Spectroscopic properties of UV Ceti-type Stars

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Abstract: Due to instrumental limitations, time-resolved studies of UV Ceti-type flare stars have been generally carried out using photometric observations. However, high resolution spectra are needed to characterize these stars. We have analysed high resolution echelle spectra of a sample of late Ke- and Me-dwafs classified as flare stars (UV Ceti-type). The observations cover a wavelength range that includes different optical chromospheric activity indicators such as the Balmer series and some Ca II, He I, Mg I and Na I lines. Several flux-flux and flux-rotational velocity relationships have been studied in detail. The results have been compared with those reported for other cool stars, finding clear differences between them.

1. Observations: the sample

The UV Ceti-type flare stars that have been analysed in this work are the late Ke- and Me-dwarfs (see Table. 1) included in our high resolution spectroscopic survey of 144 late-type stars (spectral types from F to M) classified as possible members of the young stellar kinematic groups IC 2391 supercluster (35-55 Myrs), Local Association or Pleiades moving group (20-150 Myrs), Castor moving group (200 Myrs), Ursa Major group or Sirius supercluster (300 Myrs) and Hyades supercluster (600 Myrs) (see [4, 5, 6]). The age of each star has been therefore estimated by its membership in one of these moving groups (see Table. 1).

The observations were carried out during 6 observing runs, using echelle spectrographs (MUSICOS, SARG and FOCES) at different telescopes (INT and TNG from *El Roque de los Muchachos Observatory*; and the 2.2 m telescope from the *CAHA Observatory*). The covered wavelength range is 3500 – 10700 Å, and the spectral resolution (FWHM of the arc comparison lines) ranges from 0.08 to 0.35 Å.

Star	Spectral type	Remark	$v\sin(i)$ ✓ (km/s)	P_{phot} (days)	N	Age ✓ (Myrs)
FP Cnc	K7	--	11.35±0.13	--	2	20-150
HD 160934	K7	SB1	19.07±0.38	1.84	7	20-150
DK Leo*	K7-M0	--	7.68±0.70	7.98	2	20-150
GJ 9809	M0	--	8.05±0.82	--	1	20-150
GJ 856B	M1	--	17.7±1.9	--	1	20-150
CR Dra*	M1-M1.5	SB2	17.36±0.55	--	5	--
V1054 Oph*	M3-M3.5	T	2.9±2.0	--	10	--
AD Leo*	M3.5	--	5.80±0.50	2.7	6	~200
V647 Her	M4	--	1.0±1.0	--	2	~600
EV Lac	M4	--	2.01±0.53	4.38	11	~300

Table. 1: Stellar parameters of the flare stars. Our measured projected rotational velocity ($v\sin(i)$) and estimated age are shown (see columns marked with the symbol ✓). The number of observed spectra (N) is also given. The exposure time of the spectra ranges from 10 to 30 min. Stars marked with * have also been monitored with high temporal resolution using a intermediate dispersion spectrograph (see [1, 2, 3, 7]).

2. Emission line profiles

The maximum (black) and minimum (red) emission in our spectra is shown in Fig. 1 for each flare star. Very small variations are found in almost all the stars, except in the case of EV Lac and V1054 Oph, where a strong flare is observed (note the enhancement in the He I D_3 line in both cases and the strong enhancement and broadening in the Hα line of V1054 Oph). Fig. 1 shows that, in general, the He I, Na I and Balmer emission lines are stronger in cooler flare stars. Only GJ 856B shows an exceptional strong chromospheric emission in these lines, possibly due to a flare. On the contrary, the Ca II IRT lines do not show the same correlation with the effective temperature. Note also that a clear self-reversal is also present in the Hα line for all the stars.

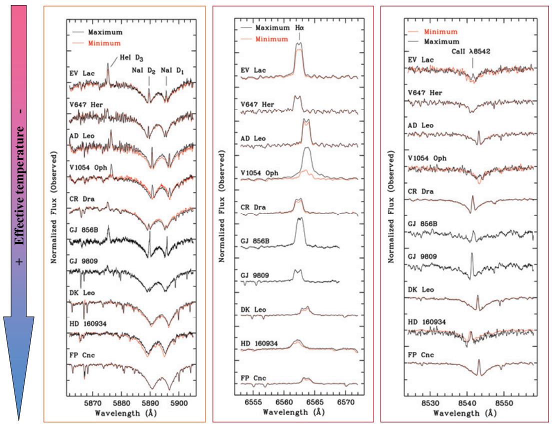

Fig. 1: Line profiles of the He I D_3 (left), Na I doublet (left), Hα (centre) and Ca II λ8542Å (right) lines for the flare stars.

3. Activity-rotation relationships

Fig. 2 shows the chromospheric flux of the Ca II λ8542Å (left) and Hα (right) lines vs. the projected rotational velocity ($v\sin(i)$) for the stars in the spectroscopic survey (see [4, 5]), including also the flare stars. Although the inclination of the rotation axis is unknown for almost all the stars in the survey, it seems that (i) the smaller the effective temperature (T_{ef}), the slower the rotation is; and (ii) the younger stars have higher rotational velocity. The flare stars also show these tendencies. Besides, the level of activity of the flare stars seems to follow the general tendency found for the other stars when we observe them in the Ca II λ8542Å line, while the Hα emission of the chromosphe appears to be independent of the rotational velocity.

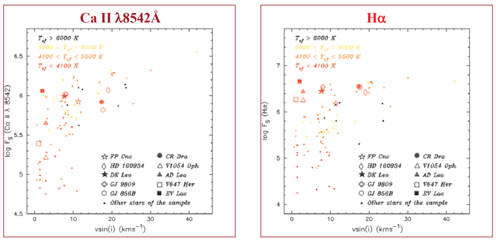

Fig. 2: Chromospheric flux vs. $v\sin(i)$. Small points represent the rest of stars in the spectroscopic survey ([4, 5]).

4. Flux-flux relationships

Clear relationships are observed between the chromospheric flux of different emission lines. Two examples are shown in Fig. 3, although similar results (but with different fit parameters) are found for other emission lines such as Ca II K, Na I D_1 & D_2, He I D_3, and the other Balmer lines. The analysed flare stars generally follow the tendencies observed for the rest of the stars in the spectroscopic survey (see [4, 5]), but it is not the case for the relationships between the Balmer series and the Ca II lines (see e.g. the left panel in the low part of Fig. 3), showing an excess in the chromospheric emission of the Balmer lines compared to the rest of stars with equal chromospheric emission in the Ca II lines. We suggest that these differences are due to microflaring activity, although further investigations are still needed.

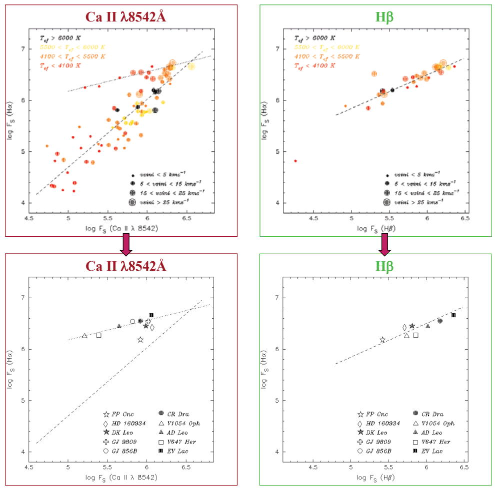

Fig. 3: Hα flux emitted by the chromosphere vs. the chromospheric flux in the Ca II λ8542Å (left) and Hβ (right) lines for all the stars in the spectroscopic survey ([4, 5]), including the flare stars (top panels), and only for the flare stars (low panels).

References

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