OBSERVATIONAL PATTERNS OF LITHIUM DEPLETION IN PRE-MAIN SEQUENCE STARS*

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ABSTRACT   We present results based on the analysis of lithium abundances in a sample of $\sim$ 50 pre-main sequence stars covering a wide range of masses (from 2 to 0.3 $M_\odot$) and luminosities (corresponding to ages of 1-100 Myr). Stars with masses estimated to be $\gtrsim 1$ $M_\odot$ show lithium abundances close to cosmic with little scatter ($\pm$ 0.3 dex). Stars with masses less than Solar present a wide range of lithium abundances, with a clear trend to lower abundances for lower luminosities (greater age). The observed Li abundances constrain theoretical predictions of lithium depletion in rotating pre-main sequence stars.

INTRODUCTION

Observations of the light element lithium are considered as a tool to gain insight on conditions inside young stars and the efficiency of matter transport between the surface and the interior. We are conducting a long-term observational program with the aim of constructing a statistically significant database for the study of lithium in the pre-main sequence (PMS). So far we have accumulated data on $\sim$ 80 PMS stars, covering a wide range of masses (1.2-0.2 $M/M_\odot$), ages (1-100 Myr), rotational periods (1-12 d) and locations (field, star-forming regions, open clusters).

In the present paper we report results based on the analysis of the LiI resonance doublet at 670.8 nm in a sample of $\sim$ 50 stars, including T Tauri stars, and K and M-type stars in two young open clusters: αPer (age 50-80 Myr) and Pleiades (age 70-100 Myr). Using the most recent model atmospheres available for cool high-gravity stars and new estimates of atmosphere parameters for each star we calculate the lithium abundance in

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Recently, Magazzù *et al.* 1992 have shown that the lithium abundances in most classical T Tauri stars (CTTs) is similar to the abundance of this element in the interstellar medium (log N(Li)= 3.2, in the customary scale of log N(H)=12). In this paper we concentrate in weak T Tauri stars (WTTs) and post T Tauri stars (PTTs) for two reasons. One is that we can derive more reliable lithium abundances for WTTs and PTTs than for CTTs because we do not have to make veiling corrections, and we can be more confident on the stellar parameters and model atmospheres that are adopted (Basri *et al.* 1991). On the other hand, we expect that the masses and ages of WTTs and PTTs derived from theoretical tracks and isochrones are more reliable than for CTTS, and the comparison of observed Li abundances with theoretical predictions (cf. Proffitt & Michaud 1989, and Pinsonneault *et al.* 1990; hereafter PM and PKD respectively).

RESULTS

Our main results are conveniently summarized by dividing the stars in 3 bins of masses as shown in Figure 1.

1.- For $M/M_\odot \geq 1$ we do not find evidence for lithium abundances significantly different from the cosmic Pop.I value. The spread in the observed abundances is about 0.6 dex, and the estimated uncertainty in each individual abundance is about 0.3 dex (1σ). There is no correlation between Li abundance and luminosity. The mean Li abundance is close to the cosmic value of log N(Li)$\approx$3.2 . These results are consistent with the models of PM and the non-rotating models of PKD, but some of the rotating models (Case B3 for example) of PKD predict depletions of about one order of magnitude for masses equal to the Sun and ages about 30 Myr. Our data do not support those models.

2.- In the range of masses 0.9-0.6 $M/M_\odot$ we find very young WTTs with undepleted lithium, and PTTs (20-30 Myr) with lithium depletions of up to one order of magnitude (see Martín *et al.* 1992 for more details) . For Pleiades stars the Li depletion increases with decreasing mass, being larger than three orders of magnitude for stars with $M{\sim}0.7$-0.6 $M_\odot$. The observed depletion is consistent with the models of PM, but not so much with the rotating models of PKD which tend to predict higher Li depletions.

3.- The lithium abundances derived for the lowest masses considered by us are plotted at the bottom of Fig. 1 as a function of stellar luminosity. We find abundances close to the cosmic value for $\log(L/L_\odot) \gtrsim -0.4$. The turning point where lithium abundances start declining towards lower luminosities is very important for comparison with the interior models. This point appears to occur at lower luminosities for the very low mass stars than for the higher mass stars, which is qualitatively consistent with the models. For the lowest mass considered by PKD (0.4 $M_\odot$) the lithium depletion starts at $\log(L/L_\odot)$=-1.1, in the model without rotation, and for the rotating models the situation is similar. We find four M2,3 WTTs without detectable lithium lines (upper limits on the Li abundances in Fig. 1) and luminosities higher

than $\log(L/L_\odot)=-1$, implying ages younger than 10 Myr. Hence, for these 4 stars the upper limits on the observed Li abundances are not consistent with theoretical expectations based on their apparent masses and ages. We note that the 4 objects are NTTs in two binary systems. It is a subject of further study if their binary nature may affect their lithium abundances and/or their estimated masses and ages. For the less luminous stars in our sample (those in the αPer cluster) we have detected the lithium line in two stars and place an upper limit on one star. We infer Li abundances about a factor 100 below the initial value. Such depletion is smaller by about one order of magnitude than predicted by the non-rotating models of PKD for 0.4 $M_\odot$ and 50 Myr.
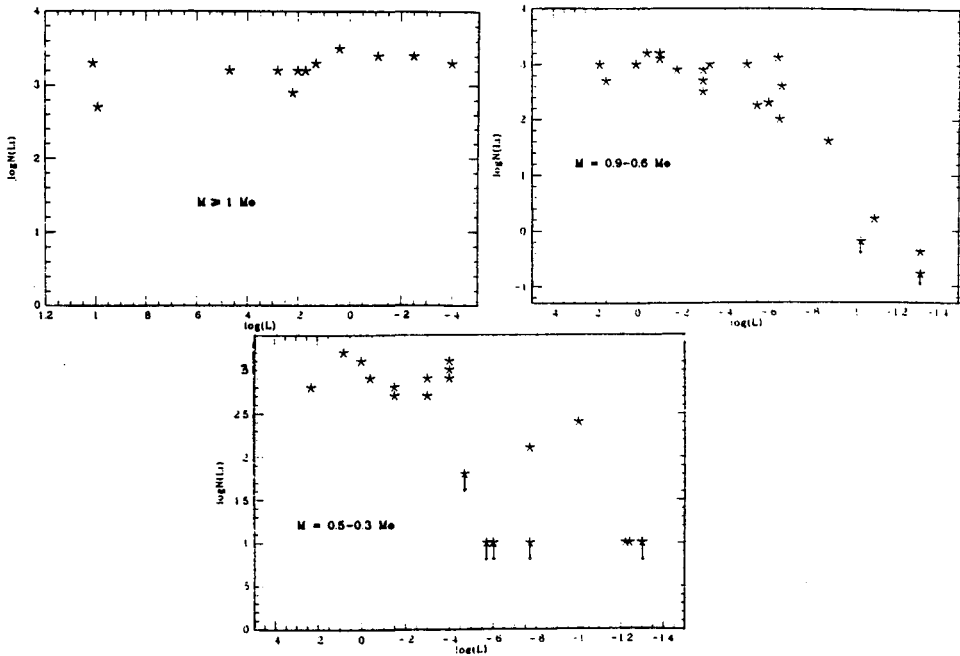

Fig. 1. Lithium abundances, defined as $\log N(Li) = 12 + \log(N_{Li}/N_H)$, for PMS stars in three ranges of masses versus $\log(L/L_\odot)$.

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