VARIABILITY IN ACTIVE BINARIES: THE STELLAR METALLICITY AND ACTIVITY CORRELATION

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Magnetic fields are known to exist in a wide variety of stars throughout all evolutionary stages. While evidence of magnetic activity has been detected in evolved stars, **stellar activity along the red giant branch (RGB) has not been studied as systematically or continuously as in solar-type stars**.

Red giants in binary systems are particularly active due to their high rotation rates, enhanced by tidal interactions with their companions. **This elevated activity produces distortions and asymmetries in spectral lines**, which can impact the determination of key stellar parameters—such as metallicity—and reduce the reliability of commonly used activity indicators.

CONTEXT

- *Extend the study of the **correlation between stellar activity and metallicity to active red giant stars** in binary systems.*

- *Determine whether there is **evidence of spectroscopic variations** that could affect the determination of fundamental parameters (effective temperature T_{eff}, surface gravity log g, metallicity [Fe/H]).*

AIM

BINARY SYSTEM RS CVn HD 119285
giant K0 III + dwarf (?)
(Kervella et al. 2019)

28 REOSC SPECTRA (CASLEO, Argentina)
extended from 2002 to 2022
within the HKα Project
(led by IAFE from 1999 to the present)

Spectral Coverage: 3,890-6,690 Å
Resolution: ~ 13,000

TARGET

M1. Stellar activity index calculation

Spectroscopically, **the chromospheric Ca II H & K lines** (Fig. 1) show significant variation in response to activity phenomena and are commonly used to quantify such activity through **the Mount Wilson S-index**, defined as the ratio between the flux in the line cores and the nearby continuum (Leighton, 1959; Wilson, 1966; Vaughan et al., 1978; Duncan et al., 1991; Baliunas et al., 1995). **See R1**.

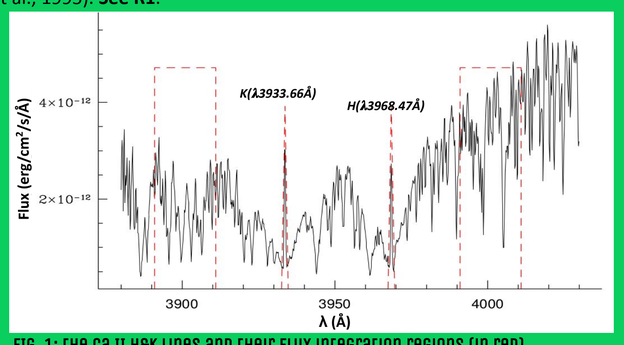
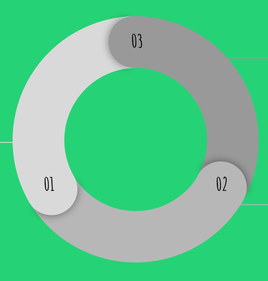


FIG. 1: the Ca II H&K lines and their flux integration regions (in red)

M2. Stellar parameters determination



Fe lines
50 Fe I; 10 Fe II
E.P.; log *gf*; EWs
Holanda et al. (2020)
M. Vieytes (2024)

MOOG code
Sneden (1973, v2019)
T_{eff} -> Ab(Fe I) vs E.P.
ξ -> Ab(Fe I) vs. EW/λ
log *g* -> Ab(Fe I)= Ab(Fe II)
[Fe/H] -> Ab(Fe)

Stellar models atmosphere
Plane-parallel 1D; LTE
Castelli & Kurucz (2009)

The determination of the parameters is iterative and interdependent. **See R2**.

METHOD

M3. Another stellar activity indicator

Phenomena associated with stellar activity can also be studied through the Hα line (Fig. 2), which is sensitive to chromospheric activity. The mean integrated flux of the line core is used as an indicator of the overall activity level of stars, and **its variability over time is related to stellar rotation and the evolution of stellar active regions.**

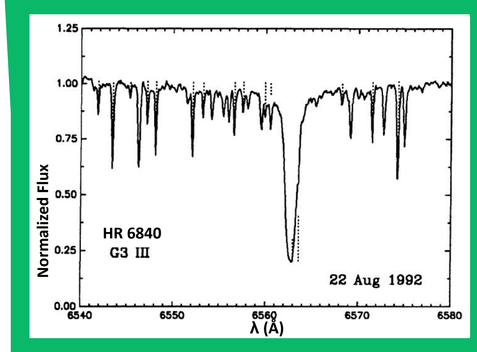


FIG. 2: Example of a typical H α line for a red giant
(Eaton, 1995)

Several authors (Livingston et al. 2007; Cincunegui et al. 2007; Santos et al. 2010; Flores et al. 2018; Meunier et al. 2022; Ibáñez-Bustos et al. 2023) have confirmed the existence of a **correlation between the Ca II H&K lines and Hα emissions** in main-sequence stars (FGKM). **See R3** for the analysis of this line in our target object.

FUTURE WORK

-Determine **stellar parameters for the remaining spectra in the sample**:

- Are the **non-significant differences** found so far indicative of imperceptible spectral variations, or are they due to instrumental resolution?

- Are they linked to the long-term stellar activity cycle that was identified?

-Complement the spectroscopic study of the HD 119285 system **with a photometric analysis with TESS** (Ricker et al. 2015) to confirm (or rule out) the occurrence of flares.

-Expand the study of this type of system to establish a robust metallicity–stellar activity correlation in evolved stars.

RESULTS

R1. Long-term variability curve

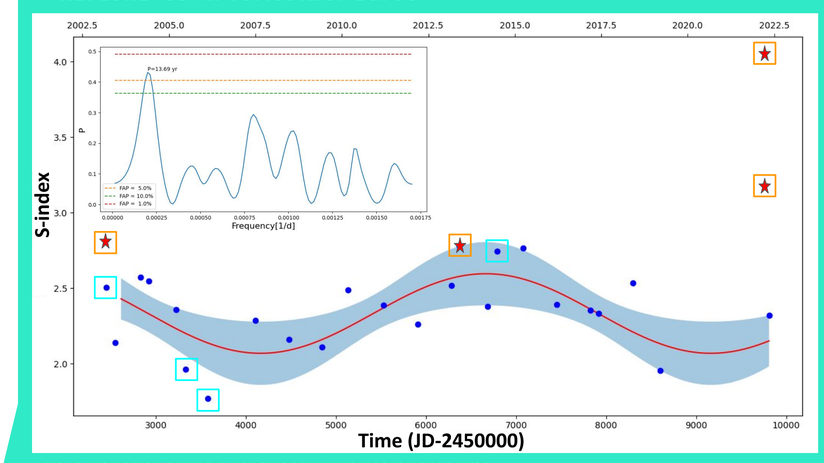


FIG. 3: Variation of the S-index activity indicator over time

From the time series of the S-index, we calculated the periodogram using the generalized Lomb-Scargle (GLS) method and the false alarm probability (FAP) of the period (Zechmeister & Kürster, 2009) to search for periodic signals (Fig. 3). For reliable periodicity detection, we applied a cutoff of FAP < 5%.

As a result, **we detected a long-period chromospheric activity cycle of approximately 13 years.**

R2. Spectroscopic parameters of the system

The stellar parameters determined for spectra with maximum and minimum activity levels, **highlighted by cyan squares in Fig. 3, are characterized by:**

- showing slight variations between spectra at maximum and minimum activity levels, although these are not significant.

- exhibiting systematically lower equivalent widths of the studied lines during the maximum activity level.

For the spectra analyzed so far, no correlation is observed between the stellar parameters and the star's activity.

R3. Hα line: evidence of flares?

Spectroscopic observations of the giant star in the HD 119285 system show **variations in both the profile and intensity of the Hα line** over the years. Figure 4 displays the temporal variation of this line **over a 12-year period:** in 2002 and 2014, coinciding with **the highest levels of stellar activity** (see Fig. 3), **the Hα line exhibits a pronounced emission above the continuum, whereas in 2006, during the minimum of stellar activity, the line appears in absorption and exhibits greater intensity.**

This behavior has also been observed in RS CVn systems (Inoue et al. 2023; Cao & Shenghong, 2024), and it is widely accepted that **asymmetries in chromospheric line profiles such as Hα are due to** mass motions and velocity gradients in stellar atmospheres, that is, to **the occurrence of flares** (Berlicki, 2007; Kuridze et al., 2015).

Although the study of these asymmetries allows the derivation of velocities in different parts of the flare, the variability of the Hα line in this case makes it unsuitable to be considered as an indicator of stellar activity, as initially proposed in M3. Moreover, spectra associated with this phenomenon, marked by orange squares in Fig. 3, were not included in the calculation of the S-index (M1).

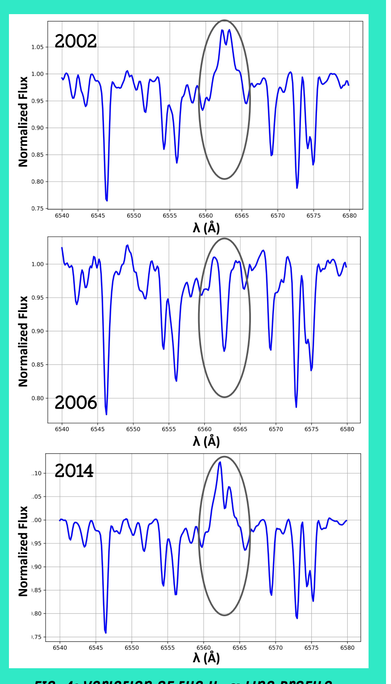


FIG. 4: Variation of the H α line profile over 12 years

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