LITHIUM DEPLETION IN LATE-TYPE STARS THROUGH WIND-DRIVEN MIXING

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1. Introduction

A well established property of late-type stars is that their rotation rate and their lithium abundance both decline with age. We understand why such stars are spun down while losing so little mass (Schatzman 1962), but we are still working on a theory which would explain all aspects of the observed lithium depletion. Although most agree that some kind of mixing must occur below the convective envelope of late-type stars, which transports ^{7}Li to the depth where it is destroyed through nuclear burning, the physical process which is responsible for this transport is still in debate. However the most recent observations of the lithium abundance in close binary stars clearly show that there is a causal link between the destruction of lithium and the loss of angular momentum: consistently, tidally-locked binaries tend to display more lithium than single stars of the same effective temperature, as observed in the Hyades (Soderblom et al. 1990, Thorburn et al. 1993) and among old disk stars and halo stars (Spite et al. 1994).

2. The physics of lithium depletion

The idea of associating the destruction of lithium with the loss of angular momentum is hardly new (Goldreich & Schubert 1967, Howard et al. 1967, Schatzman 1969). One interpretation was that the torque exerted by the wind slows down the convective envelope, building up differential rotation in the radiative region below, thus generating some weak turbulence which is responsible for the transport of matter and angular momentum. The latest calculations carried out along these lines by Pinsonneault et al. (1989, 1990) demonstrate a strong link between the depletion of lithium and the loss of angular momentum, as one should expect since a constant ratio is imposed

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between turbulent diffusivity and viscosity. However, one of the weak points in the Yale approach is the treatment of the meridian circulation.

In most papers dealing with that circulation, the rotation is assumed to be uniform, but the meridian flow advects angular momentum and therefore modifies the rotation profile, thus reacting back on itself. The main difficulty one encounters when handling this feed-back is that the differential rotation gives rise to various instabilities, which do also participate in the transport of angular momentum. In Zahn (1992) we explained that the horizontal transport mediated by such turbulence is probably much stronger than the vertical one, which permits then to calculate the meridian velocity for a given rotation profile. One finds that both the transport of angular momentum and that of Li are entirely governed by the surface condition, namely by the loss of angular momentum through the wind.

3. Conclusion

The behavior of tidally-locked binaries proves that the lithium depletion observed in single late-type stars is causally linked with the loss of angular momentum through the stellar wind (see also Cayrel de Strobel et al. 1994, Ryan and Deliyannis 1994, Zahn 1994). If this depletion did not depend on rotation, the Li abundance would be the same in single and binary stars. On the other hand, if the destruction of Li were an increasing function of the rotation rate, as has also been proposed, tidally-locked binaries would be more depleted than single stars.

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