The chromospheric activity of M Dwarfs from visible and near-infrared CARMENES spectra: analysis of flux-flux relationships

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Abstract The main objective of this work within CARMENES survey (https://carmenes.caha.es) is the extraction of all available information on the chromospheric activity and its variability (rotational modulation, flares, etc.) using for that all the chromospheric indicators included in the spectral range of the spectrograph, ranging from visible (VIS) that include the Na I D1, D2 HeI D3, and Hα lines to near-infrared (NIR) that include the Ca II IRT, HeI 10830 Å, Paschenα and Paschenβ lines. Using the spectral subtraction technique, studies of flux-flux relationships of lines formed at different chromosphere layers are the subject of this communication, aimed to a better understanding of the magnetic activity of M-type dwarf stars.

Context of the research:

CARMENES (http://carmenes.caha.es/) is a ultra-stable, double- channel spectrograph at the former Spanish-German 3.5 m Calar Alto telescope for radial-velocity surveys of M dwarfs with the aim of detecting Earth-mass planets orbiting in the habitable zones of their host stars. The CARMENES survey, which began in January 2016 and still ongoing, aims to observe approximately 300 M-type dwarf stars, spread over the complete M spectral range.

The task of studying the chromospheric activity indicators is intended to be carried out applying the spectral subtraction technique, and to this end it has been used a Python code (iSTARMOD) based on a FORTRAN one, formerly used by the research group.

The detailed analysis of these activity indicators is important from one side in order to confirm or discard all the possible planets around these stars and by the other studying its dependency with other stellar parameters as rotation, age and depth of the convective zone.
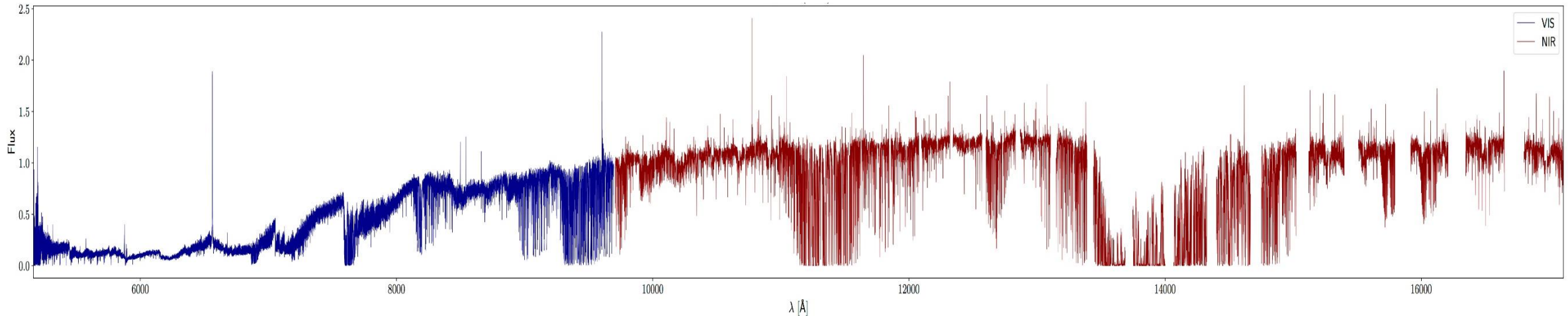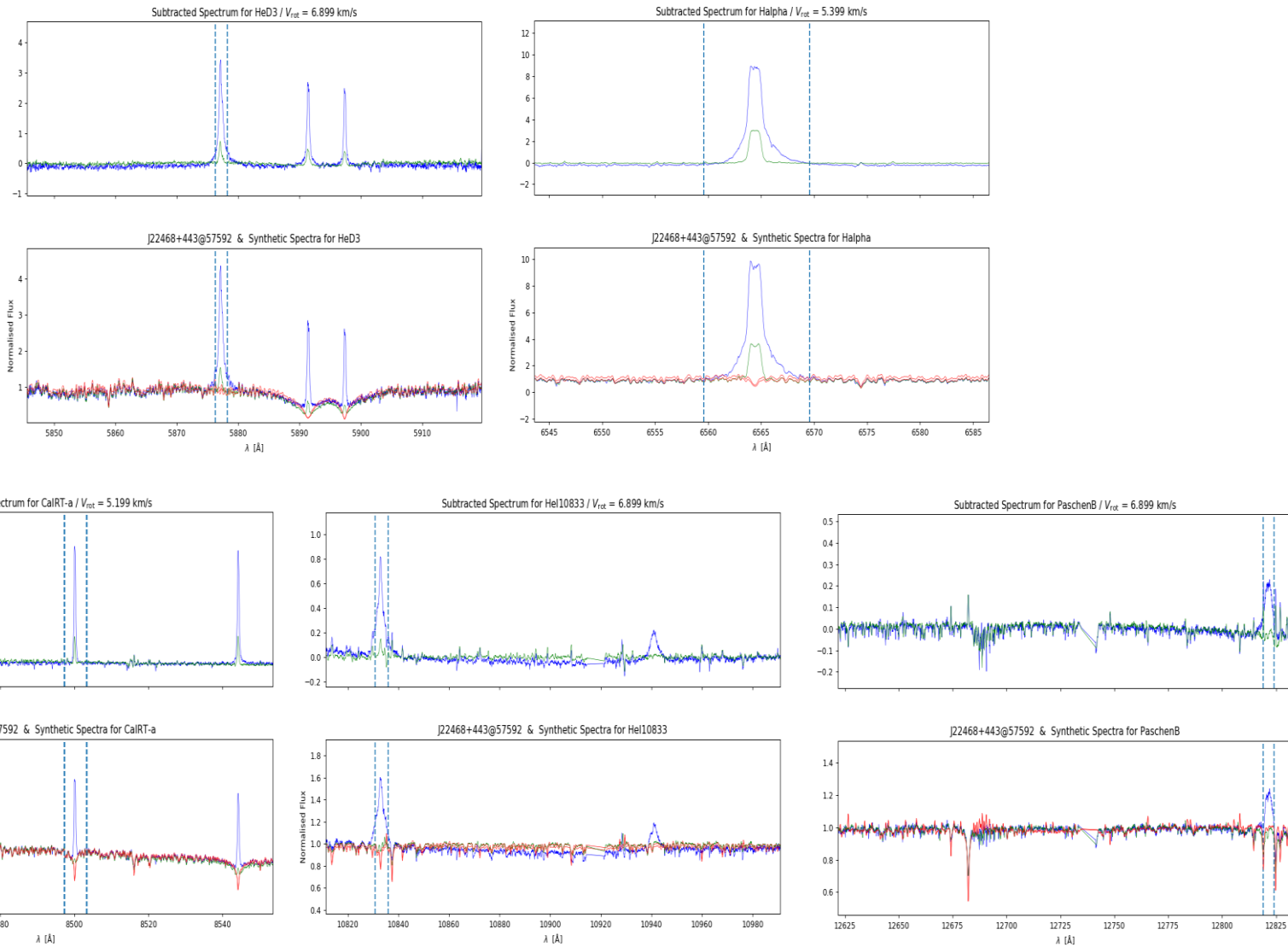
Fig. 1: Showing the results of the spectral subtraction for the chromospheric activity indicators (He I D_3, Na I D_1, D_2, Hα and the first two of three Ca II IRT lines in the VIS and He I 10830 Å, Pγ and Pβ lines in the NIR) for the CARMENES spectra of J22468+443 **(EV Lac)** at the **maximum level** of chromospheric activity (Flare) and in a previous **quiescent phase** as well as the **synthetic spectrum** obtained with a M3.5 V reference star (J22096-046). The spectra to perform the subtraction are shown at the bottom and the obtained subtracted spectra at top from where we derived the EW of the chromospheric contribution. The algorithm makes use of the python code iSTARMOD as described in a companion contribution
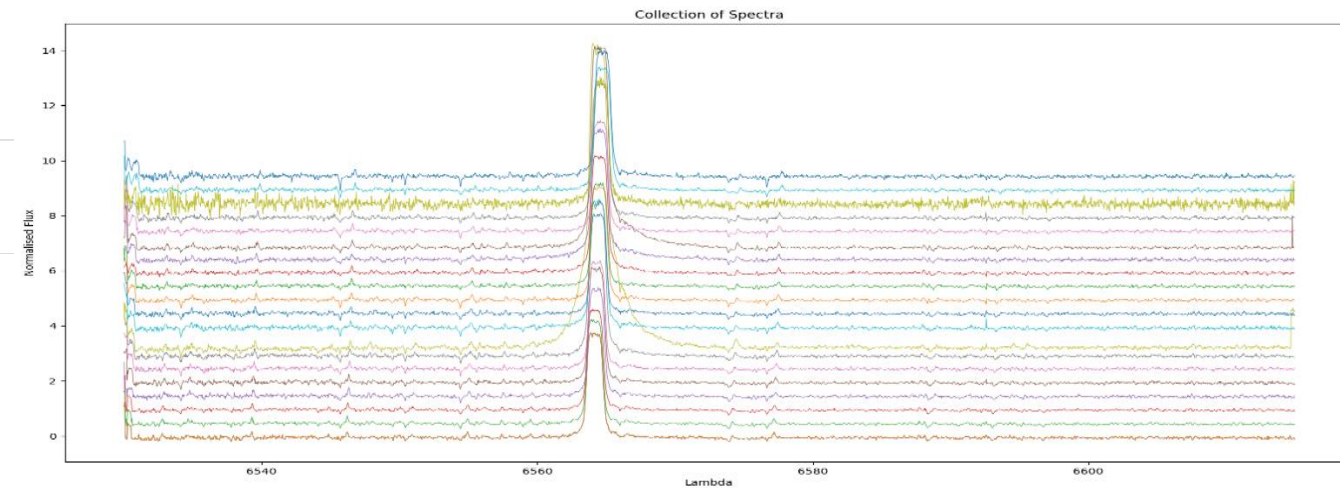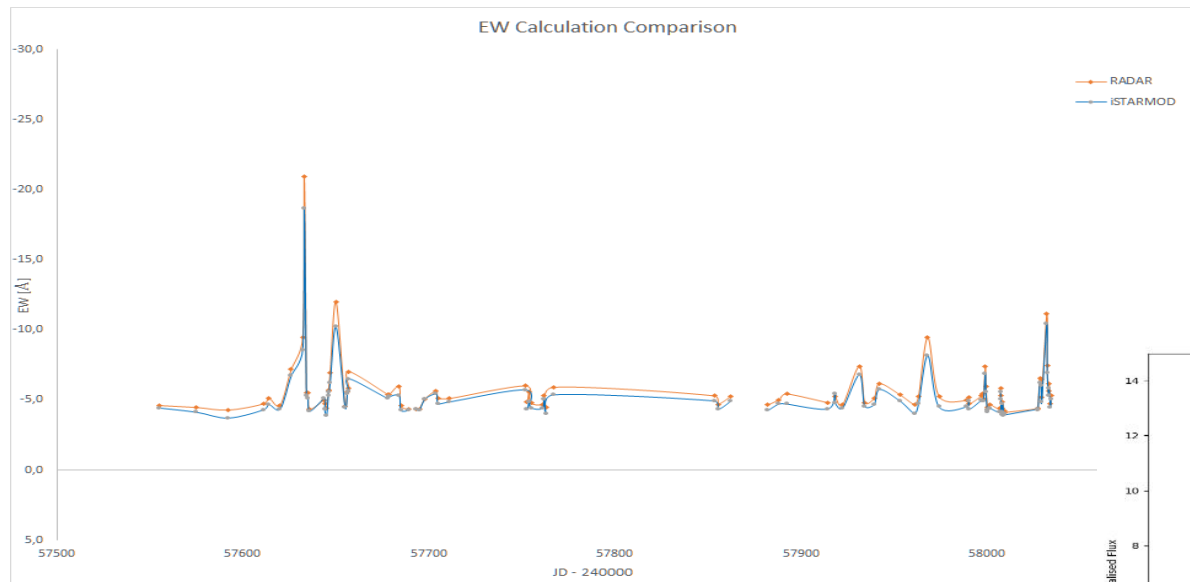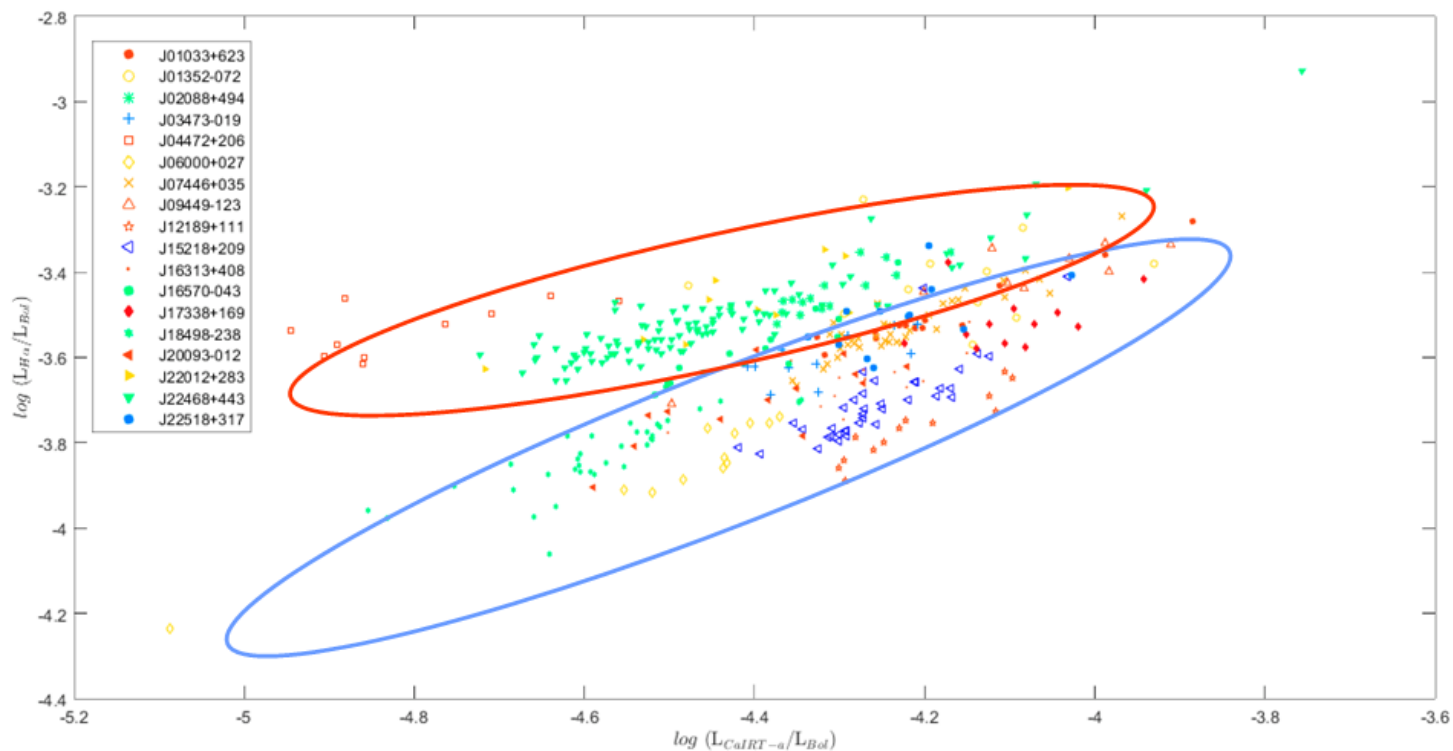
Fig. 2: The calculations of Figure 1 have been performed by means of iSTARMOD. This python code is based on a former code STARMOD (Barden 1985. See a companion contribujtion and references therein). The code has been adapted to the particular features and formats of the CARMENES spectra and include improvements as the determination of the equivalent widths and automation, in order to perform time series analysis of the set of spectra. An example of this analysis is shown in this figure, for the Hα Line. It is clearly seen the flare depicted in the subtracted spectra of Figure 1, where the EW measures reaches the maximum of the whole time series. In the figure is also compared our results with the resulting from RADAR, within the consortium

Fig. 3: The ultimate goal of this work is to obtain flux-flux relationship for the RV loud sample within the whole CARMENES survey. Here is shown the flux-flux relationship between CaIRT-a and Hα lines. There are clearly seen the different branches in the flux-flux relationship, resembling the dichotomy in the Hα emission found by López-Santiago et al. (2010). Stars in the "upper branch" in the flux-flux relationships are the stars above the Vaughan-Preston gap (believed to be younger stars probably with a different dynamo, Hartmann et al. 1984; Bohm-Vitense 2007). Similar calculations will be made, extending to the NIR range of the CARMENES spectra, in order to obtain a better understanding of the magnetic activity of M-type stars

□ J04472+206 RX J0447.2+2038 (vsini=52.20 km/s, M5.0 V)   ✳ J02088+494 G 173-039 (vsini=24.1 km/s, M3.5V)
○ J01352-072 Barta 161 12   (vsini=54.20 km/s, M4.0 V)   ● J16570-043 LP 686-027 (vsini=10.1 km/s, M3.5V)
△ J09449-123 G 161-071   (vsini=40.63 km/s, M5.0 V)
▶ J22012+283 V374 Peg   (vsini=39.49 km/s, M4.0 V)   ▼ J22468+443 EV Lac   (vsini=3.5 km/s, M3.5 V)

Impact and prospects for the future

In obtaining these flux-flux relationship is intended to extend the work of Martinez-Arnaiz et. Al to the whole M spectral range, using CARMENES spectra.

The flux-flux relationship calibration established in Reiners, A. & Basri, G. for Hα activity indicator will also be extended to other activity indicators, performing calibrations using the synthetic spectra of Cifuentes et al. also in the framework of CARMENES scientific program

References:

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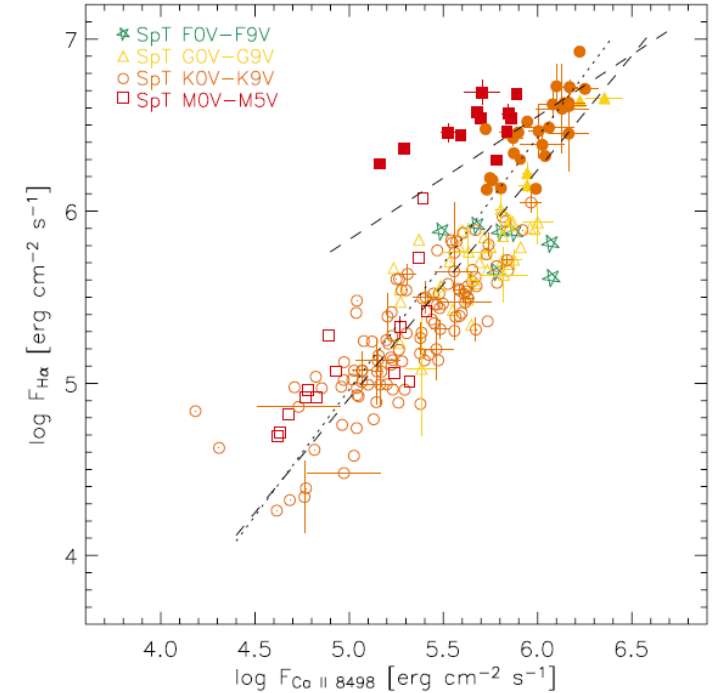
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Figure taken from Martinez-Arnaiz et al. 2011