HIGH TEMPORAL RESOLUTION SPECTROSCOPIC OBSERVATIONS OF UV CET TYPE FLARE STARS

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Abstract

We present the first results of a high temporal resolution spectroscopic monitoring of the UV Ceti-type flare stars EQ Vir, DK Leo, CR Dra, DT Vir, CE Boo, VV Lyn, DP Dra, V1054 Oph, AD Leo, BL Lyn and YZ CMi. The observations were done using the IDS spectrograph at the 2.5 m Isaac Newton Telescope (INT) of the El Roque de los Muchachos Observatory (La Palma, Canary Islands, Spain). Intermediate resolution spectra, including the Balmer series from Hβ to H_{11} as well as the He I λ4026 Å and the Ca II H & K lines, were taken using the R1200B dispersion grating (reciprocal dispersion of 0.48 Å/pixel). The great number of spectra taken each night with high temporal resolution (exposure times as short as 60 s) allows us to analyse the time evolution of the emission lines in order to identify flares. Other variations at different scales have been also observed. A comparison between all the observed stars have been done. Finally, for the strongest flares or changes, we study differences on the behaviour of the lines of interest.

Key words: Stars: activity – Stars: chromospheres – Stars: flare – Stars: UV Cet type – Stars: late-type – Stars: spectroscopy: optical

1. Introduction

UV Cet type flare stars are late K and M dwarfs in the solar neighbourhood that are known to be characterized by intense flaring activity at X-rays, optical, UV and radio wavelengths. Flares from UV Cet type stars present the greatest analogy to the solar case. Therefore, it is interesting to study how the solar-type flare models work under the physical conditions of the stellar case because there is still no convincing evidence that stellar flares are simply scaled-up versions of solar flares (Pallavicini 1990).

This work is a continuation of Crespo-Chacón et al. (2004a), (2004b) and Montes et al. (2004), where we analysed high temporal resolution spectroscopic observations of the stars V1054 Oph and AD Leo and, although we did not detect strong flares, we found very interesting short and weak variations in the emission lines with properties very similar to flares (microflares) that are produced with high temporal frequency. Here we study the variations of several UV Cet type flare stars with different spectral type.

2. Observations

The observing run took place during 21-25 March 2003. Spectroscopic observations were taken with the 2.5 m Isaac Newton Telescope (INT) at the El Roque de los Muchachos Observatory (La Palma, Canary Islands, Spain). The Intermediate Dispersion Spectrograph (IDS) was used with the R1200B dispersion grating and the 2148x4200 EEV10a CCD detector. The wavelength range covers from 3510 Å to 5200 Å, including the Balmer lines from Hβ to H_{11} as well as the He I λ4026 Å and the Ca II H & K lines. The reciprocal dispersion is 0.48 Å/pixel and the spectral resolution ($FWHM$) 1.15 Å. All the obtained spectra have been calibrated by using Cu-Ar arcs. In order to obtain the highest possible temporal resolution we have taken spectra with exposure times as short as 60 s for the brightest stars and 360 s for the faintest.

The observed stars are several UV Cet type flare stars of different spectral type that have been selected from the Pettersen (1991) catalogue. In Table 1 we list these stars together with some of their stellar and observational parameters.

3. Results

3.1. Temporal evolution of the EW

In Figure 1 we have plotted the temporal evolution of the equivalent width (EW) of the Hβ line for each star. The strongest flares have been marked with the symbol $\swarrow$ while the symbol $\downarrow$ has been used to indicate other changes that could be due to flares of lower intensity (hereafter type A); different magnetic reconnection processes that, decreasing in efficiency, occurs sequentially within the same flare (type B); or other kind of variations during the quiescent state at shorter temporal scales (type C). The notes on individual results about the kind of changes, duration (T) and variation of EW relative to the level of EW before or after the variation ($\triangle_{EW}$) are given bellow to compare both the energy and time scales.

$\star$ EQ Vir presents flares and variations type B and C. A long duration flare ($T \approx 35$ min), compared to the EW increase ($\triangle_{EW} \approx 0.20$ Å), takes place during the night

Table 1. Stellar parameters of the observed stars: spectral type (SpT), vsin(i) and photometric period (P_{phot}). The remark is SB for spectroscopic binaries (singled lined (1) and double lined (2)) and T for triple star systems. The number of spectra taken of each star (N) and the minimum and maximum exposure times (t_{exp}) and signal-to-noise ratios (SNR) are also given.

Star	SpT	$v\sin(i)$ (km/s)	$P_{\rm phot}$ (days)	Remark	N	$t_{\rm exp}$ (min-max) (s)	SNR (min-max)
EQ Vir	K5-7	8.3±0.5	3.96	–	54	60-180	19-68
DK Leo	K7-M0	7.68±0.70	7.98	–	91	60-300	19-56
CR Dra	M1.5	17.36±0.55	–	SB2	54	60-300	28-64
DT Vir	M1.5	–	1.54-2.8	–	89	60-180	14-61
CE Boo	M2-3	3.6±0.6	–	–	36	90-240	23-41
VV Lyn	M2.5-3.5	–	3	SB1	24	120-600	20-43
DP Dra	M3	10	–	SB1 (?)	51	90-360	13-37
V1054 Oph	M3.5	2.90±2	–	T	21	60-240	17-67
AD Leo	M3.5	5.8±0.5	2.7	–	32	60-240	22-73
BL Lyn	M3.5-4.5	–	–	–	24	120-600	10-24
YZ CMi	M4-4.5	4.8±2.3	2.78	–	18	360-600	15-50

2 and two shorter duration flares ($T \approx 7$ min) with less intensity occur during the night 4.

⋆ DK Leo shows a modulation along the different nights and changes type C. Nevertheless, it seems that the first part of the observations of the night 1 corresponds to the beginning of a possible flare while the second part could be related to the gradual decay phase of the same flare. A gradual increase with short variations type C ($T \approx 12$ min, $\triangle_{EW} \approx 0.28$ Å) can be seen in the night 2 and the gradual decay phase of a possible flare together with changes type B appears in the night 5.

⋆ CR Dra has flares and variations type A, B and C. The gradual decay phase of a flare together with changes type B can be seen in the night 4. Besides, several noticeable flares take place during the night 5 within a flare of greater intensity ($T > 48$ min, $\triangle_{EW} \approx 0.53$ Å).

⋆ DT Vir shows flares and changes type B and C. A large flare seems to be present in the night 5 ($T > 196$ min, $\triangle_{EW} > 1.50$ Å) while the observations of the night 4 could be related to the beginning and end of a flare that lasts 69 min.

⋆ CE Boo presents flares and changes type B. Two contiguous flares occur during the night 1 and the second one starts before the end of the first one (total $T \approx 48$ min, $\triangle_{EW} \approx 0.57$ Å).

⋆ VV Lyn does not show important variations though small changes type C seems to be present in the night 1.

⋆ DP Dra experiments flares and changes type A and B. A large flare ($T \approx 58$ min, $\triangle_{EW} \approx 3.70$ Å) appears during the night 5 and other small flares ($T \approx 12$ min, $\triangle_{EW} \approx 0.284$ Å) take place in the night 4.

⋆ V1054 Oph presents flares and variations type A and B. In the night 1 we can see a significant flare ($T \approx 6$ min, $\triangle_{EW} \approx 0.37$ Å) within the gradual decay phase of another one of greater intensity.

⋆ AD Leo shows flares and variations type A and B. The two flares detected in the night 1 last $T \approx 20$ min and have $\triangle_{EW} \approx 0.66$ Å.

⋆ BL Lyn presents a gradual increase during the night 1, in which a significant flare ($T \approx 23$ min, $\triangle_{EW} \approx 0.66$ Å) and variations type A can be observed.

⋆ YZ CMi has flares and changes type B, showing a very strong and long duration flare during the night 5 ($T > 145$ min, $\triangle_{EW} > 7.4$ Å).

3.2. Spectral features

The quiescent spectrum of the observed stars has been plotted in Figure 2. The spectra are ordered by spectral type (the star with the latest spectral type is in the top). The EW of the chromospheric lines in the quiescent state tends to be higher when the star is cooler but, for a given spectral type, it also depends on the level of activity of the star, which could be different depending on its age and rotation velocity. It is also evident the presence of molecular bands in the coolest stars.

Figure 3 shows the profile of the Hβ (left) and Ca II K (right) lines in the quiescent state (dotted line) and in the maximum observed value of the strongest variation (flare or other type of change) (solid line). It can be seen that the enhancement and broadening of the wings of the Hβ line are noticeable only for YZ CMi, BL Lyn, AD Leo and DP Dra that, together with DT Vir, are the stars that present a larger $\triangle_{EW}$. The width and enhancement of the wings depend on the phase of the flare. They decrease during the gradual decay and this is the only phase that has been observed in the case of DT Vir. Nevertheless, all the stars show an increase of the core of the Hβ line. The Ca II K line is less affected by the observed changes except in the cases of YZ CMi, AD Leo and DT Vir, but for YZ CMi and DT Vir we have only detected the gradual decay of

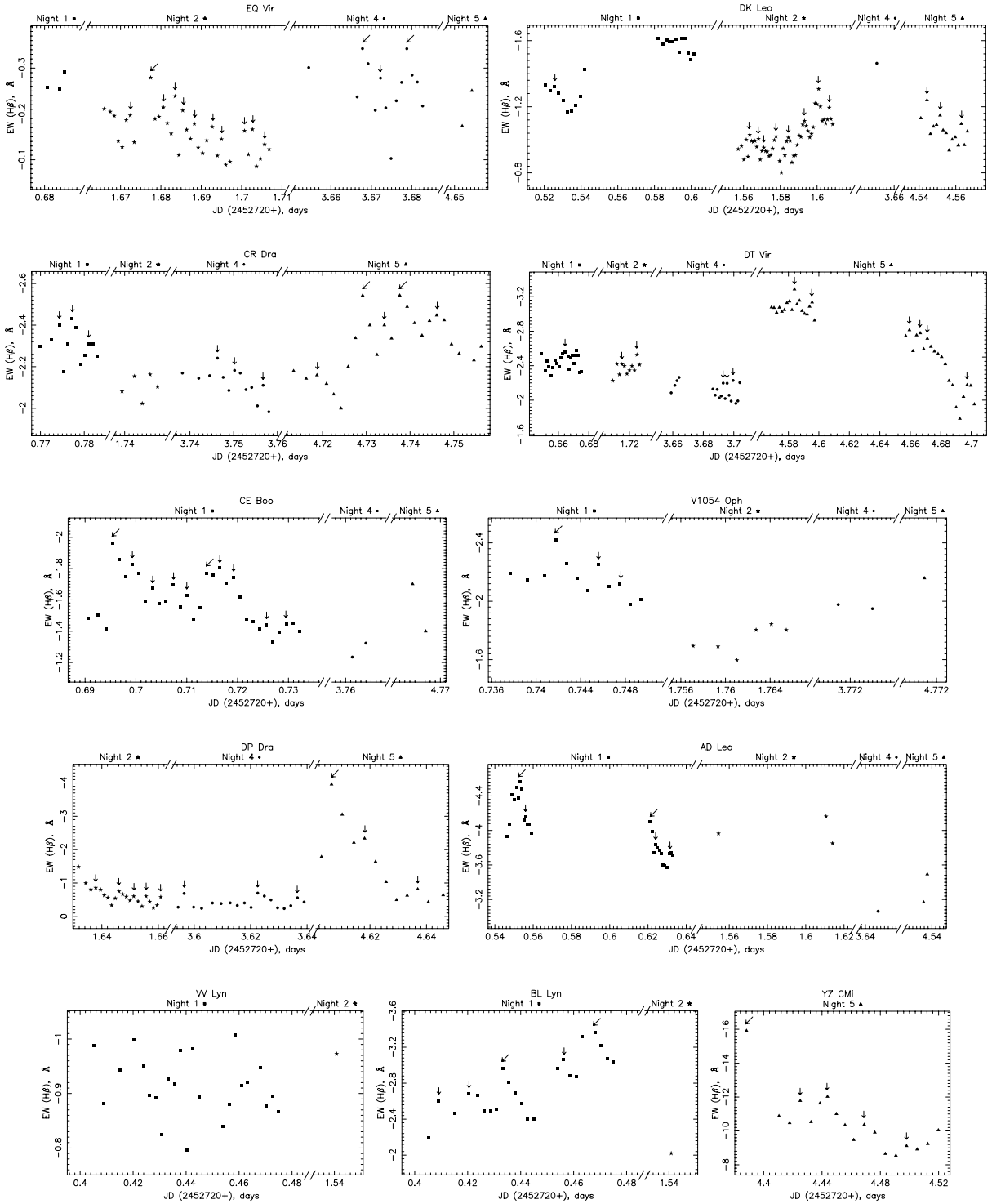

Figure 1. EW (Hβ) versus julian date (JD) during every night for the observed stars.

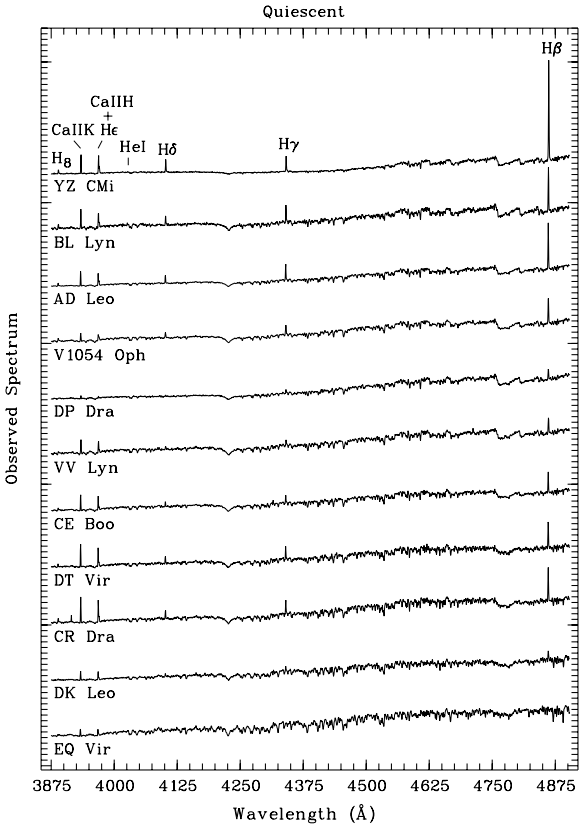

Figure 2. Quiescent spectrum of the observed stars (ordered by spectral type).

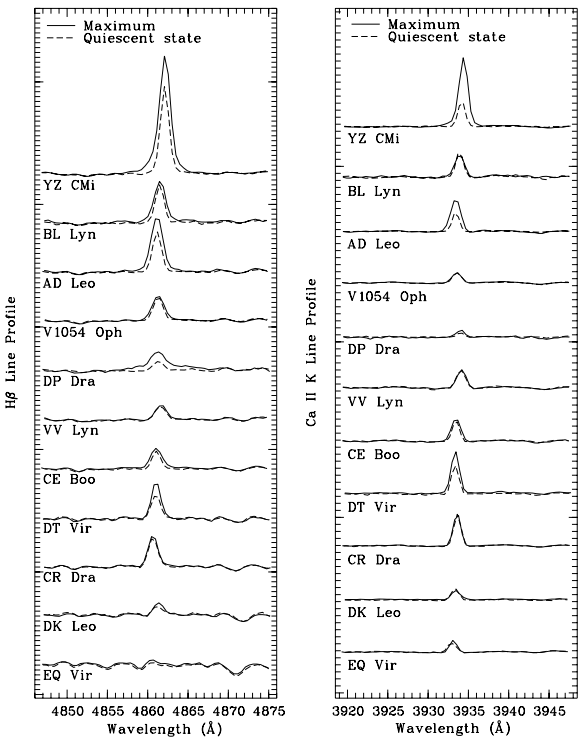

Figure 3. Profile of the Hβ (left) and Ca II K (right) lines in the quiescent state (dotted line) and in the maximum of the strongest observed flare or variation (solid line).

the Balmer lines and the Ca II lines reach the maximum in this phase because they are delayed in relation to the Balmer series.

4. Conclusions

High temporal resolution spectra of UV Cet type flare stars with different spectral type (from K5 to M4.5) have been analysed. We have found different kinds of variations, including several flares. The size of the sample of stars is not large but it seems that the later is the spectral type, the more frequent are flares. It also seems that the intensity of these flares tends to be greater for the coolest stars. However, the observed stars with earlier spectral type also present flares. The increase of the line core and the enhancement and broadening of the wings depend on the phase of the flare and the Ca II lines are generally less affected by flare-like events than the Balmer ones.

Acknowledgements

This work has been supported by the Universidad Complutense de Madrid and the Spanish Ministerio de Ciencia y Tecnología, under the grant AYA2001-1448 (Programa Nacional de Astronomía y Astrofísica). I. Crespo-Chacón would like to thank the Spanish Ministerio de Educación, Cultura y Deporte for the PhD. grant AP2001-0475.

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