Searching for flares and CME signatures in the spectra of seven cool stars

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Abstract: *Searching for and investigating coronal mass ejections (CMEs) from late-type stars is important for understanding stellar activity and its effects on the stellar evolution, space weather and exoplanet atmospheres. To this end, we performed spectroscopic observations of 4 stars of spectral type K, one M dwarf and two solar-like stars in several epochs with the NOT/ALFOSC at La Palma and the 2-m RCC telescope/ESPERO of The National astronomical observatory Rozhen. We obtained 350 spectra from three consecutive nights in 2012 from ALFOSC and 159 spectra from ESPERO during 2020 and 2021. The resulting dynamic spectra do not show evidence for flares and/or CMEs. In addition, we obtained radial velocities for the stars, which we compare with those from previous investigations.*

Introduction:

Flares are frequent phenomena on the Sun and are believed to arise from ruptures of a stressed magnetic structure, which by magnetic buoyancy is forced upwards through the photosphere into the corona and transition region. Associated coronal mass ejections (CMEs), which are large clouds of magnetized plasma escaping the Sun, can have significant impact on space weather and planetary atmospheres.

But do these phenomena and effects hold true for other stars? Based on the Sun we know that all powerful flares are associated with a CME (e.g., [1]). However, despite the frequent detection of numerous strong flares and superflares from active M dwarfs (dMes, e.g. [2]) and lately sun-like stars (e.g. [3]), so far there are only a few CMEs detected from stars other than the Sun [4]. Thus, no comprehensive study of CME parameters and rates can be carried out.

Here we present the results from spectroscopic observations aiming to detect flares or CME signatures form seven late-type stars, i.e. Doppler shifted emission/absorption in the Balmer Hα line.

Processing:

The observations were performed in eight different epochs with the ALFOSC instrument (with resolution ~ 5000) at the Nordic optical telescope [5] and ESPERO (resolution ~ 30 000) at the 2-m RCC NAO Rozhen telescope [6]. Exposure times varied between 30 sec and 500 sec. More information about the observations is given in Table 1.

Table 1. Observation log.

Object	HJD	Instrument	Standart	Number of spectra
AD Leo	2456268	ALFOSC	-	63
EK Dra	2459065 2459066	ESPERO ESPERO	HD84737 HD84737	10 14
ζ And	2456269 2459099	ALFOSC ESPERO	- HD84737	58 86
σ Gem	2456270 2456269 2458896 2459216	ALFOSC ALFOSC ESPERO ESPERO	- - HD84737 HD84737	78 66 6 26
29 Dra	2458896	ESPERO	HD84737	11
BY Dra	2458896	ESPERO	HD84737	6
DX Leo	2456269	ALFOSC	-	85

All spectra were processed using IRAF standard routines. Heliocentric and Doppler corrections were applied.

Because ESPERO is an echelle spectrograph, from each spectra the order containing Hα was extracted and was inspected. Examples of the resultant spectra from ALFOSC and ESPERO are shown in Figure 1.

In order to check our system of radial velocities we have obtained spectra of RV standard during the observations. This was HD 84737. Our measurements gave the value of 5.45 ± 0.41 km/s while the value given by Simbad was 5.20 ± 0.09. It is seen that our system of radial velocities is accurate enough and there are not any systematic shifts.

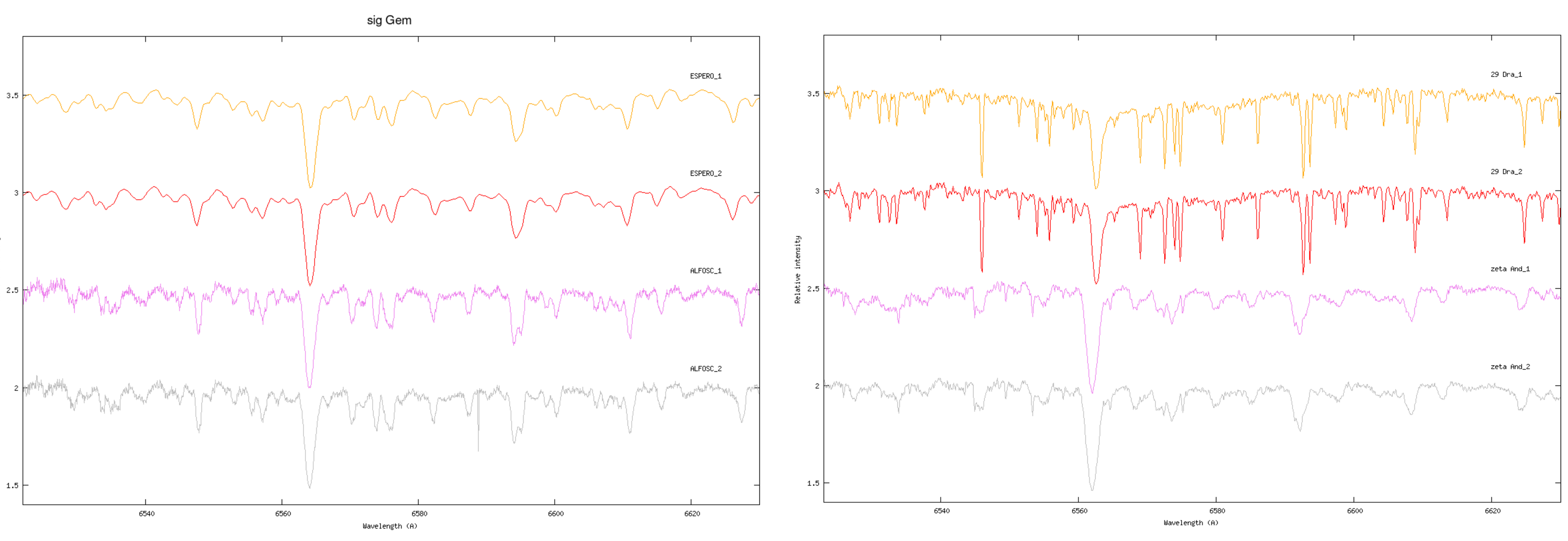

Figure 1. (left) Example spectra of σ Gem with ALFOSC and ESPERO. (right) Example spectra of 29 Dra and ζ And with ESPERO.

Results:

For better inspection the spectra for each star for each observing run were combined into dynamic spectra (Figure 2). Also, in cases where there were suspect features, residual dynamic spectra were made by subtracting an average profile and plotting the residuals (Figure 2).

We did not find any flares or CMEs signatures in any of the stellar spectra.

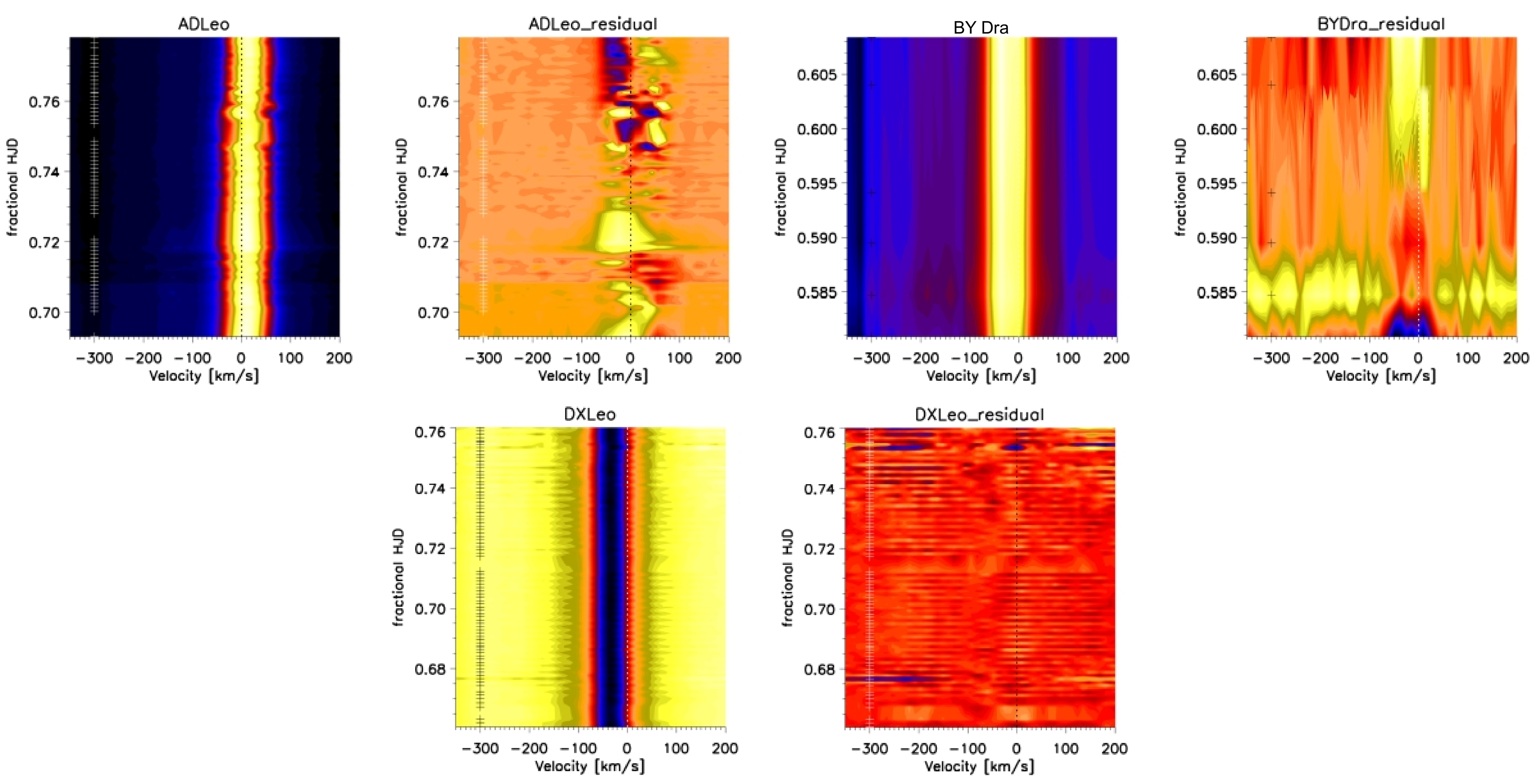

Figure 2. Dynamic and residual spectra for AD Leo (top left), BY Dra (top right), and DX Leo (bottom). All the variations in the residuals are artefacts and no indications of flares/CMEs are present in the spectra.

We measured radial velocities for 5 of the objects observed with ESPERO. Comparison with radial velocities from previous investigations shows a good agreement. The RVs are given in Table. 2.

Table 2. Observed radial velocities and rv values from Simbad.

Object	Measured rv [km/s]	rv from Simbad [km/s]
EK DRA	-20.83 ± 0.50	-20.687 ± 0.0037
ζ And	-53.82 ± 2.29	-24.43 ± 0.1
BY DRA	-20.38 ± 0.75	-25.53 ± 0.08
29 DRA	-12.37 ± 0.41	-11.55 ± 0.07
σ Gem	79.01 ± 0.28	44.15 ± 0.09

Conclusions:

Recent articles related to stellar CMEs analyzed the difference of expected and registered CME events. Our observations also confirm that even with one of the most reliable methods (Doppler effect of moving plasma) we did not find flare/CME activity for the seven studied stars. The most common technical purpose for this difference between models and observations is signal-to-noise of the spectra. It is also related to the geometry of the source toward the observer and the magnetic field of the source which can prevent CMEs from eruption.

References:

[1] Gopalswamy et al. 2005, Geophysical Research Letters, 32, 12; [2] Yang et al., 2017, ApJ, 849, 36;
[3] Doyle et al. 2020, MNRAS, 494, 3596-3610; [4] Moschou et al. 2019, ApJ, 877, 105;
[5] http://www.not.iac.es/instruments/alfosc/; [6] Bonev et al., 2017 BlgAJ, 26, 67

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