The Influence of the Rotation Velocity Gradient on the Line Profiles of Accretion Discs of Cataclysmic Variables

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We show the influence of the Keplerian velocity shear on the line profiles of cataclysmic variable discs. The complete disc structure is taken into account. The radial disc structure follows the alpha disc approximation. Based on this assumption, the vertical structure is computed using the detailed non-LTE code AcDc. The obtained opacities and source functions are interpolated in the 2D grid, where the radiative transfer is calculated with the inclusion of the velocity field gradient.

Introduction

The Doppler effect has an important consequence for the spectral line formation. Due to the frequency shift, the escape probability of photons is higher. Here, we try to find answers to these questions: How large is this effect in the discs of cataclysmic variables (CVs)? How accurate is the common approximation, where the radiative transfer is solved through a static disc?

The Doppler effect is important, because rotation velocities in CV discs reach more than 2000km/s. Usually the optical depth is large enough to prevent free photon travel through all the disc. On the other hand, discs during quiescence are optically thinner. There also exist some extreme cases, where the disc is optically thin even during the outburst phase (some AM CVn systems).

We chose SS Cyg and a star representing a typical AM CVn system for a detailed investigation. SS Cyg shows some properties of intermediate polars. The precise determination and evaluation of physical effects is necessary for the study of its boundary layer region.

Model description

The detailed description of our model can be found in Korčáková et al. (2011). Here, we only mention the main properties and assumptions. The vertical hydrostatic structure together with opacity and emissivity coefficients are calculated using the AcDc code (Nagel et al. 2004). The output from this code serves as an input for the radiative transfer code (Korčáková & Kubát 2005).

AcDc code

AcDc is based on the approximation of the disc as a set of concentric rings (Nagel et al. 2004). The hydrostatic equation, the energy balance equation, the radiative transfer equation and the NLTE rate equations are calculated consistently using the Accelerated Lambda Iteration (ALI, Werner & Husfeld 1985; Werner et al. 2003) in every ring.

2.5D radiative transfer model

The technique is very similar to the method described in Korčáková & Kubát (2005). It assumes axial symmetry. This reduces time and memory requirements and allows us to solve the radiative transfer problem through all the disc structure with inclusion of the velocity gradient.

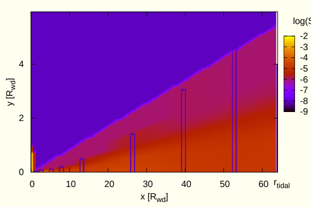

Figure 1: Source function in the Hα line center of the SS Cyg model. The rectangles show the structure in the individual rings obtained from the AcDc code.

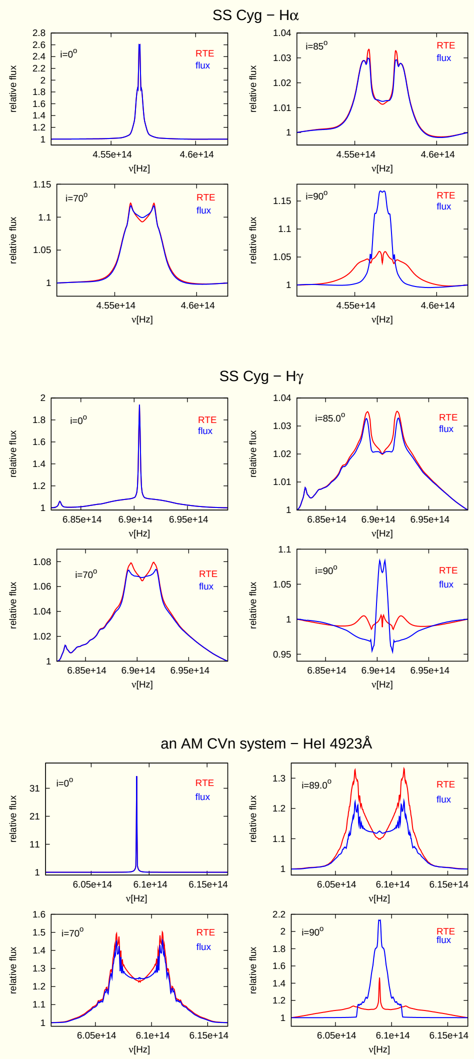

Figure 2: Line profiles of models for SS Cyg (Hα, Hγ) and a typical AM CVn system (HeI 4923Å) under different angles of view (i = $0°$ – face-on, i = $90°$ – edge-on view). The red line denotes the solution, where the velocity gradient is taken into account in the radiative transfer through the disc. The blue line indicates the result, where the velocity is included only into the final flux calculation.

Results

Figs. 1 and 3 show the distribution of source function and opacity in the disc. The resulting line profiles under different inclination angles are plotted in Fig. 2. The model is calculated for SS Cyg in Hα and Hγ lines and HeI 4923Å line for a disc of an AM CVn system. The solution, where the gradient of the velocity field is included in the radiative transfer equation, is indicated by a red line. The blue line denotes the case, where the velocity field is taken into account only in the flux calculation.

Conclusion

The results (see Fig. 2) prove, that the Doppler shift in the media itself has a negligible effect on the line formation. Even for high inclinations (the third graph in the individual figures is a view just above the edge of the disc) the difference is very small.

A huge difference is obtained at the edge-on view. The specific intensity integration along this boundary includes only the lowest value of the rotation velocity. To reflect all the velocity distribution in this case, the velocity must be included in the radiative transfer. Even if the outgoing radiation in this region is about an order of magnitude weaker than at the face-on view, it can have an important influence for the study of self-shielding discs (e.g. some UX UMa or SW Sex systems).

Due to the integration of the radiation field at the disc boundary and sufficiently opaque media our calculations prove, that the rotation velocity field has a negligible influence in the line formation in discs of CVs. The classical approximation of the disc as a set of the concentric rings is valid with high accuracy.

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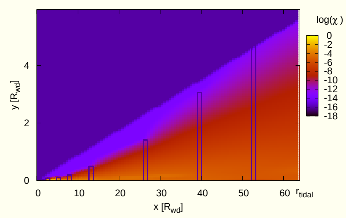

Figure 3: Opacity in the Hα line center of the SS Cyg model. The rectangles show the structure in the individual rings obtained from the AcDc code.

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