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Spectral Variations and Simple Models of FS CMa

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Abstract. Investigation of FS CMa type objects is difficult due to a lack of systematic observations. We present a study of the group prototype, FS CMa, based on a long-term observational campaign. Our unique set of spectra obtained in 2005 − 2013 allows to study line formation in various parts of the circumstellar environments. We observed both short- and long-term changes in several spectral line parameters. We estimated the ionic density from the observations of the Balmer jump region and used it in modeling the spectral energy distribution (SED) and Hα profile.

1. Data

In this study we used 90 high-resolution optical spectra taken at the McDonald Observatory and South African Astronomical Observatory with the spectral resolving powers of R = 60,000 and 40,000, respectively. In these spectra, we observed line profile changes over short-time intervals. Additionally, we used spectra from the Ondřejov Observatory with $R \sim 12,500$ taken in 2005–2013 allowing investigation of long-term changes. We detected spectral lines originating in various parts of the disk. The Si II $\lambda\lambda$ 6347, 6371 Å lines and the He I 6678 Å line form in the inner parts of the disk, the [O I] $\lambda\lambda$ 6300, 6364 Å lines form in the very outer parts, while the Hα line forms throughout the majority of the disk.

2. Results

The metallic lines change profiles on a timescale of hours. Not all of them originate in the same environment since the Si II lines behave similarly to each other, but the

He I line behaves differently. We found long-term changes in the Hα peak separation (Fig. 1), radial velocities (RV) of the peaks, and the red peak relative flux. Moreover, there are also changes of the [O I] lines RV.

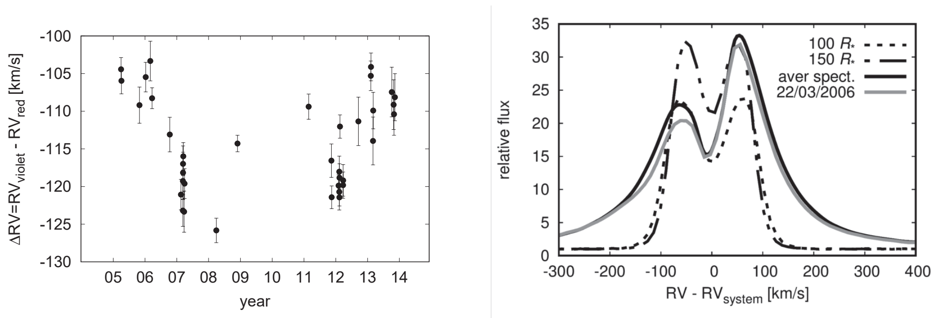

Figure 1. *Left:* Long-term evolution of the Hα peak separation. *Right:* Results of the Hα profile simulations for two radii of the equatorial Keplerian disk viewed at an inclination of 85° compared with the average observed spectrum and one specific spectrum.

We found a significant correlation in the evolution of the RV of the Hα central depression and that of the [O I] 6300 Å line. Analyzing the observed phenomena, we conclude that a possible cause for the changes is an epoch of an accelerated expansion of a part of the envelope: we simultaneously observed a decreasing RV of the Hα blue peak and an increasing relative flux of the red peak followed by a more chaotic behavior of both the Hα and the oxygen doublet lines as the disturbances reach the envelope outer parts. The large number of the observed Balmer lines (41) indicates that the local ionic density of the environment is very low ($\sim 10^{11}$ cm^{-3}, according to Inglis & Teller 1939) and that the medium at the place of their origin is almost static. We observed the occurrence of quasi-emission peaks in absorptions of Hα to Hϵ. We calculated several models of the FS CMa system using the HDUST code (Carciofi & Bjorkman 2006). The code uses the Monte Carlo method to solve the radiation transfer problem. Calculations of the temperature structure of the environment were used to obtain the SED and the Hα line profiles. Our models included a single star surrounded by a Keplerian disk that contains only hydrogen. The vertical density profile was Gaussian. While considering these restrictions, comparison of calculated SED and Hα profile with observations gives an estimate for the envelope extension ($100 - 150\ R_\star$) when using our estimate of the ionic density from the number of Balmer lines. To keep the density at the derived above value for a large span of radii, we used a constant surface density and Gaussian profile for the vertical density structure. The results compared to the observations are shown in Fig. 1.

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References

Carciofi, A.C., & Bjorkman, J.E. 2006, ApJ, 639, 1081
Inglis, D.R., & Teller, E. 1939, ApJ, 311, 643