Identifying activity- and magnetically-sensitive spectral lines in M dwarfs using CARMENES visible and near infrared spectra

D. Montes[8], A. López-Gallifa[8], F. Labarga[8], E. Marfil[8], C. Duque-Arribas[8], H.M. Tabernero[10], J.A. Caballero[10], M. Lafarga[4], S.V. Jeffers[5], I. Ribas[4], A. Reiners[5], A. Quirrenbach[3], P.J. Amado[2], and the CARMENES Consortium[1,2,3,4,5,6,7,8,9,10,11]

[1]Max-Planck-Institut für Astronomie • [2]Instituto de Astrofísica de Andalucía • [3]Landessternwarte Königstuhl • [4]Institut de Ciències de l'Espai • [5]Institut für Astrophysik Göttingen • [6]Instituto de Astrofísica de Canarias • [7]Thüringer Landessternwarte Tautenburg • **[8]Universidad Complutense de Madrid**, IPARCOS-UCM • [9]Hamburger Sternwarte • [10]Centro de Astrobiología • [11]Centro Astronómico Hispano-Alemán – Calar Alto Observatory • http://carmenes.caha.es/

In In this contribution we summarize our project devoted to identify **activity-** and **magnetically-**sensitive spectral lines in the **CARMENES** (Quirrenbach et al. 2020) visible and near-infrared spectral range of **M dwarfs**. The aim is to contribute to solve **the problem of stellar activity in radial velocity (RV) measurements** to search for exoplanets around these stars and in the determination of precise stellar parameters. To identify lines with a significant chromospheric contribution, apart from well known activity indicators (**Na I D_1, D_2 He I D_3**, **Hα**, **Ca II IRT** lines, **He I 10830 Å**, **Paγ** and **Paβ** lines), we have used the **spectral subtraction** technique using our Python code **iSTARMOD** Labarga & Montes (2020) based on a former code *STARMOD* (Barden 1985; Montes et al. 2000). We choose as reference the spectrum of the star with lower activity level. We confirm the new activity-sensitive lines by analysing the correlation with the other well known activity indicators in the same spectra and their temporal evolution. In addition, we have analysed line by line the template spectrum (co added of all the individual spectra available) applying also the spectral subtraction using in this case as reference star an inactive M dwarf star of similar spectral type to search for magnetically-sensitive spectral lines, that is lines with detectable **Zeeman broadening**.

Activity-sensitive lines

The spectral subtraction was applied to all the CARMENES spectral orders (VIS + NIR) of two "*active RV-loud stars*", **EV Lac** and **YZ CMi** (Tal-Or et al. 2018) and compared the subtracted spectra at **Quiescent** state and at **Flare maximum** to identify new activity-sensitive lines.

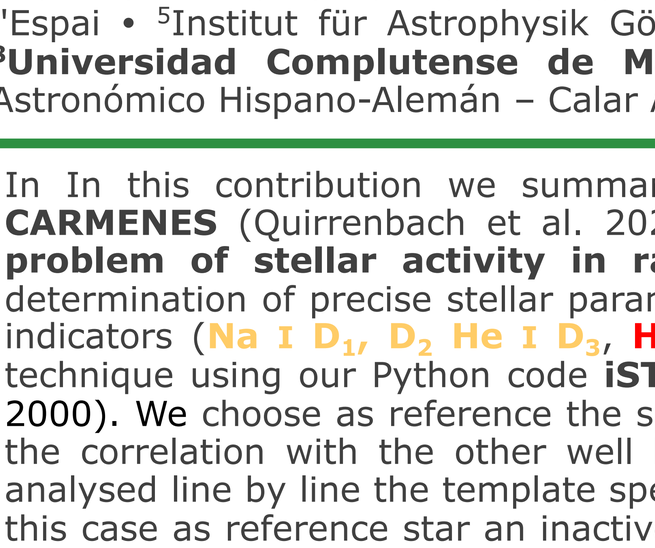

Fig. 1: Example of identification of some activity-sensitive lines in the spectrum at the **Flare maximum** on EV Lac. The lower panel shows the observed+syntethic spectra and the upper panel shows the subtracted spectrum where several emission lines are detected.

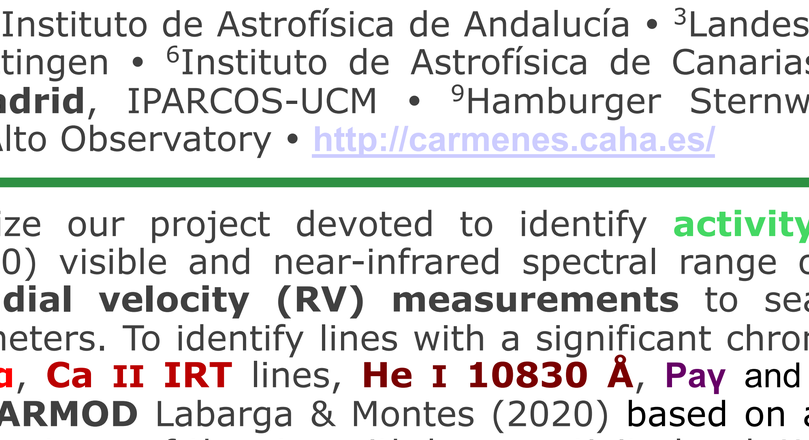

Fig. 2: An example of ***EW* time variation** for EV Lac for one of the new activity-sensitive lines (FeI 5429,706 Å) and for the Hα line to confirm that follows the same behaviour.

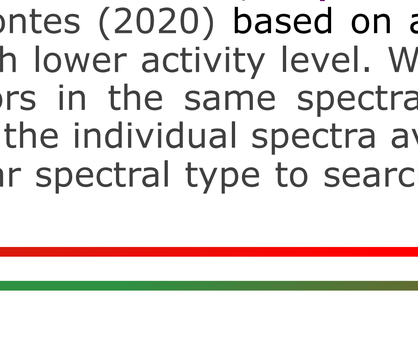

Fig. 3: Correlation between the *EW* of the activity-sensitive line (FeI 5429,706 Å) in the spectra where is detected (during flares) and the EW of the Hα line.

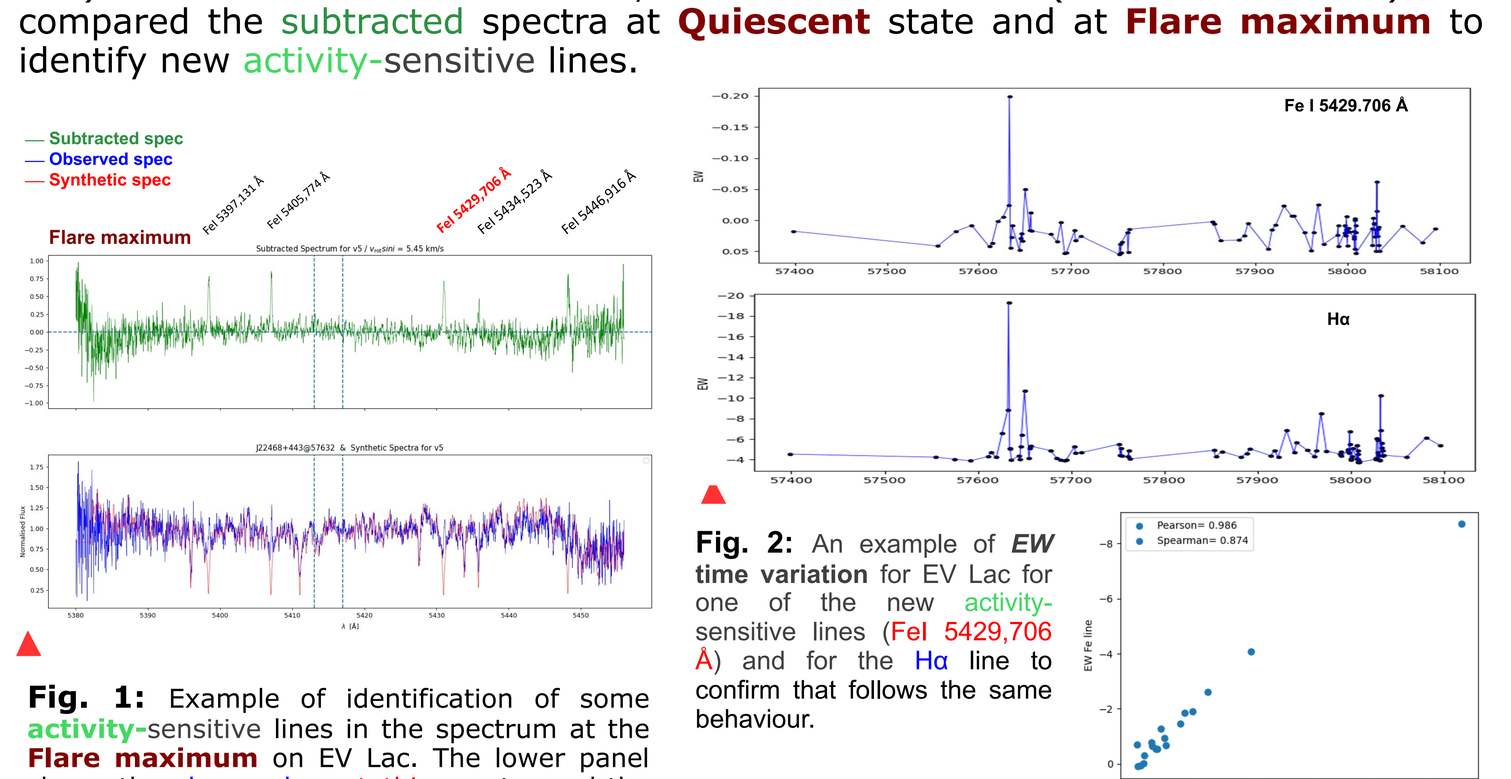

Fig. 4 Some of the identified activity-sensitive lines on EV Lac. Plotted spectra are as in Fig. 1.

Magnetically-sensitive lines

The spectral subtraction was applied to all the CARMENES spectral orders (VIS + NIR) of **EV Lac** and **YZ CMi** (that have high **magnetic field** (Reiners et al. 2022) of the template spectrum using in this case as reference star an inactive M dwarf star to search for magnetically-sensitive spectral lines, that also have large effective Landé – factor.

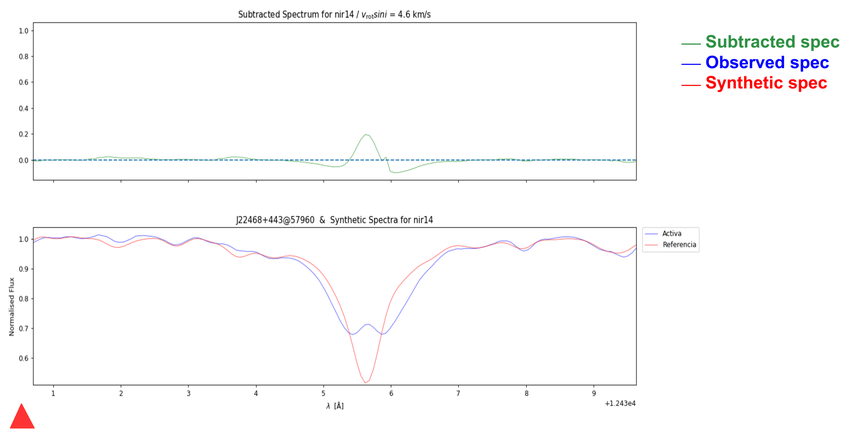

Fig. 5: Example of identification of an **magnetically-**sensitive line on EV Lac. The lower panel shows the observed+syntethic spectra and the upper panel shows the subtracted spectrum. Note the **Zeeman broadening.**

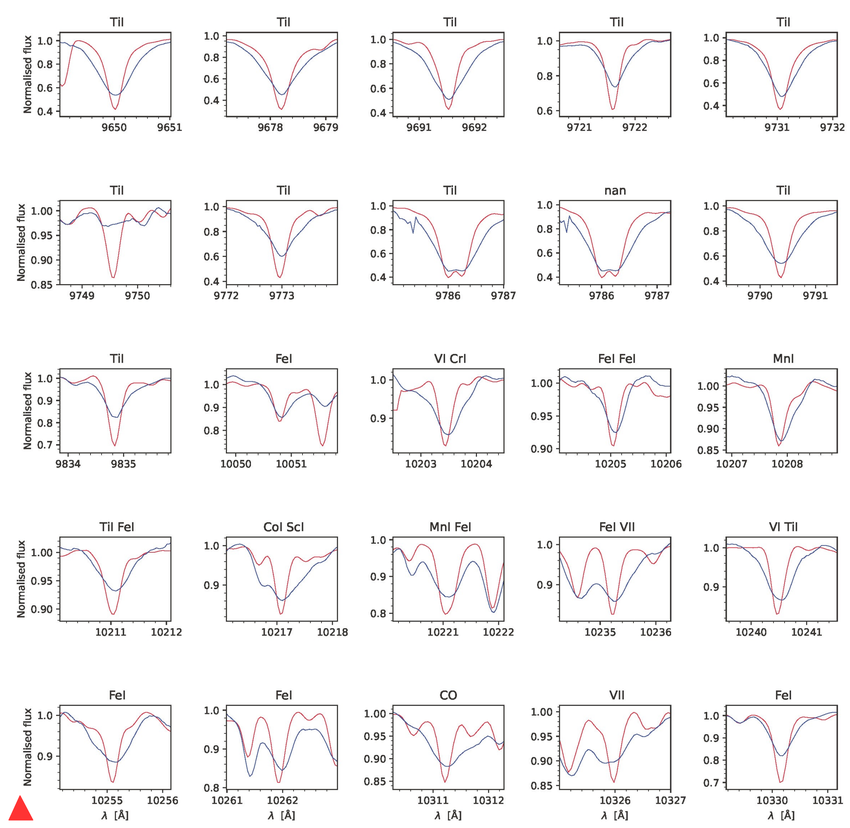

Fig. 6 Some of the identified magnetically-sensitive lines on EV Lac. Plotted spectra are as in Fig. 5.

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We are now studying the impact of the elimination of the lines identified in this way on the RV determination using cross correlation functions with weighted binary masks as in Lafarga et al. (2020) and comparing with activity-sensitive lines identified by line-by-line RV analysis in Lafarga et al. (2023).

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