ANALYSIS OF HIGH TEMPORAL RESOLUTION SPECTRA OF LATE-TYPE RAPID ROTATOR STARS: BD +201790

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1. INTRODUCTION

When studying stellar activity, we always use the Sun as a representative model. However, some characteristics of the most active stars are not easily explained in terms of solar analogy, the active phenomena are seen to occur on much more enhanced scale than the Sun. Their flares are orders of magnitude more energetic (Byrne 1989, 1995), their coronae are hotter and denser, and starspots cover a much larger fraction of surface (Byrne 1992). Since these features are intimately related to the topology and stability of magnetic fields, we present the preliminary results of high temporal resolution spectroscopic observations of the K5Ve star BD+20 1790. High resolution echelle spectra have been obtained in February 2004 using SOFIN spectrograph at 2.56m Nordic Optical Telescope (NOT, La Palma) and in April 2004 using FOCES spectrograph in 2.2m Telescope at Calar Alto Observatory (Spain). In each run continuous series of spectra were taken during visibility time of the star. The analysis of these spectra allow us to monitoring the temporal evolution of the Hα line profile. From the EW, radial velocity and bisector variation with rotational phase, it is possible to detect the presence of prominence-like clouds (dense and cool material embedded in the hotter stellar corona). Different techniques are used to analyse the line profile: subtraction, bisector, etc. A discussion about different features present in the line profile is included.

Key words: Stars: activity – stars: chromospheres – stars: late-type – stars: prominences – spectroscopic: BD +201790

2. OBSERVATIONS AND DATA REDUCTION

2.1. Observation runs

The spectroscopic observations of BD+201790 were obtained during two observing runs:

- 2, 5, 6, 7 February 2004 using SOFIN spectrograph at 2.56m Nordic Optical Telescope (NOT, La Palma, Spain). The SOFIN spectrograph was used with the camera 1 and the 2052x2052 Piskonov Loral CCD as detector. With this configuration the wavelength range covers from 4200Å to 7490Å in 24 orders, including Hβ (4861Å), He I D3 (5876Å) and Hα (6562.8Å). The reciprocal dispersion achieved ranges from 0.019 to 0.03 Å/pixel, and the resolution 0.07 to 0.16Å (FWHM)
- 29 March to 7 April 2004 using FOCES spectrograph in 2.2m Telescope at Calar Alto Observatory (Almeria, Spain). The FOCES spectrograph was used with the 2048x2048 pixel 150µ Site#1d15 CCD detector. With this configuration the wavelength range covers from 3720Å to 10850Å in 100 orders, from Ca ii H&K (∼3950 Å) to Ca ii IRT (8498, 8542, 8662 Å). The reciprocal dispersion achieved ranges from 0.019 to 0.03 Å/pixel, and the resolution 0.07 to 0.16Å (FWHM)

In order to obtain high temporal resolution a continuous series of spectra were taken, with exposure time of 600 sec and S/N about 50.

2.2. DATA REDUCTION AND ANALYSIS

The spectra have been extracted using the standard reduction procedures in the IRAF echelle package (bias subtraction, division by a normalised flat-field, extraction of the spectra, wavelength calibration and normalization to time, even of several days (Hall and Ramsey 1992, 1994; van den Oord et al. 1997; Eibe 1998; Donati et al 2000; Barnes et al 2000). Prominence-like clouds are forced to co-rotate with the star by the confining closed magnetic fields and also contribute to the observed activity. They explain the high X-ray emission seen in active late-type stars and constitute a mechanism of transferring material between chromospheres and coronae. In some cases prominence-like matter is seen in connection with flare events.
the observed continuum). The chromospheric contribution has been determined using the spectral subtraction technique using the program STARMOD, developed at Penn State University (Barden 1985). The subtracted spectra were obtained only for the Hα line.

3. BD +201790

BD +20 1790 was classified by Jeffries et al. (1995) as a KVe star with V=9.9. Montes et al. (2001) proposed its membership in the Local Association moving group. We have detected strong chromospheric activity in this star in a previous observing run (2.2m-FOCES 2002/04). In this run a strong flare was observed. In spite of the fact that BD +201790 rotational velocity is approximately 10 km/s, the emission in chromospheric lines Hα and Hβ is very strong and lead us to make a detailed study of the existence of chromospheric structures like plages or prominences. BD +20 1790 has not been previously studied in detail. The rotational and photometric periods are uncertainly known. The photometry is incomplete and there is not a preliminary spectroscopic study to tipify the chromospheric and photospheric activity. We present the preliminary study of chromospheric and photospheric activity.

4. CHROMOSPHERIC ACTIVITY

4.1. EQUIVALENT WIDTH AND RADIAL VELOCITIES

Equivalent width was measured using splot command of IRAF package. Figure 1 shows the equivalent width (EW) variation of the Hα line during the night of 2 February for the subtracted spectra. The radial velocity was determined by the difference between the λc of gaussian fit for every individual spectra and the λc of the average. Figure 2 shows the radial velocity (RV). A clear correlation between the variation of EW, RV from gaussian fits and the bisector is observed (Figure 4).

4.2. PROFILE LINE VARIATION

We study the Hα line variation to infer the kind of structure present in the chromosphere. Figure 3 shows the profile line variation. On the left there is a sequence of subtracted spectra of Hα line. The ratio spectra were obtained using the average of all the observations. They are show on the right of the Figure 3. Averaging all the spectra it is expected to remove effects due to transient events in the profile. The shape of the average profile will not be affected significantly. The shape of average spectra present a blue-shifted absorption. One possible interpretation may be an intensive and continuous flow of material along magnetic loops, which is typical of solar loop prominence. The ratios show that individual spectra have been affected by transient feature. The more symmetric subtracted spectra is, the less deeper the absorption marked in the ratio is, and when the subtracted spectra present a red-shifted absorption, is in emission.

4.3. PROFILE LINE ASYMETRY

Prominence-like clouds can be detected as transient absorption features moving across the Hα line profile. To study profile variations we have used the bisectors technique, calculating a bisector for line profile. Temporal evolution of bisectors show in Figure 4, for the first night of NOT-SOFIN run. Any feature moving across the Hα profile must disturb the bisector. Variations in the asymmetry are related with the presence of transient of prominences.
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Figure 3. Sequence of Hα subtracted profiles and the ratios on the night of 2 February 2004. The time sequence occur 1-15. The number correspond to the observation number in the night.

Figure 4. Temporal evolution of bisectors of the subtracted emission line profiles of Hα, for the first night of NOT 2004/02 run.

Dynamic ratio spectrum was constructed by dividing each individual subtracted spectrum by an average of all observations and then displacing consecutive vertically with one spectrum per line. Time runs from bottom to top. The features marked with black arrows in Figure 3 are seen clearly in the dynamic ratio spectrum shows in Figure 5. They appear more brilliant when is in emission. As we indicated, the line profile become red-shifted.

5. Flare event

In the FOCES 2004/02 run a flare event was observed at night 7 April. Figure 6 shows the sequence of consecutive Hα line profiles of subtracted Hα line and He I D3 for the gradual decay of the flare. The flare maximum is marked with bold line. Minimum Hα width is marked with black spotted line and maximum width is marked with green spotted line. The wings of the Hα profile are more wider at the flare maximum. The He I D3 emission (marked with a red line) is strongest when the flare is at maximum and shows a progressive decrease during the gradual decay. Figure 7 shows the dynamic spectrum for the subtracted He I D3 line profiles on 7 April 2004.
of 10 minutes. We only observed the gradual decay of the flare, during about 2h 40m. The first observation may be near the flare maximum.

Figure 7. Dynamic spectrum for the observations on 7 April 2004. Time runs from bottom to top.

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