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A Spectroscopic Survey and Data Reduction of Young Fields Stars

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Abstract: We present high-resolution spectroscopic observations for a sample of 12 young solar-type stars near the Sun. All observational data were reduced using Image Reduction and Analysis Facility (IRAF) package in the standard fashion, including image trimming, bias subtraction, flat-field division, spectrum extraction etc. Among these 12 young solar-type stars, we find 3 Weak-line T Tauri stars. We also find lithium depletion take place during PMS evolution for our sample stars. The result support predict by Piau and Turck-Chieze that the surface Li depletion will take place during PMS evolution for low-mass stars.

Key words: Stars, abundance, evolution, pre-main-sequence

INTRODUCTION

Solar-type stars are low-mass, late spectral type stars. They are similar to the Sun in mass and evolutionary state. This means that physically they have broadly similar structure and present a convective envelope but without totally dominant convection, as is found in M dwarfs. Young Solar-type stars (Weak- line T Tauri (TTS), low-mass Zero-Age and young Main Sequence (MS) stars) display various forms activity caused by dynamo processes.

For a long time, lithium has been recognized as a powerful tool in investigating the internal mixing of low-mass stars. Because its isotopes are destroyed by proton capture at low temperatures, they allow us to probe directly the depths of the outer mixed envelopes. The importance of lithium depletion in Pre-Main-Sequence (PMS) stars is not only limited to PMS evolution itself but has far reaching implications, such as, for example, in the calibration of lithium depletion mechanisms on the MS (gravity waves, diffusion, winds, etc. (Maeder, 2009; Pinsonneault *et al*., 1989; Pinsonneault, 1997), the evolution of lithium in the Galaxy(the initial lithium content of TTSs is a measurement of the current lithium abundance in molecular clouds (Ryan *et al*., 2001; Matteucci *et al*., 1995; Valle *et al*., 2002; Travaglio *et al*., 2001) and the identification of substellar objects (Martin *et al*., 1994).

By far the dominant population of X-ray sources within star-forming regions consists of TTSs (Bertout, 1989). X-ray emission is therefore a ubiquitous and important property of young, low-mass stars (Montmerle, 2002). The field stars that have strong X-ray emission (X-ray emissions is a ubiquitous and important property of young low-mass stars, (Montmerle, 2002) owing to both age and relative proximity, where we can study solar mass stars after evolving for a short time on main sequence and low mass stars as the finish PMS evolution. We selected a group of stars that were X-ray sources who has the counterpart object in Tycho Catalogue and has a high L_x/L_{bol} ($\log L_c + 0.4\ V > 3.25$, X-ray luminosity in the total band: 0.5~8.0kev) ratio as candidate of young solar-type stars. In this context, we have carried out high-resolution spectroscopic observations for 12 young solar-type stars. Since the connect binaries are also strong X-ray emission source, some binaries has been selected in our sample. The Li I λ 670.8 nm Equivalent Widths (EW(Li)) of these binaries can be use to test the results we obtained.

This study is organized as follows. The observations and data reduction are presented in Section 2. And the discussions and results are presented in Section 3.

OBSERVATIONS AND DATA REDUCTION

Spectroscopic observations were carried out on 3 nights from 2012 Dec. 1 to 2 with the Coude Echelle Spectrograph and a 1024×1024 Tek CCD attached to the 2.16m telescope at the Xinglong station of the National Astronomical Observatories, Chinese Academy of Science (NAOC). The red arm of the spectrograph with a 31.6 grooves mm^{-1} grating was used in combination with a prism as cross-disperser, providing a good separation between the echelle orders (Zhao and Li 2001). With a 0.5 mm slit (1.1 arcsec), the resolving power was on the order of 37 000. The exposure time was chosen in order to obtain a signal-to-noise over 100 and the spectral coverage is 580-880 nm. This relatively high resolution

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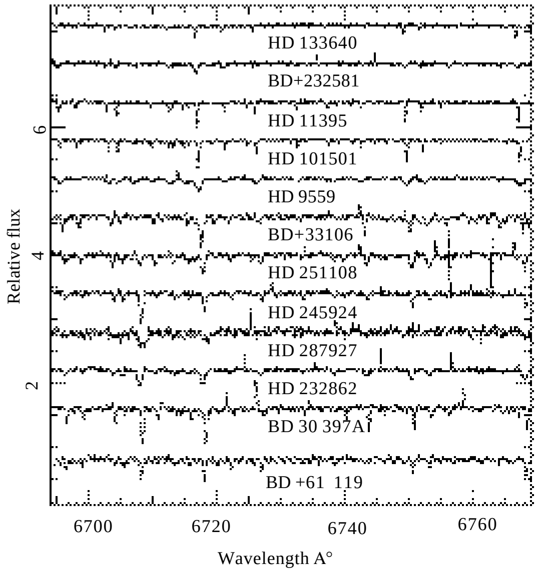

Fig. 1: Spectra in the Li I λ 6707Å line range for our star sample

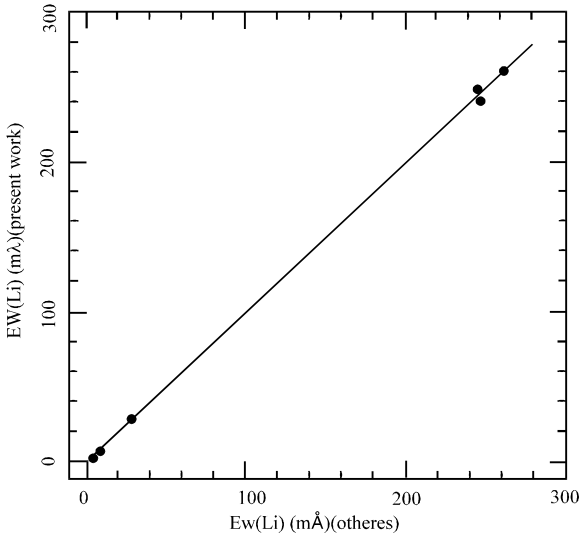

Fig. 2: Comparison of our measurement of the Li equivalent width obtained with gaussian fit and those measurements obtained by other authors

was judged to be important in view of the relatively weak lithium lines in some stars.

All observational data were reduced using Image Reduction and Analysis Facility (IRAF, a general purpose software system for the reduction and analysis of astronomical data. It is written and supported by the National Optical Astronomy Observatories (NOAO) in Tucson, Arizona) package in the standard fashion, including image trimming, bias subtraction, flat-field division, spectrum extraction and cosmic ray removal. The wavelength calibration was obtained by taking spectra of a Th-Ar lamp. Finally, all spectra were normalized using a cubic spline fit to the observed continuum. Fig. 1 shows the spectra of 12 sample stars in the range of the Li Iλ 670.8 nm line.

CCD data obtained with no exposure will have some counts. These values are called bias. The values are dependent on the CCD pixels in general, though the differences are usually quite small. The corrections for bias are made using the frames obtained with no exposure. In order to increase the data quality, several frames should be combined by adopting the median of the values of each pixel.

In order to correct the pixel-to-pixel inhomogeneity of the sensitivity of the detector, images of white light (practically the light of a halogen lamp) are obtained with the same setup of the spectrograph. Flat fielding of the object data are made by dividing the object frame by the flat frame.

For the determination of Li I λ 670.8 nm equivalent widths, all spectral of the relevant order were averaged to find regions in the continuum unaffected by metal lines. These regions were then used to fit the continuum with a straight line. The equivalent width of the Li I λ 670.8 nm line then was determined by fitting a Gaussian curve. The nominal resolving power λ/Δλ was 37 000, sufficient to resolve the Li I feature from a nearby Fe I line at 6707.44 Å in all. Since we observed bright stars and the seeing conditions were generally good, the S/N ratio of our observations was usually high, between 100 and 300. However for stars with large rotation rates v sini≥20 km s^{-1}, the blue side of the LiI line is blended with the Fe I λ 6707.441Å line. So that the measured equivalent width (EW[Li I + Fe I]) of fast rotation stars are corrected using the empirical relation of Soderblom *et al.* (1993):

$$EW(6707.441\text{Å}) = 20(B-V) - 3\ \text{mÅ}$$

valid for 0.4 = (B-V) =1.4. According to Soderblom *et al.* (1993) this relationship is accurate from 3 to 5 m Å.

The accuracy of the Li I ë 670.8 nm of present work is estimated by comparing them to previous measurements. Fig. 2 shows a graphical comparison between the EW(Li) measured on our spectra and previous measurements by several groups (Takeda and Kawanomoto, 2005, 1 star respectively by Li and Hu(1998) Mentuch *et al.* (2008) and Gregorio-Hetem and Hetem (2002). We find an agreement better than 15 for 6 stars when comparing with the literature data. Based on these, we estimate an average

Table 1: Photometric results and other parameters of our sample stars

Stars	α(2000)	δ(2000)	SpT.	B-V	EW(Li) ((mA)
BD+30 397A	02 27 29.3	30 58 24	K8	1.205	215
HD 232862	03 57 19.19	50 51 18	G811	0.878	191
HD287927	05 30 48.0	02 59 34	F2	0.800	248
HD 245924	05 39 30.9	23 06 33	G5	0.880	247
HD251108	06 04 14.9	12 45 51	K2	1.332	115
BD+33 1646	0808 56.4	3249 11	K7	1.400	15.3
HD 95559	11 02 02.2	22 35 45	K0V	0.872	38.9
HD 101501	11 41 03.0	34 12 05	G8V	0.723	25
HD111395	12 48 47.0	24 50 24	G5V	0.703	29
BD+232581	13 32 41.6	22 30 06	KV:e	1.030	19
HD 133640	15 03 47.3	47 39 14	G2IV	0.647	24
BD+61 119	00 34 38.3	62 37 19	F8	0.590	132

error bar of 5% in the equivalent width values at 1σ, coming mainly from uncertainty in the continuum placement. The EW(Li) of 12 observed sample stars are reported in Table 1.

RESULTS AND DISCUSSION

The effective temperature of our 12 sample stars was determined from the (B-V) color index, using the calibrations of Casagrande *et al.* (2006). Applying implementation of the Infrared Flux Method to multi band photometry, Casagrande *et al.* (2006) derive the empirical effective temperature and bolometric luminosity calibration for G and K dwarfs. They conclude that temperatures calibrations for lower main-sequence G and K dwarfs retain systematics of the order of a few per cent. The effective temperature of program stars are listed in Table 1.

The correlation between the evolutionary state of a star and its position in the H-R diagram makes it a useful tool for astronomers to age different of stars. In Fig.3 we show the position of sample stars in the log $(L/L_{¡Ñ})$ -logT_{eff} diagram using the PMS evolutionary models of Palla and Stahler (1999). Here the luminosity is given by:

$$L/L_{¡Ñ} = 0.0813\times r^2\times 10^{-0.4\times m}$$

where, r is the distance to star, m is the apparent magnitude of the star. The distance derived from the trigonometric parallax which search from VizieR.

The lithium measurements were used to estimate the evolutionary status of the sample through the analysis of the diagram of W(Li) against T_{eff}. This diagram is shown in Fig.3, where the line indicates the upper envelope of Pleides as the dividing line between PMS and ZAMS stars by Bouvier *et al.* (1997) and the dashed line indicates the cut-off proposed by Martin *et al.*(1997) to separate weak-line TTS and post TTS, the dashed line represents the cut-off at T_{eff}=5250K for TTs. This line also indicates the L abundance N(Li) = 2.8 adopted as a minimum abundance for TTS (1997). The region above this line is considered to be the expected locus of WTTS.

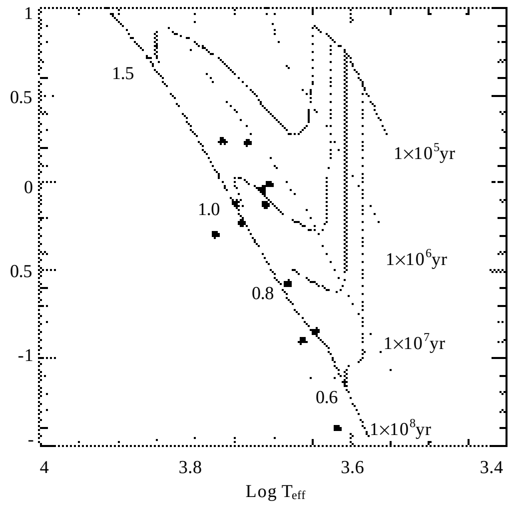

Fig. 3: Our sample of young solar-type stars in the H-R diagram (filled circle

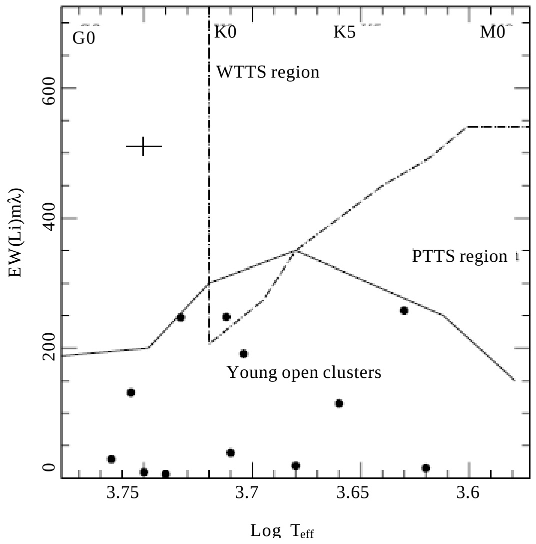

Fig. 4: Equivalent width of the Li I line as a function of effective temperature for young solar-type stars. W(Li) vs. Teff for Pleiades (crosses), ROSAT-discovered young solar-type stars of this work (filled circles). The line indicates the upper envelope of Pleides as the dividing line between PMS and ZAMS stars by Bouvier et al. (1997). The dashed line indicates the cut-off proposed by Martin to separate weak-line TTS and post TTS, defined by the limits adopted for TTS (Teff < 5250K and log N(Li) > 2.8)

The position of members of young open clusters is below the dotted line, while the region of Post T Tauri Stars (PTTS) is in the right-hand side of the diagram (below the dashed line and above the dotted one). We note, in the EW(Li) versus T_{eff} plot, that most of the sample stars fall in the region of low-mass members of young open clusters. The remaining two stars (HD 245924 and HD 287927) in this part of the diagram falling in the WTTS region are considered to be WTTS and another one star (BD+30 397A) in the PTT region are considered to be post TTS or objects in the transition WTTS/PTTS.

T_{eff} for Pleiades (crosses), ROSAT-discovered young solar-type stars of this work (filled circles). The line indicates the upper envelope of Pleides as the dividing line between PMS and ZAMS stars by Bouvier *et al.* (1997). The dashed line indicates the cut-off proposed by Martin to separate weak-line TTS and post TTS, defined by the limits adopted for TTS (T_{eff}< 5250K and log N(Li) > 2.8)

On the other hand, the results of EW(Li) for our sample young solar-type stars indicates that the surface lithium depletion take place during PMS evolution for low-mass stars, since PMS star have higher EW(Li) than ZAMS or young solar-type star with same spectral type. The results also support predict of Piau and Turck-Chieze (2002) that the surface Li depletion will take place during PMS evolution for low-mass stars.

CONCLUSION

In this study, We present high-resolution spectroscopic observations and the results for these observation of a sample of 12 young solar-type stars near the Sun. All observational data were reduced using Image Reduction and Analysis Facility (IRAF) package in the standard fashion, including image trimming, bias subtraction, flat-field division, spectrum extraction etc. The results of our study of lithium abundance of the sample of young solar-type stars are summarized as follows:

- Spectroscopic observations for a sample of 12 young solar-type stars discovered in the X-ray wave-length range were carried out
- Among these 12 young solar-type stars, 3 optical counterparts to the X-ray sources could be identified as new WTTS and 4 could be identified as ZAMS stars. Another 5 optical counterparts to the X-ray sources could be identified as young lolar type stars
- We find evidence for lithium depletion in our sample stars. This result support the predict of Piau and Turck-Chieze (2002) that the surface Li depletion will take place during PMS evolution for low-mass stars

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