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A statistical analysis of Hα-Ca II relation for solar-type stars of different activity levels

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Abstract. Based on our large spectral database obtained at CASLEO Argentinian Observatory, we analyzed the relation between simultaneous measurements of Hα and Ca II H+K fluxes. Although the correlation between both proxies is positive for the solar case, in 2007 our group found that while some stars exhibit correlations between Hα and the Ca II lines, the slopes change from star to star, including cases where no correlation was found. To discern if this flux-flux relation depends on the level of activity of the star and if it is associated with the distribution of active regions in the stellar atmosphere, in this work we analyze the relation between Hα-Ca II fluxes for the whole set of 44 G dwarf stars and individually for a subset of several solar-type stars of different level of activity.

Keywords. stars: activity, late-type, line: profiles, methods: statistical

1. Introduction

It is well known that the correlation between the Ca II K and H line-core fluxes and the Hα emission is positive in the solar case for the whole solar-cycle (Livingston *et al.* 2007).

However, Cincunegui *et al.* (2007) reported that the correlation between Ca II and Hα is not always valid for stars. In that paper they studied this relation for a set of 109 dF to dM stars and found that while some stars exhibit correlations between both proxies, the slopes change from star to star. Furthermore, in several cases Hα and the Ca II fluxes were not correlated, as in the binary system Gl 375 (Díaz *et al.* 2007) and the M dwarfs Gl 229 A and Gl 752 A (Buccino *et al.* 2011), and other stars even exhibit anti-correlations.

Motivated by these results, Meunier & Delfosse (2009) re-analyzed the Ca-Hα relation for the Sun for different solar-cycle phases and they found that this correlation depends on the balance between the emission in plages and absorption in filaments.

2. Observations

Since 1999, we systematically observed more than 140 main-sequence stars, with the Echelle spectrograph on the 2.15 mts telescope of the CASLEO Observatory located in the Argentinean Andes. To date, we have more than 5000 spectra, ranging from 3890 to 6690 Å with R = 13000, which constitute an ideal dataset to study long term activity. Following Cincunegui & Mauas (2004) spectra are calibrated in flux which allow us to simultaneously study different spectral features, from the Ca II lines to Hα.

In this work, we extended the analysis presented in Cincunegui *et al.* (2007) by adding 5 years of simultaneous CASLEO observations of Ca II and Hα chromospheric lines. The 12-year-length of both series allow us to discern if the Ca II-Hα relation depends on the level of activity of each individual star and if it is associated to the distribution of active regions in the stellar atmosphere. In the present work, we specifically summarize our results obtained for the dG stars of our stellar sample.

3. Hα-Ca II H+K for dG stars

For a set of 767 CASLEO spectra of 44 G0-G9 dwarf stars, we obtained simultaneous measurements of Ca II and Hα fluxes. On each spectrum we integrated the Ca II H and K line-core fluxes with a triangular profile of 1.09Å FWHM and we computed the flux in the Hα line as the average surface flux in a 1.5 Å square passband centered on 6562.8 Å. In Fig. 1 we plot both surface fluxes obtained.

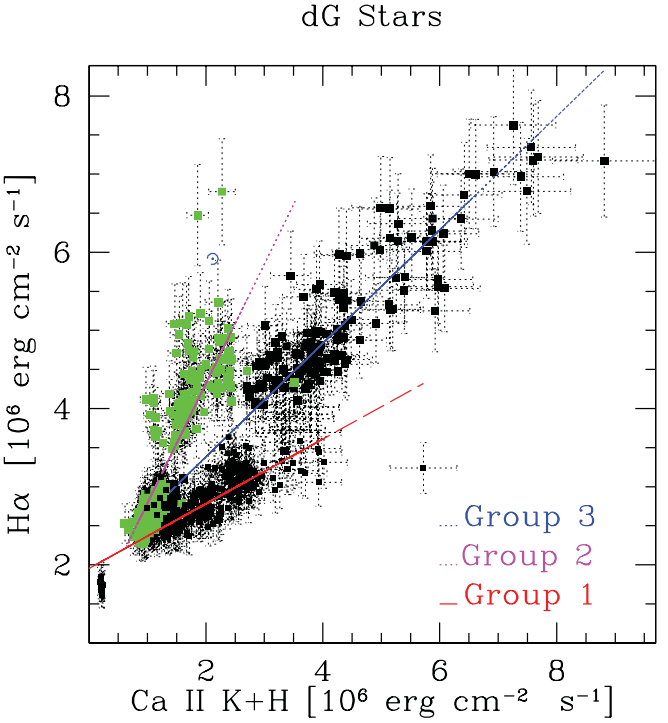

Figure 1. Hα vs. Ca II H+K fluxes for a set of 44 G dwarfs obtained from CASLEO spectra. We also included these values for the Quiet Sun, derived from Kitt Peak spectra ($\odot$).

In Fig. 1 we observe that there is not a single Hα-Ca II relation for G stars. It seems that we could recognize three groups with different trends, which could be related to the balance of different magnetic structures in the stellar atmosphere. The Quiet Sun ($\odot$) seems to belong to the group with high Hα emission and low Ca II fluxes, coherent with results presented in Meunier & Delfosse (2009).

Assuming that these three different Hα-Ca II tendencies in dG stars cannot be due to differences in color, we analyzed the relation for each star individually. In Fig. 2 we plot an histogram of the Pearson correlation coefficient and the slope obtained for each group of stars.

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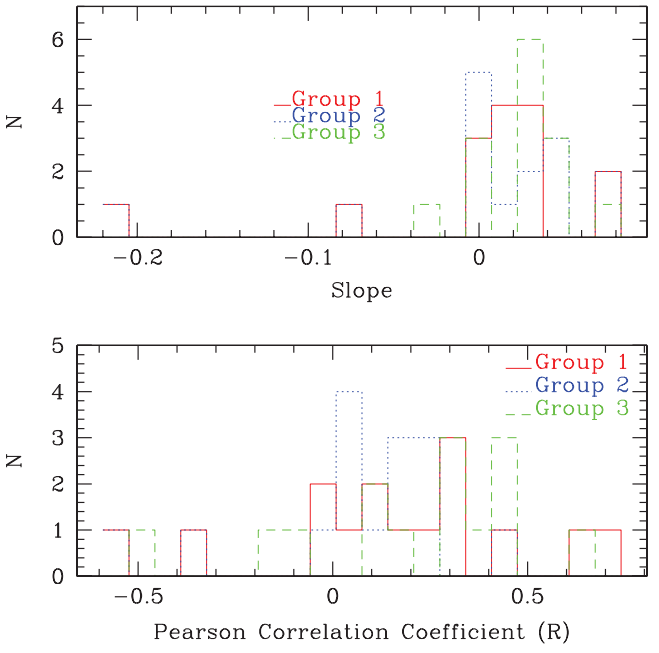

Figure 2. Histogram of Pearson correlation coefficients and slopes of the Hα-Ca II relation for each individual star.

Most of the stars present a positive correlation between Hα and Ca II fluxes as observed in the Sun. Nevertheless we observe a great dispersion in both correlation coefficients and the slopes, confirming Cincunegui *et al.* (2007).

4. Hα-Ca II H+K for solar analogues

Meunier & Delfosse (2009) found that the Hα-Ca II correlation coefficient in the solar case is not the same along the solar cycle, as it is even higher than for the whole solar-cycle at the end of the ascending phase and much lower (R<0.5) at cycle minimum. To analyze this result for stellar cases, in Fig. 3 we plot the Hα and Ca II fluxes for solar analogues of different activity regime (see Vieytes *et al.* 2005), we computed the Hα-Ca II correlation coefficient R for the whole dataset and for the most active phase of the star (R_{act}). We observe that although Hα and Ca II fluxes show a low correlation for the whole series, the correlation is strongly positive during the maximum active phase (indicated with red circled points) .

5. Conclusion

In this work, we extended the analysis between the Hα and Ca II fluxes presented in Cincunegui *et al.* (2007) by adding 5 years of simultaneous CASLEO observations of these chromospheric lines. In particular, we analyzed the fluxes derived from 767 spectra of 44 G0 to G9 stars obtained between 1999 and 2010. As a preliminary result, we found that there is not a single Hα-Ca II relation for G stars. We also analyzed this relation for each G star individually and we obtained a great dispersion in both correlation coefficients and the slopes for the whole stellar sample, confirming Cincunegui *et al.* (2007).

On the other hand, we analyzed the Hα-Ca II relation for several solar-type stars of different activity levels. For HR 6060, the best solar-twin, HD 1835 and HD 172051 we

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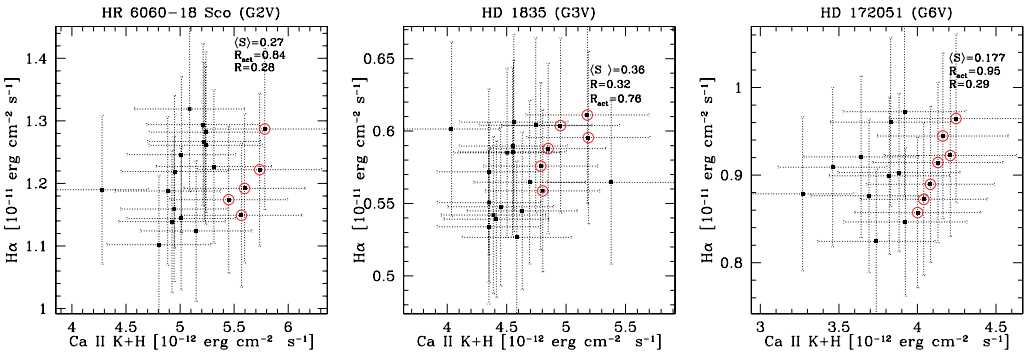

Figure 3. Hα-Ca II relation for three solar-analogues of different active regimes quantified by the mean Mount Wilson index ($\langle S \rangle$). We computed the Pearson correlation coefficient for the whole series (R) and for the red circled points (R_{act}), which indicate those points where the level of activity of the star excceeds in more than 0.5σ the mean.

found that the correlation between both proxies is strongly positive near the maximum active phase. In particular, HR 6060 (about solar-age) and HD 1835 (about Hyades-age, an older Sun) present similar correlation coefficients, probably indicating preservation of this correlation over epochs in which other observables change dramatically.

In future works we will explore these conclusions in detail.

References

Buccino, A. P., Díaz, R. F., Luoni, M. L., Abrevaya, X. C., & Mauas, P. J. D. 2011, AJ, 141, 34
Cincunegui, C., Díaz, R. F., & Mauas, P. J. D. 2007, A&A, 469, 309
Cincunegui, C. & Mauas, P. J. D. 2004, A&A, 414, 699
Díaz, R. F., González, J. F., Cincunegui, C., & Mauas, P. J. D. 2007, A&A, 474, 345
Livingston, W., Wallace, L., White, O. R., & Giampapa, M. S. 2007, ApJ, 657, 1137
Meunier, N. & Delfosse, X. 2009, A&A, 501, 1103
Vieytes, M., Mauas, P., & Cincunegui, C. 2005, A&A, 441, 701

https://doi.org/10.1017/S1743921312005030 Published online by Cambridge University Press