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

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Abstract. CARMENES is a brand-new, ultra-stable, double- channel spectrograph at the 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 (Quirrenbach et al. 2016), which began in January 2016 and will last for at least three years, aims to observe approximately 300 M-type dwarf stars, spread over the complete M spectral range. The main objective of this work 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 **NaI D_1, D_2 HeI D_3**, and **Hα** lines to near-infrared (NIR) that include the **CaII IRT**, **HeI 10830 Å**, **Pγ** and **Pβ** lines. For this task we apply 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. 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.

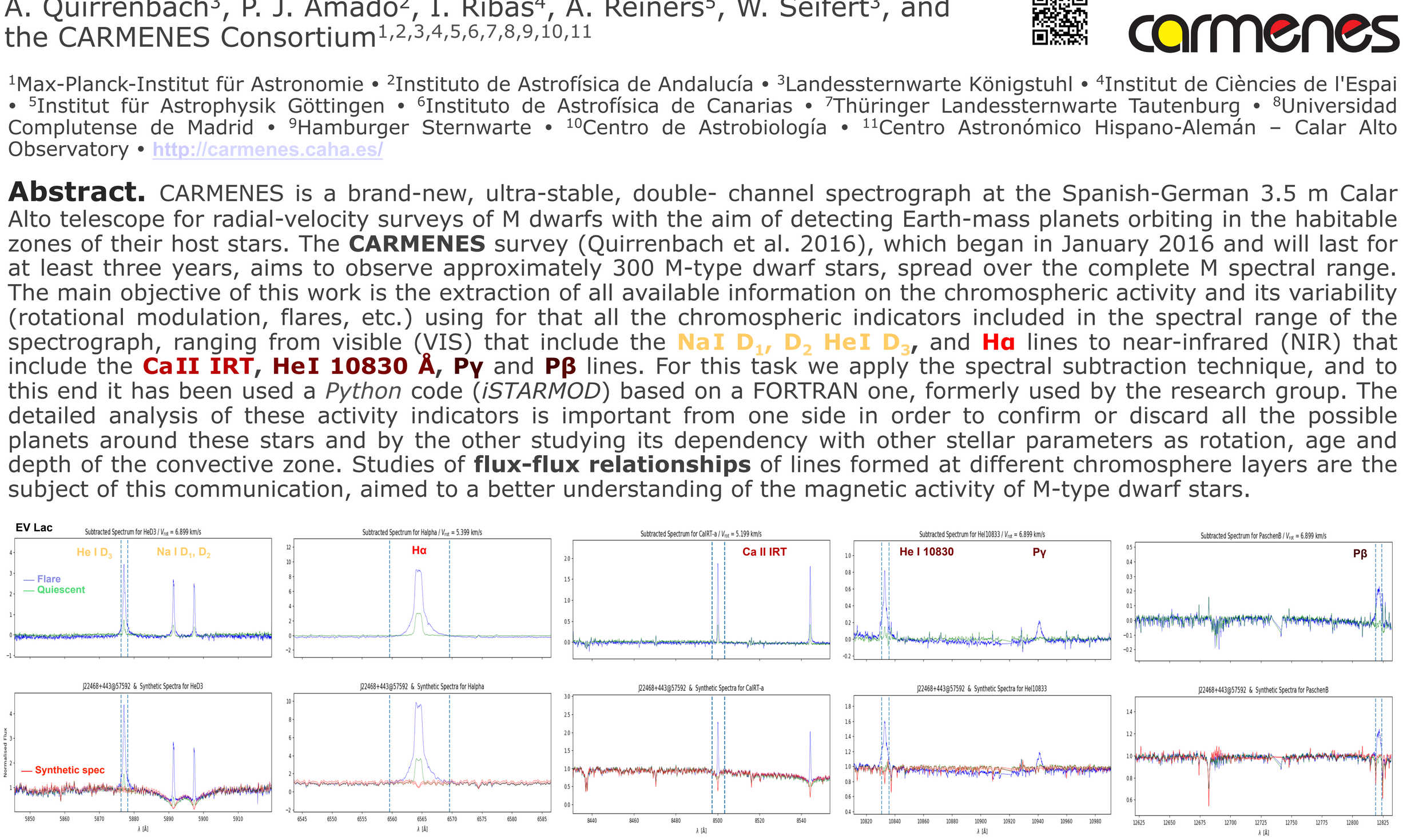


Fig. 1: Results of the spectral subtraction for the chromospheric activity indicators (He I D_3, Na I D_1, D_2, Hα and the first two of three Ca II IRT lines in the VIS and He I 10830 Å, Pγ and Pβ lines in the NIR) for the CARMENES spectra of J22468+443 (**EV Lac**) at the **maximum** level of chromospheric 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.

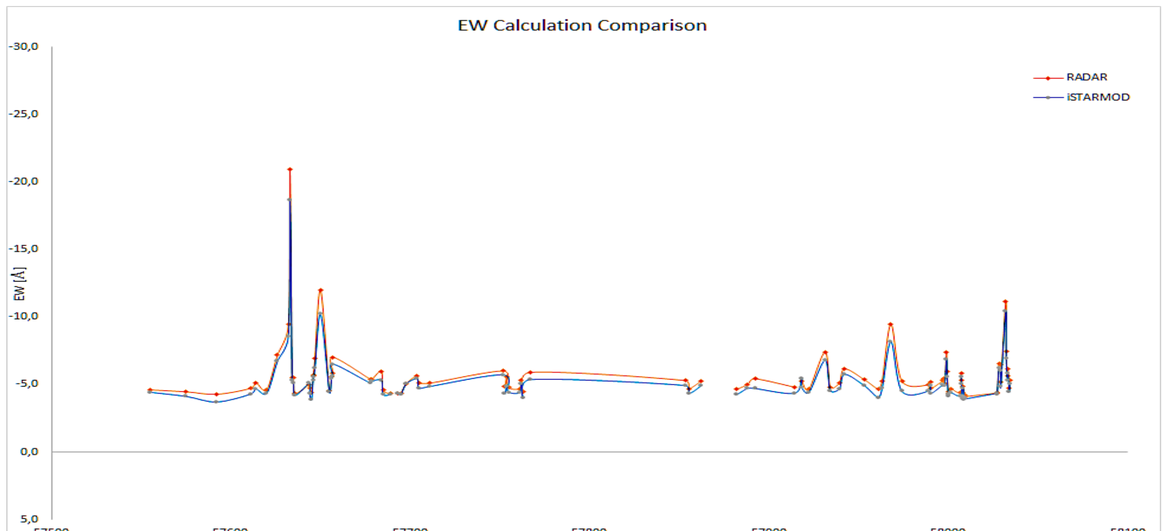
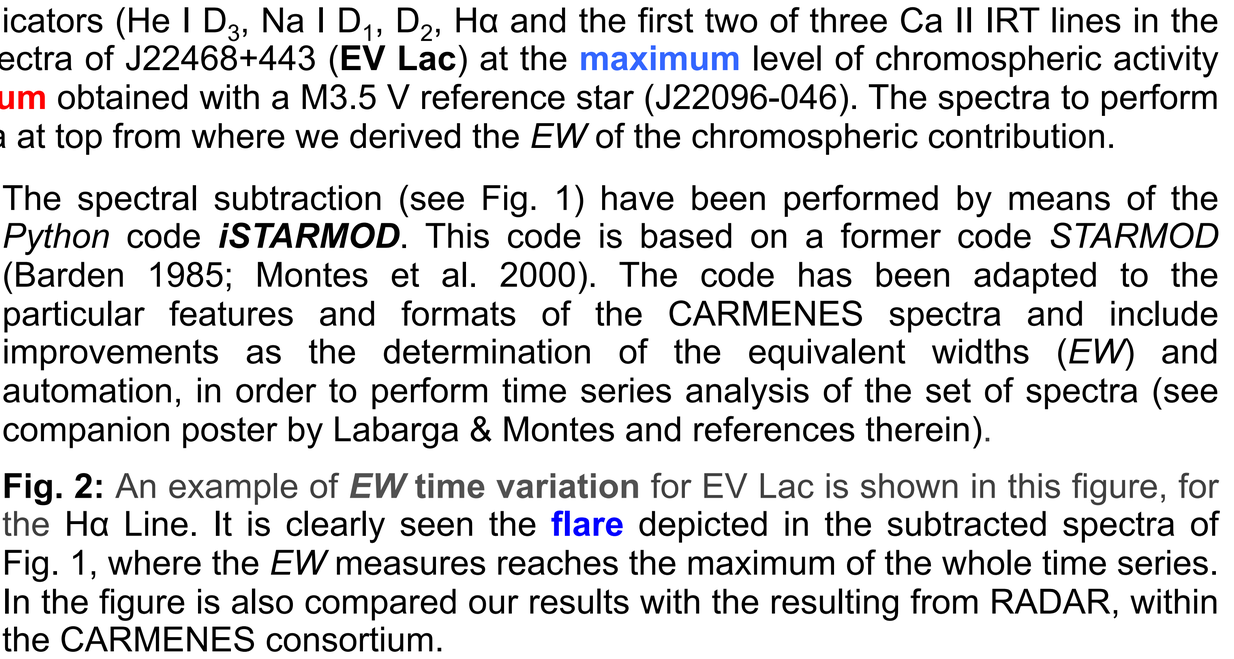


Fig. 3: The ultimate goal of this work is to obtain **flux-flux relationship** for the RV loud sample (Tal-Or et al. 2018) within the whole CARMENES survey. Here is shown the flux-flux relationship between Ca II IRT and Hα lines. There are clearly seen the different branches in the flux-flux relationship, resembling the dichotomy in the Hα emission found by López-Santiago et al. (2010) and Martínez-Arnáiz, et al., (2011). 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**). In our sample also the stars in the "upper branch" are the more rapid rotators and young stars. Similar analysis 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.

The spectral subtraction (see Fig. 1) have been performed by means of the *Python* code ***iSTARMOD***. This code is based on a former code *STARMOD* (Barden 1985; Montes et al. 2000). 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 (*EW*) and automation, in order to perform time series analysis of the set of spectra (see companion poster by Labarga & Montes and references therein).

Fig. 2: An example of ***EW* time variation** for EV Lac is shown in this figure, for the Hα Line. It is clearly seen the **flare** depicted in the subtracted spectra of Fig. 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 CARMENES consortium.



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Acknowledgements: Based on data obtained for the CARMENES project, the German-Spanish priority programme at Calar Alto Observatory. This research is partially supported by the Universidad Complutense de Madrid (UCM), the Spanish Ministerio de Economía y Competitividad (MINECO) from project AYA2016-79425-C3-1,2,3-P