.* (2004) show that, in an effective temperature range between 5600 and 5850 K, the planet host stars present a significant lithium underabundance compared to the stars without planets. We have studied this phenomena in order to discriminate the different planetary formation scenarii.

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Planet host stars are on average overmetallic by 0.2 dex compared to stars without detected planets (Santos *et al.* (2001)). This peculiarity could be explained in two different ways: the star is either fully overmetallic or the surface metallicity excess is due to the accretion of metal-rich matter during the process of planetary formation. Israelian *et al.* (2004) compare a sample of planet host stars with a sample of stars without detected planets. They point out that planet host stars which have an effective temperature between 5600 and 5850 K, show an underabundance of lithium compared to stars without planets.

Here we compute the evolution of three types of models with the Toulouse-Geneva evolution code: normal models (with a solar metallicity), overmetallic models (three different models, with $[Fe/H]_0 = 0.18$, 0.24 and 0.30 from the centre to the surface), and accretion models (three different models with the same metallicity as the overmetallic ones in their outer layers, i.e. accreted mass of metals of respectively $M_{acc} = 1.1$, 1.7 and 2.5 M_J), for different masses (0.95, 0.97, 1.00 and 1.02 $M_\odot$). All the models include microscopic diffusion, and take into account the rotation-induced turbulence including the effect of μ-gradients as in Richard *et al.* (1996).

The evolution of the surface lithium abundances, presented in Figure 1, shows a fast decrease due to the rotation-induced turbulence which brings the lithium from the bottom of the convective zone down to the depth where it is burned by nuclear reactions. This is followed by a weaker decrease when the diffusion-induced helium gradients below the convective zones become large enough to stabilize most of the mixing region. The different slopes during the fast decrease of the surface lithium in the overmetallic models in Figure 1 are explained by the temperature profiles: the higher the temperature at a given depth, the stronger the lithium destruction. In the accretion models, the temperature profiles are almost the same so that the evolution of the surface lithium is similar until the μ-gradient takes over.

The helium gradients (Figure 2) are smoother in the accretion models than in the overmetallic and normal cases. Indeed, the creation of an inverse μ-gradient due to the accretion partly contradicts the one due to helium. As a result, turbulence is more efficient and consequently reduces the helium gradient itself. Altogether, the mixing process

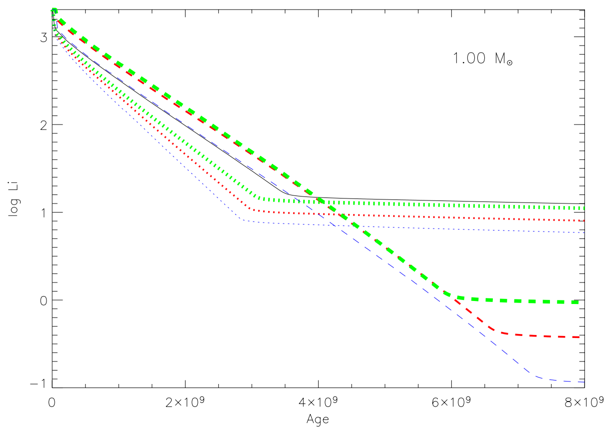

Figure 1. Lithium evolution for models of 1.00 $M_{\odot}$; solid line : normal metallicity ; dotted lines: overmetallic models ($[Fe/H]_0$ = 0.18 (thick green) , 0.24 (red) and 0.30 (thin blue)) ; dashed lines : accretion models (M_{acc} = 1.1 (thick green), 1.7 (red) and 2.5 (thin blue) M_J).

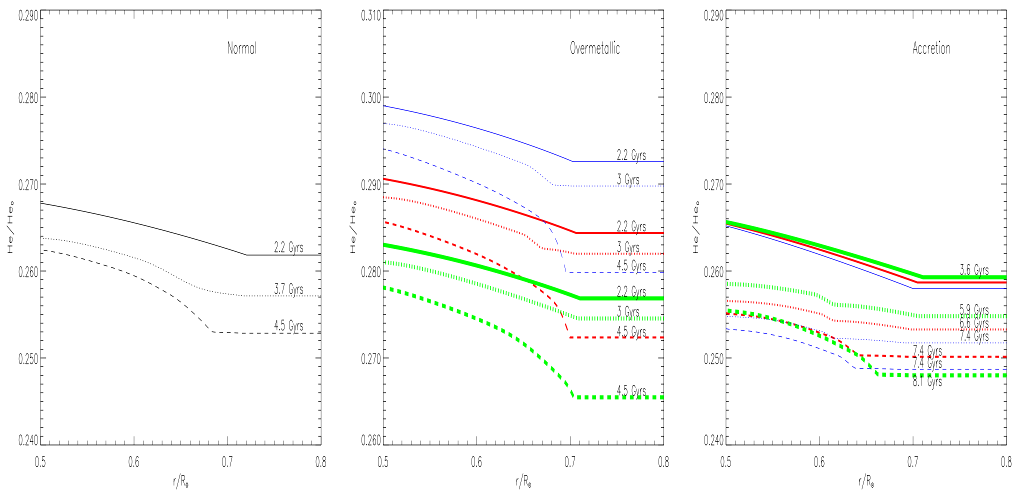

Figure 2. Helium profiles for the same models as in Figure 1 at different ages indicated

down to the lithium burning layer lasts much longer than in the normal or overmetallic cases. Then the final lithium abundances are smaller than in overmetallic models.

In the framework of the evolutionary models presented, we have shown that the lithium underabundance in the planet host stars with an effective temperature between 5600 and 5850 K, is better reproduced with the accretion models. In the future, we need to improve the treatment of the mixing by using a more sophisticated parametrization.

References

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