New Perspectives on Solar Prominences, IAU Colloquium 167
ASP Conference Series, Vol. 150, 1998
David Webb, David Rust, and Brigitte Schmieder (eds.)

Prominences and Circumstellar Emission Around FK Comae Berenices: Balmer Lines Diagnostics from MUSICOS Spectra[1]

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Abstract. We present results from the analysis of spectra of the fast rotating active giant star FK Comae Berenices. The extended emission is interpreted as arising in giant active loops and prominences. The absorption is due to a shell of cold and dense gas (like solar filaments).

1. Introduction: Solar-like Activity in FK Com

Solar-like activity manifests itself in stars where chromospheres, spots, active regions, coronae and flares are observed. Only recently stellar prominences have been detected by their clear spectroscopic signature, as they transit the stellar disc of fast-rotating dwarfs (Collier Cameron and Robinson 1989). Fast rotating giants are another interesting case for searching for the equivalent of prominences in different gravity and magnetic configurations than in the solar case.

FK Comae Berenices is a rapidly rotating, single G5II type giant. One of its most striking peculiarities is its extreme rotational velocity, $v \sin i \sim 162.5 \pm 3.5$ $\mathrm{kms^{-1}}$ (Huenemoerder et al. 1993), for a single star. The rotational period is P=2.4 days (Bopp and Stencel 1981.

Its spectra exhibits an Hα emission feature, very broad and erratically variable (e.g., Bopp and Stencel 1981), with an asymmetric, double peaked appearance (Ramsey, Nations and Barden 1981). The emission is attributed to giant structures extending to several stellar radii (Huenemoerder et al. 1993).

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Some spectral characteristics found in FK Com are common to the RS CVn binary systems: CaII H&K (Bildeman 1954) and Hα emissions, quasi-sinusoidal optical light curves (Holtzman and Nations 1984), and radio and X-ray emissions (due to an active corona). These similarities indicate a very enhanced solar-like activity.

We present new spectroscopic observations of FK Com. The Balmer absorption and emission are analysed in the frame of extended structures, confined in corotation with the star. The absorption component is interpreted as due to the obscuration by the star and by a near-stellar cool gas shell. The emission is attributed to giant structures, similar to active loops or prominences.

2. ESA-MUSICOS Spectra Acquisition and Reduction

The data were obtained in May 1996 with the 2.5 m Isaac Newton Telescope (INT), La Palma, Spain during the commissioning campaign of the (fiber-fed) ESA-MUSICOS spectrograph. The specific performances and experimental set-up of this spectrograph on INT are given in Foing et al. (1998). The frames were obtained with the "red" operating mode, in the range 4700 to 8100Å. The resolving power of these spectra is $R = 23,000$. For the data reduction we used the MIDAS Nov94 echelle reduction package.

3. Results

Artificially broadened spectra of the low-activity star HD145001 (G8 III) were subtracted from the Balmer lines spectra of FK Com (Figure 1) to remove the photospheric contribution and to derive the effect of its extreme activity.

3.1. Circumstellar Balmer Emission and Prominences

The difference spectrum shows an emission extending to $\sim$ 780 kms^{-1} in Hα. Both in Hα and Hβ, the wings of the extended emission, outside $v \sin i$, can be adjusted by gaussian profiles, Figure 2. The FWHM of the gaussian fitted profiles are FWHM (Hα)=642 ± 12 kms^{-1} and FWHM (Hβ)=381 ± 20 kms^{-1}.

Assuming corotating material, we derive as a maximum extent of the emission $\sim 4.75 R_\star$ sin i for Hα and $\sim 2.66 R_\star$ sin i for Hβ ($R_\star$ sin i is the projected stellar radius). The ratio between the total fluxes for these two Balmer lines is approximately 8.3, reminiscent of solar-like active prominences.

We modelled the emission wings profile by taking a 3D gaussian distribution of source material around the star (Oliveira et al. 1997). If we assume an effectively thin, corotating emission, the measured FWHM relate directly to the emission scale height. Such a 3D distribution represents well the profile wings but differs strongly in the central absorption profile.

3.2. Model of the Near-Stellar Shell of Filament-like Absorption

The central absorption can partly be interpreted as the effect of projected obscuration by the star itself. As this absorption is in fact slightly broader than $2v \sin i$, it indicates the presence of a near-stellar shell of absorbing material

https://doi.org/10.1017/S0252921100047679 Published online by Cambridge University Press

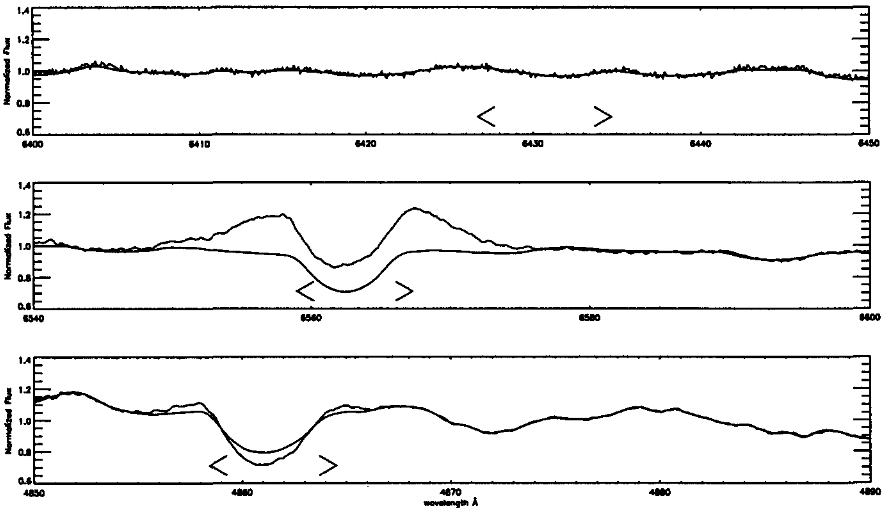

Figure 1. FK Com and reference star broadened spectra are shown for photospheric lines around 6430Å (for comparison) and for Hα and Hβ (from top to bottom). Note the good adjustment for the photospheric lines, and the strong difference in the core and the wings of the Balmer lines (Oliveira et al. 1997). The marks <> indicate $2v \sin i$.

(Oliveira et al. 1997). This shell also absorbs the background photospheric profile by a factor ε, to be adjusted.

The numerical integration of the 3D gaussian emission is computed at a given velocity, considering the obscuration effect by the star. This modelled profile is then corrected for the extra absorption by subtracting the function $\varepsilon * I_{phot}$, where I_{phot} is the photospheric spectrum. The resulting profile is compared with the difference spectrum in Figure 2. The values for the parameters that give the best agreement between the two profiles are $R_{abs}^{H\alpha}$=1.25 $R_\star \sin i$, $R_{abs}^{H\beta}$=1.1 $R_\star \sin i$, ε=0.225 ± 0.02. The residuals are interpreted as inhomogeneous active regions at, or near, the stellar surface and denser than the circumstellar environment, accounting for $\sim$ 10% of the total emission.

4. Differences with Solar Active Loops and Prominences

In FK Com, the surface gravity and photospheric scale height are, not accounting for the fast rotation, $g \leq 0.025 \sin^2 i g_\odot$ and $H \geq 40 \sin^{-2} i H_\odot$, respectively, where $g_\odot$ and $H_\odot$ are the solar values and i is the inclination. The low effective gravity and fast rotation create conditions for loop structures extending to large height, magnetically confined in corotation and filled with emitting material. These loops could be responsible for the very broad Balmer emission. This is reminiscent of circumstellar structures observed in RS CVn stars which, at times, undergo exceptional flaring (Foing et al. 1994).

These same combined effects can cause the hot coronal loops to undergo

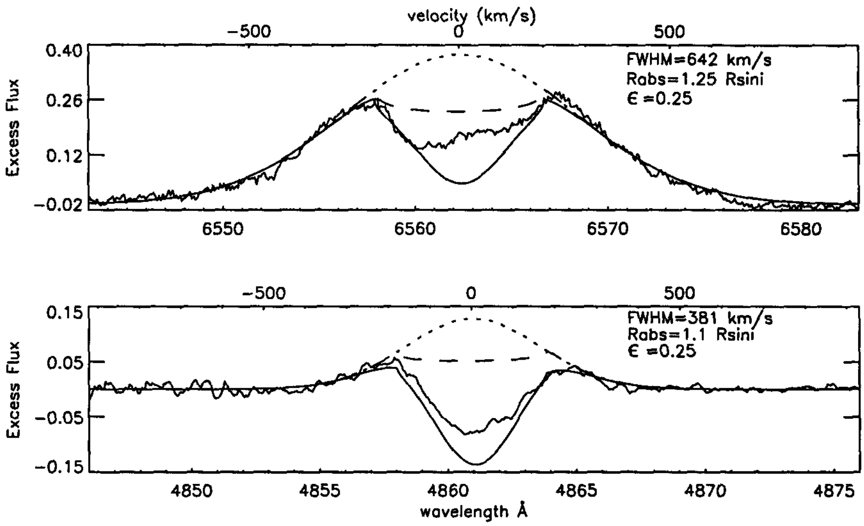

Figure 2. The Hα (top) and Hβ (bottom) average difference spectra, as well as the gaussian profiles (dotted line), fitting the wings of the extended emission. The obscuration by the star and the absorption of the near-stellar shell are displayed (dashed line) and also the effect of the extra absorption of the background photospheric profile (full line) (Oliveira et al. 1997).

thermal instabilities and condense into cool loops. According to our model, the near-stellar shell of absorbing material is just beyond the break-up radius, $R = 1.12 R_\star \sin i$, therefore consistent with this very unstable region.

Acknowledgments. The author J.M.O. was supported by the grant BM7023/95 from JNICT (PRAXIS XXI), Portugal. The authors wish to thank the INT staff for their help during the commissioning campaign of the ESA-MUSICOS spectrograph (http://ing.iac.es/~jht/musicos/musicos.html).

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https://doi.org/10.1017/S0252921100047679 Published online by Cambridge University Press