LITHIUM ABUNDANCES IN LATE MAIN SEQUENCE STARS. THE CASE OF THE HYADES

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It is well known that light elements like lithium are good indicators of the hydrodynamical behaviour of the outerlayers of the stars. As they are nuclearly destroyed at low temperature, i.e. close to the surface, their surface abundances reflect the nature of the transport process at work between the photosphere and the nuclear destruction region.

For intermediate temperature stars ($T_e \simeq 6\ 000$ °K) neither microscopic diffusion nor laminar circulation can account for the observed depletion (Fig. 1). A mild turbulence has been suggested by Vauclair, Vauclair, Schatzman, Michaud (1978). In low mass stars Strauss, Blake and Schramm (1976) concluded that a variable convective overshoot from 0 to 3 pressure scale height could explain the observed abundances.

Recent observations by Cayrel et al. (1983, this Symposium) on the Hyades cluster allow to reexamine the problem. They give abundances for a homogeneous set of main sequence stars of the same age in the interval $5\ 200 < T_e < 6\ 000$ °K.

I THE MODEL.

- Envelope models.

Main sequence model envelopes have been used, computed with a code originally constructed by Latour (1970). The chemical composition is chosen as $X = .73$, $Y = .25$, $Z = .02$. Opacities are from the Los Alamos opacity library. Luminosities and effective temperatures are derived from the observations (Cayrel et al., 1983). The masses are deduced from a fit of the observed and theoretical Hyades main sequence (Perrin et al., 1977; Cayrel de Strobel, 1980). The age of the Hyades stars is taken as $8\ 10^8$ years (Patenaude, 1978).

- Transport processes.

Two different transport processes are considered:

. A mild turbulence described by a turbulence diffusion coefficient

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 529–531.

$D = R_e^{*}\nu$, as suggested by Schatzman (1977).

. An extension of the fully mixed region below the classical boundary of the convective zone : h = Ov.Hp (Hp pressure scale height). This extension is probably due to overshooting but we will not discuss this point here. R_e and Ov are the two parameters of the problem to be adjusted. It is assumed that they have the same values for all the models. Determinations of R_e^{*} have been made in several cases (initial region of the Sun, outer layers of A stars) and lead to $R_e^{*} \simeq 30$, 100. The penetrative convection has been estimated using more or less refined description of the convective motions. The most recent computations (Latour et al., 1981 ; Hulburt et al., 1983) seem to indicate that Ov could not be larger than several tenth.

The concentration of Li is supposed to be constant from the surface fown to the lower boundary of the fully mixed layers. Below that it satisfies a diffusion equation in which the nuclear destruction is taken into account :

$$\rho \frac{\partial c}{\partial t} = \frac{\partial}{\partial z} (D\rho \frac{\partial c}{\partial z}) - K(\rho, T) \rho c$$

z geometrical depth, c Li concentration, $\rho = \rho(z)$, $T = T(z)$ density and temperature (given by the model),
D diffusion coefficient, $D = R_e^{*}\nu$, ν viscosity, $\nu = \nu_{mol}+\nu_{rad}$,
$\nu_{mol} = 2.21\ 10^{-15}\ T^{5/2}\ \rho^{-1}\ (1+7X)/\ (8 \times \ell n\Lambda)$, from Spitzer (1962) for a mixture of ionized hydrogen and helium $\ell n\ \Lambda \simeq 5$.
$\nu_{rad} = 6.728\ 10^{-26}\ T^4/\chi\ ^2$, $\chi(\rho,T)$ Rosseland mean opacity.
$K(\rho, T)$ is the nuclear destruction rate taken from Fowler et al. (1975).

It is assumed that no nuclear depletion occurs in the pre-main sequence stage and that the zero age main sequence lithium abundance is $\log N_o(Li) = 3.0$.

II RESULTS.

-1- In the hottest models the turbulent diffusion region is quite extended and a reasonable amount of overshooting $Ov \lesssim .5$ does not affect significantly the surface abundance.

A first order determination of R_e^{*} is then possible from these models leading to $50 \lesssim R_e^{*} \lesssim 70$.

-2- In the coolest models the convective zone extends to hotter and denser regions and the distance between its lower boundary and the nuclear destruction region is much smaller. The Li surface abundance is then very sensitive to the amount of overshooting. Using the first determination of R_e^{*}, Ov can then be determined $.3 \lesssim Ov \lesssim .4$.

-3- This determination of Ov is then reintroduced in the hottest models to fix R_e^{*} and a value of $R_e^{*} \simeq 70$ is obtained.

-4- The set of parameters $R_e^* \simeq 70$, Ov ≃ .3 is then used all along the sequence. Figure 1 shows the fit with the observed values.

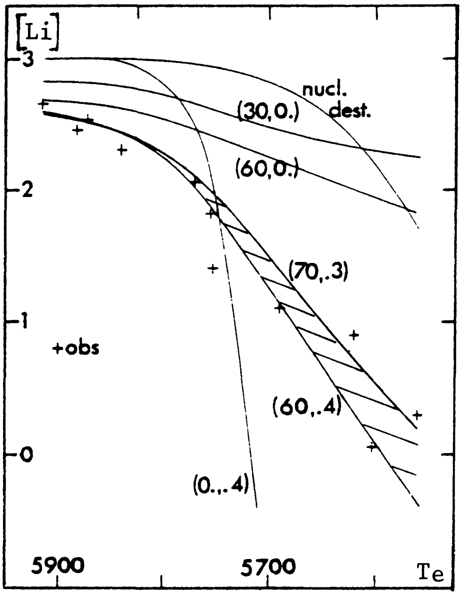

Figure 1.- Comparison of observed and predicted abundances.
Models with turbulent diffusion only.
Models with overshooting only.
Models with $R_e^* = 60$, Ov = .4.
Models with $R_e^* = 70$, Ov = .3.

III CONCLUSIONS.

The slight depletion in the hottest models cannot be reproduced by any kind of reasonable overshooting; a mild turbulence is necessary. Note that this model is also consistent with the lithium abundances observed in the Sun. The fast depletion at low temperature is explained by the fast deepening of the convective zone with effective temperature. But a model containing only overshooting leads to a complete absence of lithium around $T_e \simeq 5\,300$ °K due to the very sharp temperature dependance of the nuclear burning rate of lithium. The turbulent diffusion extends the region of nuclear burning and allows for the smooth decrease of Li abundance a low temperature. This preliminary study is being extended to other test observations as lithium abundances in Pop II stars, Be and B in Pop I stars.

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