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Magnetic activity in main sequence and evolved stars

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Abstract. The complexity of cool star's magnetic field demands an investigation of magnetic activity along the stellar evolution. In this work, we use Least-Squares Deconvolution (LSD) to look for magnetic signal in a base composed of 63 (main sequence, giant, and supergiant) stars. We also computed the chromospheric activity index (S-index) — based on Ca II H and K lines — for the stars in our base. It was found magnetic field signature for eight main sequence stars and nine evolved stars. Our preliminary results show an evident decay of magnetic field and chromospheric activity with age for main sequence stars. For evolved stars, we find what seems to be a trend between S-index and Teff.

Resumo. A complexidade do campo magnético das estrelas frias demanda uma investigação da atividade magnética ao longo da evolução estelar. Neste trabalho utilizamos o método do LSD (do inglês *Least-Squares Deconvolution*) com o intuito de procurar por sinal magnético em uma base composta por 63 estrelas que se encontram em três estágios evolutivos distintos: sequência principal, gigantes e supergigantes. Nós também calculamos o índice de atividade cromosférica (S-index) — baseado nas linhas H e K do Ca II — para as estrelas da nossa base. Foi encontrado sinal de campo magnético para 8 estrelas da sequência principal e para 9 estrelas evoluídas. Nossos resultados preliminares mostram um decaimento claro do campo magnético e da atividade cromosférica com a idade para as estrelas da sequência principal. Para as estrelas evoluídas, encontramos o que parece ser uma tendência entre S-index e Teff.

Keywords. Stars: activity – Stars: magnetic field – Stars: late-type

1. Introduction

It is a known fact to the astronomical community that the magnetic field plays a crucial role in the formation and evolution of stars. However, it has been only in the last two decades that we became capable of investigating the real influence of magnetism in the lives of stars. The construction of high-resolution spectropolarimeters such as ESPaDOnS (CFHT) and NARVAL (TBL) has been providing the scientific community with an amount of data never seen before. As a result, the quality of the work done grew significantly along with the development of new methods of data analysis. In this way, stellar magnetism is today a well-established field of research, where observational results feed theorists with new constraints to their models.

However, despite significant advances, there remain many unsolved questions. We do not have yet the complete awareness of the differences between the solar dynamo and other kinds of dynamos operating in cool stars. Moreover, some renowned researchers are also not sure about the reliability of the tomographic imaging methods currently used to reconstruct magnetic maps of stars, Zeeman-Doppler Imaging (ZDI) as an example.

This work was set up to investigate other unsolved questions not mentioned above, but also important. At what stage during the evolutionary track a star switch from being magnetic active to becoming magnetic inactive? Are our methods limited to detect magnetic fields only in low-mass stars? This article does not intend to solve those questions but rather show what the possible answers based on the results obtained are.

2. Sample

We selected 63 cool stars (except for two stars that present T_{eff} greater than 7000 K) from different luminosity classes: main sequence, giants and supergiant stars (Figure 1). Some of the giant stars studied here were select from Aurière et al. (2015). Meanwhile, all main sequence stars were extracted from Boyajian et al. (2012). We downloaded the spectra utilized in this work from PolarBase (Petit et al. 2014).

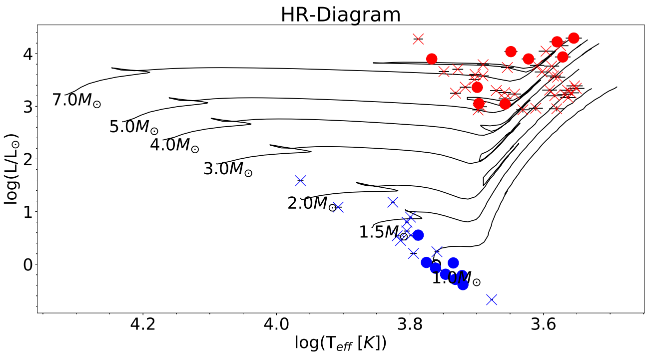

Figure 1. Hertzsprung-Russel diagram with evolutionary tracks showing our data base of 63 stars.

3. Methods

We used two methods to instigate signs of magnetic activity in our database. First we calculated the S-index as described in Tsvetkova et al. (2017) in order to identify chromospheric activity in the stars of our base (Equation 1 and Table 1).

Then, we applied the Least-Squares Deconvolution (LSD) method (Donati et al. 1997) to compute longitudinal magnetic field for the stars that showed at least marginal field detection (Equation 2).

$$S_{index} = \frac{aF_H + bF_K}{cF_{R_{HK}} + cF_{V_{HK}}} + e \tag{1}$$

$$B_l = 2.14 \times 10^{11} \frac{\int \nu V(\nu) d\nu}{\lambda g c \int [1 - I(\nu)]\, d\nu} \tag{2}$$

Table 1. Constant values used in the calculation of the S-index (Refer to Equation 1).

coefficients	values
a	-6.394
b	164.816
c	94.996
d	20.665
e	0.03253

4. Results

Some of our results can be seen in Figures 2 and 3, both related to the main sequence stars, and Figure 4, related to evolved stars.

There is a natural relation between magnetic field intensity and chromospheric activity. We expect that stars with field detection present higher S-index than stars that did not present field detection. However, it is possible that spectra with high noise give us a false high value for the chromospheric activity even though a magnetic field does not exist on the atmosphere of the star or is too low to be detected. It would be necessary to look spectrum by spectrum to identify for this kind of problem.

Figure 2 presents the expected result: as the stars evolve, its angular momentum loss makes it spin slower. As a consequence, the dynamo effect gets weaker, and we end up measuring a decrease in the magnetic field.

The result shown in Figure 3 is in complete accordance with Figure 2. In other words, a decrease in the magnetic field is directly related to a decrease in chromospheric activity what results in lower values for the S-index.

In Figure 4 we seem to have a low decrease of the S-index with T_{eff}. However, this result needs further analysis to be confirmed.

The results obtained from this work lead us to believe that more massive stars situated on the main sequence either do not present a global magnetic field or our methods cannot resolve it. For the evolved stars, we need further investigation to see if there is any trend between physical structure features of giant stars and the presence of a magnetic field.

5. Perspectives

We intend to continue to investigate the presence (or not) of magnetic fields in more massive stars. Nonetheless, we know that a radiative envelope might be the reason why we cannot detect such fields. Furthermore, we will also study the physical differences that exist in the top layers of the atmosphere of giant and supergiant stars — what ends up creating a dividing line (Linsky & Haisch 1979) in the cool region of the HR-diagram — and the role magnetic fields play in this feature.

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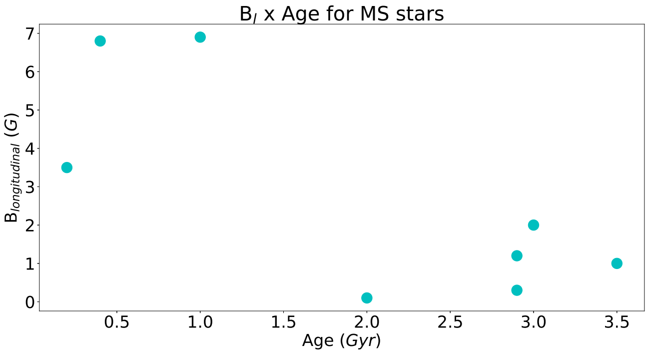

Figure 2. $B_{longitudinal}$ vs Age for main sequence stars.

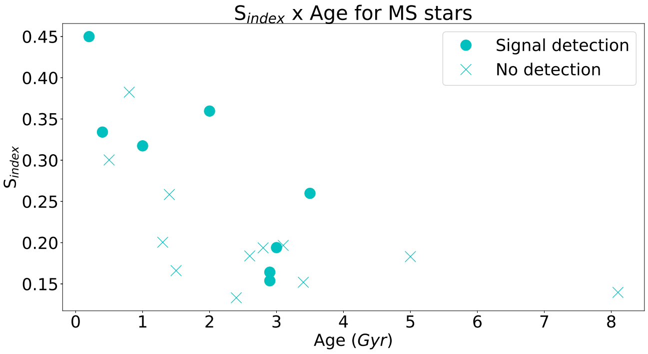

Figure 3. S_{index} vs Age for main sequence stars.

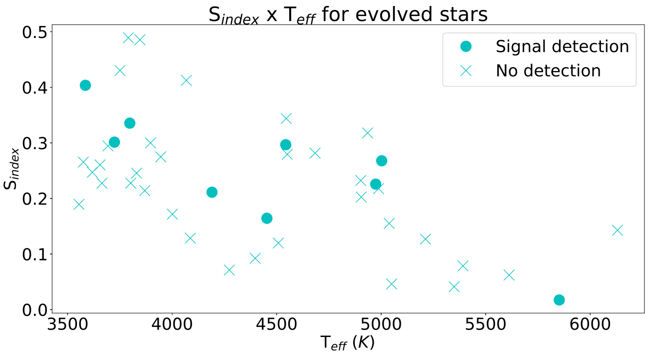

Figure 4. S_{index} vs T_{eff} for evolved stars.