LITHIUM ABUNDANCES IN ATMOSPHERES OF PMS STARS FN TAU AND V927 TAU

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We present the fits of synthetical spectra to the observed spectra of the young pre-main sequence stars V927 Tau (M5.5IV) and FN Tau (M5IV). The profiles of K line at $\lambda\,7699\,\text{Å}$, resonance and subordinate doublets of Li at $\lambda\,6708\,\text{Å}$ and $\lambda\,8126\,\text{Å}$ are simulated. The model atmospheres of Alard and Hauschildt (1995) are used to compute the spectra. Rotational velocities for FN Tau $v\sin i = 13\,\text{km/s}$ and $22\,\text{km/s}$ for V927 Tau are adopted. We determine $\log g = 4.0$ for V927 Tau and $\log g = 3.5$ for FN Tau for $T_{\text{eff}} = 3100\,\text{K}$, using the K line profile fits. For V927 Tau $\log N(Li) = 2.5$ for $\lambda\,6708\,\text{Å}$ and 2.7 for $\lambda\,8126\,\text{Å}$ region, and for FN Tau 3.0 and 3.3, respectively were obtained.

INTRODUCTION

Substantial progress has been achieved over the last few years due to observational and theoretical efforts devoted to studies of the lithium depletion in pre-main sequence (PMS) stars. Investigations of cool PMS stars [3, 4] give strong arguments that lithium has been effectively depleted during the early evolution of low-mass stars. But low-mass PMS stars are expected to preserve their initial lithium content during their first few million years of existence ([2], see also [3, 5]).

Here we present fits of synthetical spectra to the observed spectra of the two young PMS stars V927 Tau (M5.5 IV) and FN Tau (M5 IV).

PROCEDURE

The high resolution ($\lambda/\delta\lambda$=45000) observational data were obtained with Keck Telescope in 1994. For calculations of synthetical spectra we used the WITA6 program by Pavlenko [6]. Calculations were completed in classical approaches: LTE, hydrostatic equilibrium for one-dimensional model atmospheres, absence of energy sources and flowings. Equations of ionization-dissociation equilibrium were solved for the environment of atoms, ions and molecules. The molecular data used in these calculations were taken from [12]. The data on atomic lines were from VALD [8]. The calculations of molecular opacity were completed in JOLA and LBL approximations. For latter one we took the line-lists by Plez [9] and Shwenke [11]. We used the model atmospheres of Allard and Hauschildt [1] with T_{eff} = 3000–3300 K, $\log g = 3.5$–5.0 and metallicity $\mu = 0$.

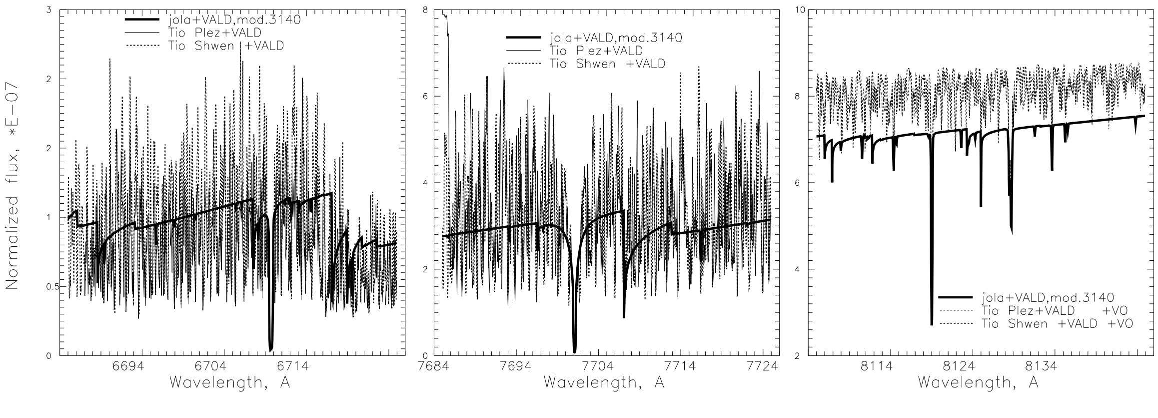

Figure 1: Theoretical spectra of M-dwarfs computed with different approximations of molecular opacity

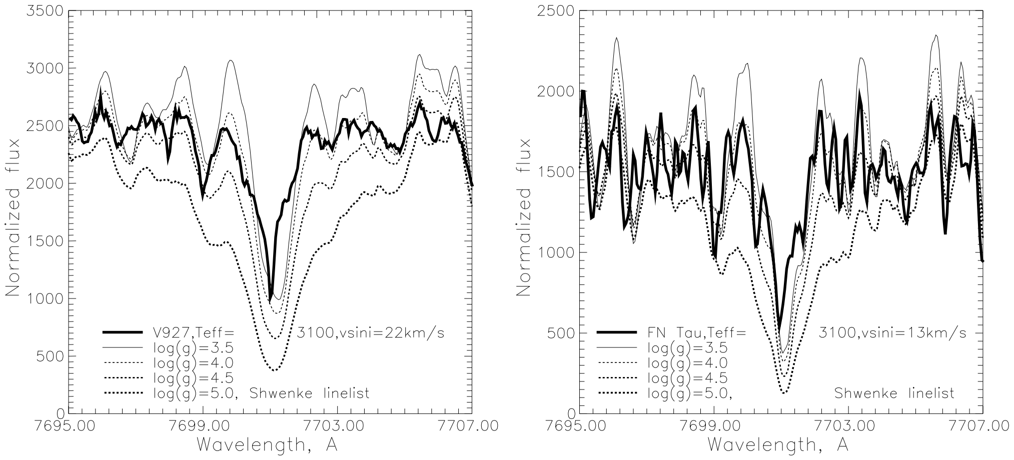

Figure 2: Fit of observed spectra to synthetical ones, computed with different $\log g$ for region centred at KI line λ=7699 Å

RESULTS

Spectra of late M stars is formed mainly by the molecular bands of TiO and VO, but there are number of strong atomic lines, which can be used in quantitative analysis. Here we consider the regions of Li λ 6708 Å and λ 8126 Å and KI λ 7699 Å.

In the frame of this work we examine two approaches of molecular opacity – JOLA (just overlap line approximation) and line-by-line, with two independently obtained line-lists of TiO by Plez [9] and Shwenke [11]. Comparison of the results shows rather good coincidence of these approaches in λ 6708 Å and λ 7699 Å regions and some lack of agreement in λ 8126 Å region (Fig. 1). To our mind the Shwenke's line-list of TiO is more full then Plez's one, and reproduce observational spectra more accurate. That's why in further calculations we use only this line-list of TiO.

For the region centred at the KI line, λ 7699 Å, we examine the flux dependence on temperature. It is proved to be rather weak. Also, for the KI line region for both stars we carried out the calculations of flux dependence on $\log g$. Synthetical spectra were computed for $\log g = 3.5$, 4.0, 4.5 and 5.0 for $T_{\rm eff}$ = 3100 K. It is worth to note that this dependence is rather strong, and it can be used to define $\log g$ in stars along with the well known gravity test based at the sodium subordinate doublet at $\lambda\lambda$ 8183, 8195 Å [10]. The best fit to observed spectra was obtained for the synthetical spectra with $\log g = 4.0$ for V927 Tau and $\log g = 3.5$ for FN Tau (Fig. 2).

Lithiun lines in spectra of V927 Tau and FN Tau are broadened by rotation. We assume the values of $v \sin i = 22$ and 13 km/s for V927 Tau and FN Tau, respectively [7]. For calculations of synthetical spectra we used 3100/4.0/0 model atmosphere for V927 Tau and 3100/3.5/0 for FN Tau.

For V927 Tau we obtained Li abundances – 2.5 for λ 6708 Å region, and $\log N(Li) = 2.7$ for λ 8126 Å (Fig. 3).

For FN Tau we determine $\log N(Li) = 3.0$ and 3.4 for λ 6708 Å and λ 8126 Å, respectively (Fig. 4).

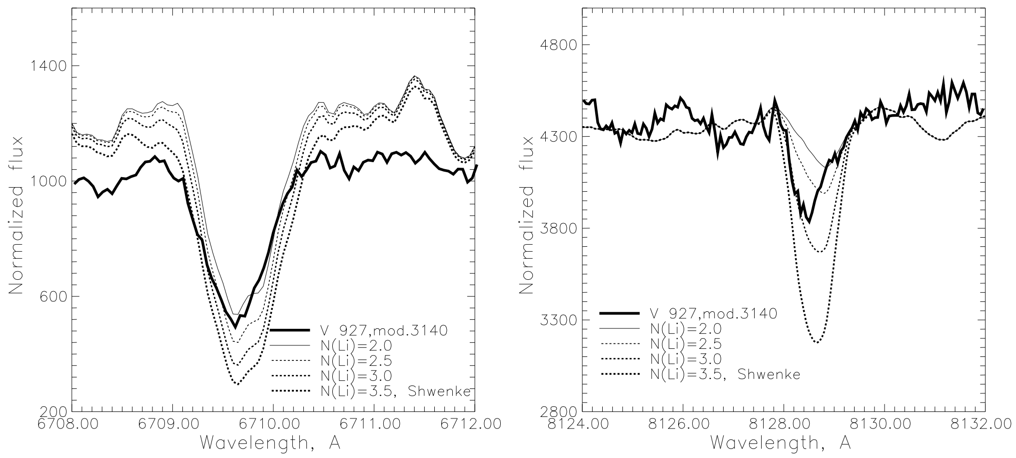

Figure 3: Fits to lithium lines in V927 Tau spectrum

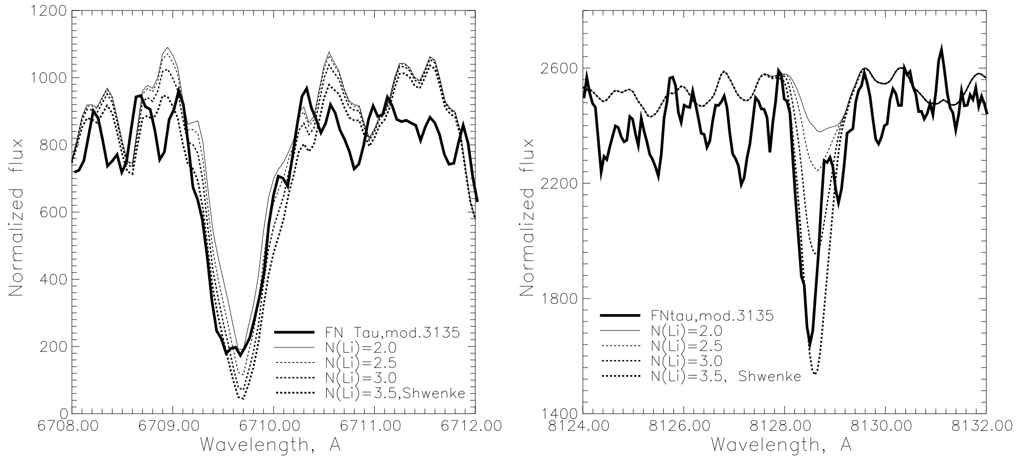

Figure 4: Fits to lithium lines in FN Tau spectrum

Thus, the main results of the work are following:
— two approximations of molecular opacity – JOLA and LBL are compatible;
— Shwenke's line-list of TiO is more accurate to reproduce the observational spectrum than Plez's one;
— synthetical spectrum dependence on $T_{\rm eff}$ is not strong for region centred at K line, λ=7699 Å;
— dependence of K line (λ=7699 Å) profile on $\log g$ is rather strong. Finally, we determine the $\log g = 4.0$ for V927 Tau and $\log g = 3.5$ for FN Tau;
— we determine the abundances of Li using two regions for V927 and FN Tau. They are for regions λ=6708 Å and λ=8126 Å, $\log N(Li) = 2.5$ and 2.7 for V927 and $\log N(Li) = 3.0$ and 3.4 for FN Tau, respectively.

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