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THE INFRARED CALCIUM TRIPLET AS A CHROMOSPHERIC ACTIVITY INDICATOR: FROM NARVAL AND ESPADONS TO GAIA DR4

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Abstract. This work represents a first step toward the large-scale study of stellar activity with Gaia DR4 data (2026-2027). For this purpose, I use the infrared calcium triplet (Ca II IRT) as an alternative chromospheric activity indicator, particularly suited to the spectral domain of Gaia, where the blue region is missing. To assess the sensitivity of Ca II IRT and test the performances expected with Gaia DR4, I present an analysis of a large sample of time-series (FGK stars) high-resolution spectra obtained with NARVAL and ESPaDOnS. These two instruments provide simultaneous access to the Ca II IRT and to the standard chromospheric activity index $\log R'_{HK}$. I tested several indicators in detail to analyze chromospheric activity: one of S-index type without photospheric correction, and another based on the subtraction of LTE models of inactive stars, thereby correcting for the photospheric contribution. Correlations with $\log R'_{HK}$, both on average values and on individual time series, allow us to test the reliability and sensitivity of the Ca II IRT. I observe promising correlations, which also make it possible to characterize the amplitude of the variability in both indicators. To ensure the feasibility of this analysis on Gaia DR4 data, I studied the impact of several factors on the robustness of the Ca II IRT indicators, in particular the effect of Gaia's medium spectral resolution. In the longer term, Gaia DR4 will enable the study of chromospheric activity, together with photometric variability, as a function of fundamental stellar parameters (temperature, surface gravity, metallicity) for a very large stellar population.

Keywords: Stellar activity, spectroscopy, activity indicators

1 Introduction

Chromospheric activity in solar-type stars is usually traced by the $\log R'_{HK}$ index, derived from the Ca II H and K lines in the blue. This activity is closely related to stellar magnetic fields and manifests as temporal variability. Previous studies (Radick & al. 2018) showed that young stars typically exhibit an anticorrelation between brightness and chromospheric emission (spot-dominated regime), while older stars like the Sun display a positive correlation (plage/faculae-dominated regime). However, the transition between these regimes remains ambiguous. Extending such analyses to large stellar samples requires new proxies adapted to the infrared domain.

2 Infrared activity indicators, calibration and results

We focus on two indicators derived from the Ca II infrared triplet: the Ca IRT index and the α-index. The Ca IRT index is an analogue of the S-index in the red, without photospheric or bolometric corrections. The α-index compares observed spectra with an inactive LTE model to quantify chromospheric excess in the IRT lines, explicitly accounting for the photospheric contribution. Since $\log R'_{HK}$ cannot be measured in the infrared, validating these indicators is essential for their application to *Gaia* DR4.

We used an FGK stellar sample observed with the high-resolution spectrographs NARVAL and ESPaDOnS. The comparison of Ca IRT and α-index with $\log R'_{HK}$ allows us to assess their reliability. Both indicators show a clear correlation with $\log R'_{HK}$, particularly strong for the α-index in active stars (see Figure 1). The Ca IRT index also correlates, although with slightly larger scatter, as expected due to the lack of photospheric correction.

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Both α and Ca IRT indices are validated as robust chromospheric activity tracers. Applying these proxies to *Gaia* DR4 time series spectra will provide measurements of the mean activity level and its variability (see Figure 2)for millions of stars. This will enable large-scale studies of magnetic activity regimes (spot- vs plage-dominated), the influence of metallicity and spectral type, and stellar cycle characterization. Such diagnostics are crucial for *PLATO* target selection and for improving stellar characterization.

2.1 Figures

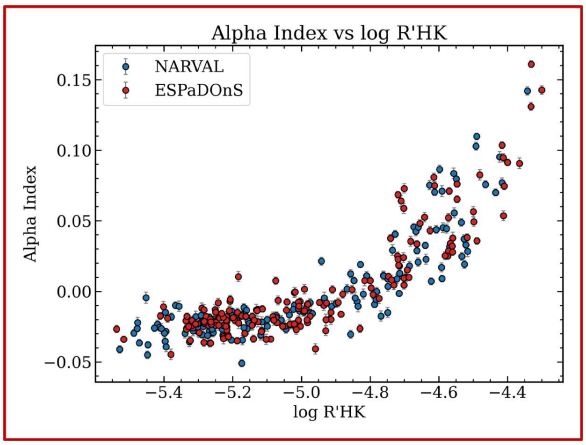

Fig. 1. α-index against log R'_{HK} from NARVAL and ESPaDOnS spectra

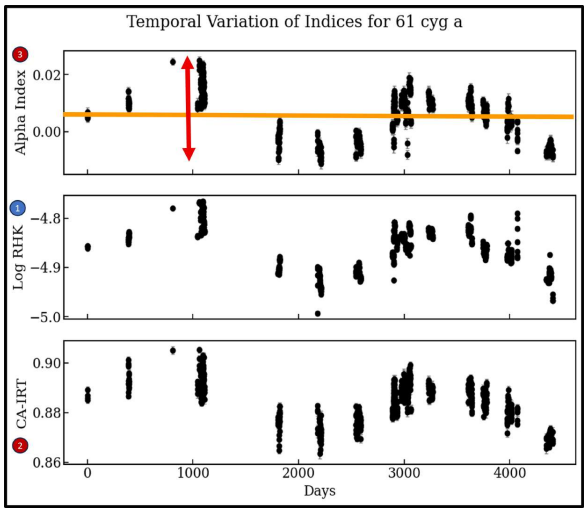

Fig. 2. Temporal variations of the α-index, log R'_{HK}, and Ca IRT index for 61 Cyg A.

3 Conclusions

- The systematic comparison of several chromospheric indicators provides a robust activity index.
- Infrared indicators applied to the Gaia DR4 time series spectra can reveal both the average level of stellar activity and its amplitude of variation.
- Enables large-scale studies to distinguish between spot-dominated and facule-dominated regimes and to analyze the impact of metallicity, spectral type, and other stellar parameters.
- Provides valuable diagnostics for monitoring PLATO mission targets and stellar characterization.

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References

Radick, R. & al. 2018, ApJ, 855, 75