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Line Profile Variations of Solar Analog Stars: Chromospheric Indexes vs. Li Abundance. The Host Star Search.

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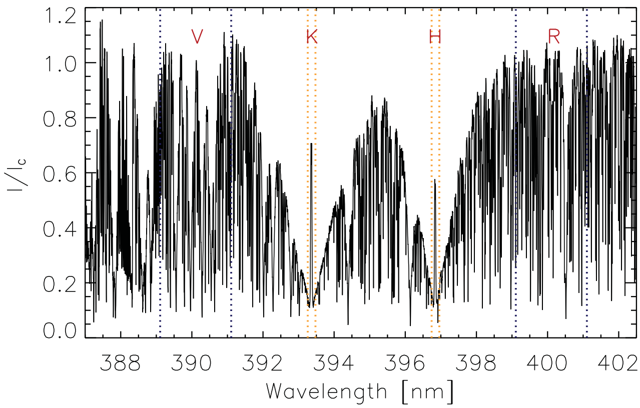
Abstract. PolarBase contains stellar spectropolarimetric data collected with the NARVAL & ESPaDOnS instruments (Petit *et al.* 2014). Their respective spectral resolutions are 65 000 and 68 000, in spectropolarimetric mode. As the first part of this work, we use the NARVAL spectropolarimetric repositories. We selected spectra from a sample of cool stars with effective Temperature ($T_{\rm eff}$) ranging between 4900 to 6000 K. This sample contains stellar systems with and without reported exoplanets. We exploit the full wavelength range from 380 to 900 nm in order to obtain chromospheric indexes such as the Ca II H&K S-Index, and a Ca II IRT and Hα index. We calibrated our measurements using the Mount Wilson S-Index values. Furthermore, we employ lithium (Li) abundance measurements from the literature (Gonzalez *et al.* 2010; Delgado Mena *et al.* 2014; Israelian *et al.* 2004), investigating in this way a possible correlation between the chromospheric activity measurements and the Li abundance in 32 selected cool stars.

Keywords. Cool stars, Chromospheric Index, Li-abundance, Exoplanets.

1. Introduction

Previous studies have considered the possibility of a relation between the Li abundance and the planetary presence in Sun like stars (Chen *et al.* 2006). This idea has generated some controversy in the exoplanets research field. Israelian *et al.* (2009) showed a statistical relation between a low Li content and the planetary presence. Two possible mechanisms have been considered in the low Li abundances of stars with planets. One of them considers that the rotation induces mixing due to the conservation of angular momentum by the protoplanetary disk. The second one is related with a shear instability triggered by planet migration (Chen *et al.* 2006). However, Baumann *et al.* (2010) showed that this correlation can be explained considering the age of the stars, without invoking a planetary connection. This debate is not over and some other publications have supported the idea binding the amount of lithium and the planetary presence (Sousa *et al.* 2010; Figueira *et al.* 2014). In this sense, we will try to address this problem in addition to other physical parameters such as the activity indicators and surface magnetic field in these stars.

The measurement of chromospheric activity indexes in cool stars show us indirectly the magnetic field characteristics. Moreover, the activity can be linked to the plasma motions in the convective envelope of the star. In such stars the differential rotation



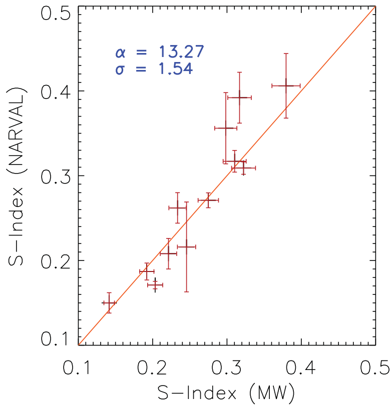


Figure 1. (Left) Ca II H&K lines for HD22049. (Right) The measured S_{index} from NARVAL and the adjusted reference values from Mount Wilson (MW).

leads to the amplification of magnetic fields through a dynamo mechanism (Charbonneau 2013). In addition, the mechanisms suspected for surface lithium depletion in cool stars are possibly related to convection in the outer layers and the overshooting into the stellar atmosphere (Cox *et al.* 1991). This may suggest that there might be a relation between the Li abundances and the atmospheric magnetic fields in these types of stars. On the other hand, it is believed that during planetary accretion and ongoing star formation, part of the original mass and angular momentum of the star is lost by gravitational effects exerted by the planets onto the star. This phenomenon affects the rotation rate of the star (Shajn & Struve 1929). If all the angular momentum contained within a collapsing pre-stellar core was conserved during their formation, proto-stars would reach rotation rates exceeding their break-up velocities before they reached the main sequence. The angular momentum lost from the star is preserved by transferring it to the disk through a process invoking magnetic braking. Additionally, the stellar angular momentum can be lost from the star-disk system entirely via stellar winds and disk-winds (Davies *et al.* 2014). The correlation between stellar rotation period, temperature, chromospheric indexes and Li abundance has been studied in cool binary systems in the work developed by Strassmeier *et al.* (2012), finding a trend of increased Li abundance with rotational period.

In this proceeding we attempt to analyze a possible physical correlation between the magnetic activity in cool stars, their lithium content and the presence of planetary companions. We used measurements of Li abundance reported in the literature and measured chromospheric activity indicators from spectra in the PolarBase-NARVAL archive. In Sect. 2, we present the activity indexes and their calibration. Section 3 contains the magnetic activity and Li abundances results. The analysis and discussion of our findings are presented in Sect. 4.

2. Activity Indexes and Calibration

The chromospheric indexes are defined as follows:

$$\mathrm{S-Index} = \alpha\frac{\mathrm{H+K}}{\mathrm{R+V}}, \tag{2.1}$$

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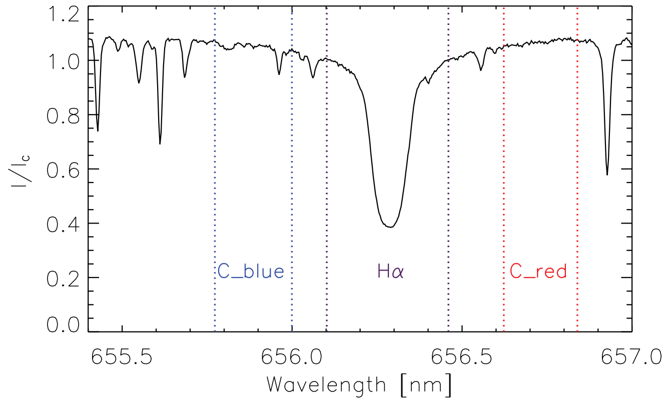

Figure 2. Hα line of HD22049 and the various bandpass definitions. See text.

$$\mathrm{H}\alpha - \mathrm{Index} = \frac{\mathrm{F}_{\mathrm{H}\alpha}}{\mathrm{C}_{\mathrm{Red}} + \mathrm{C}_{\mathrm{Blue}}}, \tag{2.2}$$

$$\mathrm{Ca\,II\,IRT} - \mathrm{Index} = \frac{\mathrm{F}_{\mathrm{CaI}} + \mathrm{F}_{\mathrm{CaII}} + \mathrm{F}_{\mathrm{CaIII}}}{\mathrm{F}_{\mathrm{R}} + \mathrm{F}_{\mathrm{V}}}. \tag{2.3}$$

The S-Index value from NARVAL is measured from the flux in the cores of the H& K lines of Ca II at 396.8469 nm and 393.3663 nm, respectively. Two 0.218 nm bandpasses centered on each line, and two rectangular bandpasses in the continuum, R & V, centered in 400.107 nm and 390.107 nm, respectively are used for the continuum fluxes (Figure 1, left). To calibrate our measurements with the Mount Wilson scale, we adopt the calibration from (Wright *et al.* 2004; Schroeder *et al.* 2009) to find the corresponding instrumental factor, α, in Eq.(1.1) for the NARVAL spectrograph. We find a calibration factor of α =13.27 $\pm$ 1.54 (Figure 1 , right).

We determined an Hα index by using the definitions suggested by Gizis *et al.* (2002), Eq. (2.2), where the fluxes are integrated between 656.10 to 656.46 nm, and with the continuum band passes $\mathrm{C}_{\mathrm{red}}$ from 656.62 to 656.84 nm and $\mathrm{C}_{\mathrm{blue}}$ from 655.77 to 656.0 nm (Figure 2).

The Ca II IRT-Index measurements were determined using the Eq.(1.3) (Marsden *et al.* 2014), where the fluxes are taken at the central wavelengths of Ca_{I} =849.802 nm, $\mathrm{Ca}_{\mathrm{II}}$ = 854.209nm, and $\mathrm{Ca}_{\mathrm{III}}$ =866.214 nm with 0.2 nm band passes (Figure 3).

3. Results

Figures 4 and 5 show the different activity indicators (S-Index, Hα-Index, and Ca II IRT-Index) obtained from our calibration versus lithium abundance. The values range mostly between 0.2 and 0.6, which indicates a significant presence of magnetic fields in these stars. The logarithmic Li abundance covers a large range from $\sim$0 to 3 on the usual H-scale (=12.0) but are found to be relatively homogeneously distributed with magnetic activity. There seems to be no distinctive relation between activity and Li abundance in our sample of stars and also not a clear dependency on a planetary or not.

The plots show us a reiterative shift to the right on the three different activity indicators, S-Index, Hα-Index and Ca II IRT-Index, for stars without confirmed exoplanet; nevertheless, caution is advised with the interpretation, because it is possible that a high

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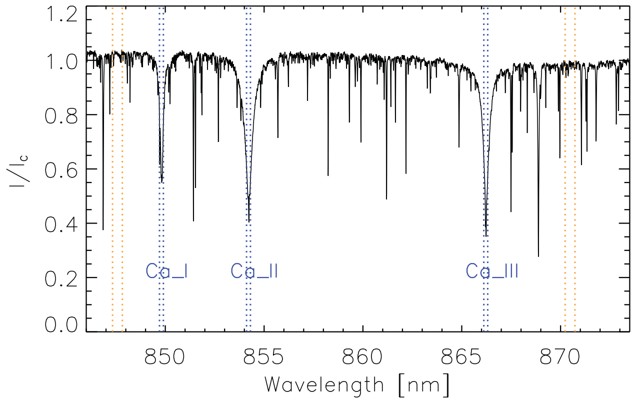

Figure 3. NARVAL spectrum of the three Ca II infrared triplet lines for HD22049.

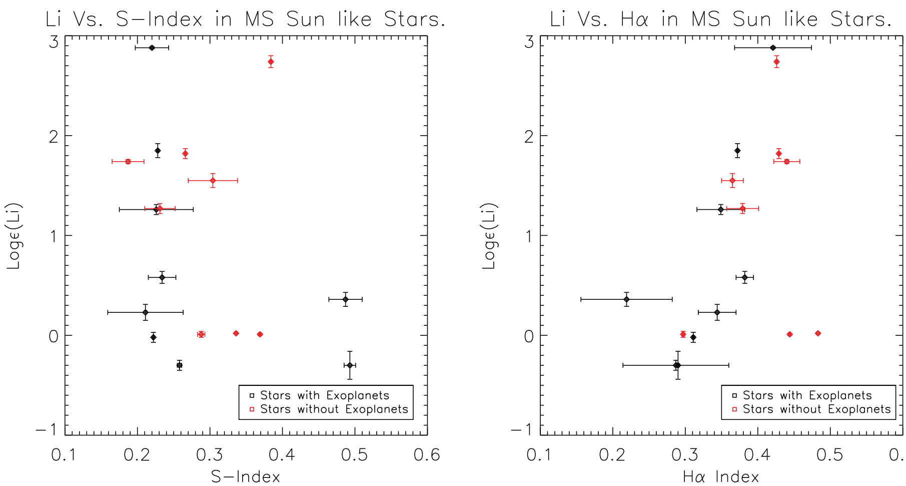

Figure 4. (left) S-index Vs. Li abundance (right) Hα-Index Vs. Li abundance. See the on-line edition of this book for a color version of this figure.

magnetic activity in a star can produce a distortion in the broadening of the lines, and this effect can generate difficulties in the radial velocity measurements, and therefore in the exoplanets detection. Also we do not have yet a enough sample for assuming any correlation between the magnetic activity and the host-stars.

4. Analysis and Discussion

During the process of planet formation it is possible that the host star loses a high percentage of its initial angular momentum to its proto-planets and thereby also alters its lithium content when the system contains Jupiter-like giant planets (Israelian *et al.* 2004, Delgado Mena *et al.* 2014). This is likely linked to the rotational speed of the star and therefore indirectly to its age (Skumanich 1972). The aim of our work is to explore the possibility of a physical correlation between these quantities.

We use existing lithium abundance measurements from the literature (Gonzalez *et al.* 2010; Delgado Mena *et al.* 2014; Israelian *et al.* 2004) and try to correlate them to

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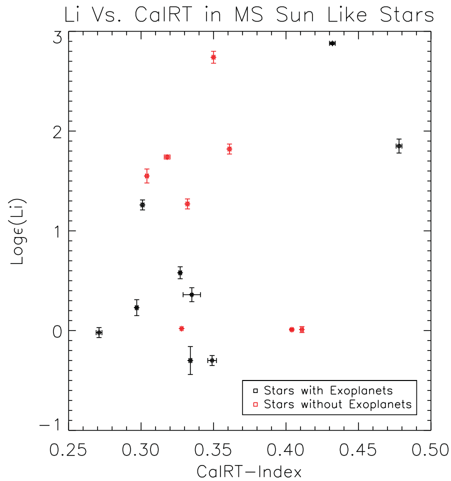

Figure 5. CaIrt -Index Vs. Li abundance. See the on-line edition of this book for a color version of this figure.

the NARVAL-based activity indexes. Our result in Figs. 4 and 5 are not conclusive yet because the analyzed data set in this work is still not enough in order to build a relation between the measured indexes of chromospheric activity and the reports of Li abundance in stars with and without exoplanets. Although we select the 32 stars with a limited $T_{\rm eff}$ range, the number of stars, the age variation and spectral type in the selected sample is still sufficiently inhomogeneous. We conclude that we need a bigger and more homogeneous stellar set with similar parameters like age and rotation velocities, because these parameters affect the magnetic behavior and the lithium content in a star. The consolidation of this work will be completed in a future paper (Amazo-Gómez *et al.*, in prep.).

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