A RANDOM WALK APPROACH TO THE PROBLEM OF TURBULENT DIFFUSION AND LITHIUM DESTRUCTION IN MAIN SEQUENCE STARS

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1. INTRODUCTION

It has been suggested by Schatzman (1977) that the empirical lithium content/age relationship found by Herbig (1965) could be explained by exchange of matter between the convective zone and deeper layers, where the rate of lithium burning is higher, by turbulent diffusion. The claim by Tassoul and Tassoul (1983) that such a turbulence is necessary to obtain a self-consistent description of stellar rotation and meridional circulation has given some momentum to Schatzman's proposal, as well as other successes of the turbulent diffusion hypothesis (Schatzman et al. 1981).

We describe here a way of computing the evolution of the lithium content in the convective zone of a main sequence star, using a random walk model for the mixing instead of the differential equation for diffusion. The advantage of this approach is that the finite scale of turbulent eddies can be taken into account. The burning rate of lithium does increase so fast with temperature that it cannot be taken for granted that the free path of turbulent motions is small compared to the scale-height of the burning rate (this last being of the order of $R_\odot/30$ or a sixth of the pressure scale-height Hp) H_p.

2. THE MODEL

We assume that the convective zone exchange matters with the underlying radiative zone (RZ) at a rate of $r = \delta m / \delta t$. We assume that the path of matter in the RZ is a random walk of step L and time flight τ. The resulting velocity of turbulent eddies is therefore $v = L/\tau$ and this sets also the rate r by:

$$r = 2\pi \rho_c R_c^2 v$$

ρ_c and R_c being respectively the density and the radius of the bottom of the convective zone (CZ). After a time $t = n\tau$ three kinds of paths have occured: A) some matter has left the CZ without returning to it; B) some matter has left the CZ and has returned to it

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after being exposed to a high destruction rate in the RZ; C) some matter initially in the RZ has merged into the CZ. It is interesting to note that systemic motions are a particular case of this approach (when $t < \tau$) as well as microscopic diffusion (when $L \ll H_\odot$).

3. RESULTS

We give in Table 1 the results obtained for t = 0.66×10^9 years (age of the Hyades), L = Hp/2 and two values of the velocity v.The computation was done using models supplied by W.Däppen (1/Hp = 1.5, Z = 0.016, X = 0.73) and the rates of Fowler et al. (1975).

Table 1

Lithium depletion after 0.66×10^9 years for various cases (in dex). L is taken equal to Hp/2.

Stellar mass (in $m_\odot$)	mere burning in the CZ	burning plus over shoot (to $0.30 \times$Hp)	random walk $v=1.6\times10^{-6}$ cm sec^{-1}	random walk $v=3.0\times10^{-6}$ cm sec^{-1}	Observed (Hyades)
1.0	-10^{-4}	-0.005	-0.24	-0.49	-0.24
0.9	-0.005	-0.362	-0.67	-1.13	-1.08
0.8	-0.042	-2.70	-1.08	-1.91	$\leqslant$-2.7

CONCLUSION

It can be seen from table 1 that the lithium depletion produced by turbulence and computed using the random walk algorithm has a considerably smoother variation with mass that burning with or without overshooting. The producted slope is in much better agreement with observations. However, a moderate amount of overshooting would improve the fit with the observations.

REFERENCES

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DISCUSSION

Nissen: What is the relation between your velocity of random walk (10^{-6}cm sec^{-1}) and other hydrodynamical velocities in stellar interiors?

R. Cayrel: I have not yet attempted to connect my velocity with other hydrodynamical velocities in stellar interiors. But I know that in the tomorrow session somebody else will speak about velocities induced by differential rotation and we may then connect the two things. For the time being the velocity I gave has the meaning that with $\ell \simeq H_p$ such a velocity gives rough agreement between the predicted and observed lithium depletion in the Hyades.

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