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MODELING OF THE ACCRETION DISC SPECTRA IN AM CVN SYSTEMS

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Abstract. An attempt has been made to model the helium accretion disc with parameters expected for AM CVn type systems. In the spectrum of such a system we expect to see signatures of all its parts: the central white dwarf, the degenerate secondary, the disc and the wind. Spectral modeling of each component will allow us to determine the properties of the system, which could help to understand the evolution of this particular type of cataclysmic variables. The theoretical spectra are compared to the observed spectra of AM CVn and V 803 Cen.

Key words: stars: close binaries, cataclysmic variables, accretion discs, individual: AM CVn, V 803 Cen

1. INTRODUCTION

AM CVn was first catalogued by Humason & Zwicky (1947). The star was found to have broad, shallow lines of He I and was classified as a DB white dwarf by Greenstein & Matthews (1957). Five years later its variability was discovered, and the object received the AM CVn designation (Smak 1967). Since 1971 five other stars with similar properties have been discovered. Their common properties are helium-rich composition (no hydrogen lines seen), ultra-short period variability and broad absorption lines. Some members of the group have distinct high and low states, which suggest a mass transfer.

AM CVn and EC 15330-1403 have broad absorption line spectra similar to nova-like CVs with a high mass transfer rate through their discs, being in a constant high state. GP Com has strong emission lines, typical for low mass transfer systems like dwarf nova in quiescence, other AM CVn type stars change their spectra from predominantly absorption spectra in their high states to wide emission line spectra or plain continua in their low states.

Estimated parameters of the AM CVn type stars, shown in table 1, are taken from Solheim (1996, 1997).

Table 1. Estimated parameters of the AM CVn type stars.

Object name	$P_{\rm orb}$ s	$P_{\rm s}$ s	$M_1/M_\odot$	q	M $M_\odot$/yr
AM CVn	1051	1028	1.09	0.084	$4.7\cdot10^{-9}$
EC 15330	1119		$\leq$1.2	$\leq$0.066	$\leq3.5\cdot10^{-9}$
CR Boo	1471	1493	1.10	0.057	$7.1\cdot10^{-10}$
V803 Cen	1611		$\leq$1.2	$\leq$0.043	$\leq3.2\cdot10^{-10}$
CP Eri	1724		$\leq$1.2	$\leq$0.039	$\leq3.23\cdot10^{-10}$
GP Com	2970		0.63	0.039	$1.2\cdot10^{-11}$

2. COMPUTATION OF THE DISC MODELS

La Dous (1988), in her paper "Synthetic optical and ultraviolet spectra of stationary accretion discs", discusses complications arising in the computation of disc models. She shows, for the most cases, that LTE is a valid assumption except for the very hot inner rings. In our case the cold outer rings also introduce problems due to the extremely low opacity of neutral helium. To solve this problem, we introduce other opacity sources, as metals and some hydrogen. Models, presented below, have mainly solar composition with the ratio of helium to hydrogen increased ten times. Synthetic spectra for these models were calculated using the program TLUSDISK (Hubeny 1994). The main properties of models are given below.

2.1. Specifics of the disc models

The disc is assumed to be in a steady state, geometrically thin and in Keplerian rotation. The vertical structure is solved for a set of axially symmetrical concentric rings where a plane-parallel 1-D atmosphere calculation is performed. No a priori assumption about optical thickness is made. The atmosphere at each disc radius R, specified in the disc midplane, is in hydrostatic equilibrium, with a depth-dependent gravity g which arises from the vertical component of the central star's gravitational force on the disc material. Self-gravity of the disc is neglected and the assumption that R is much larger than the distance from the central plane z has been made. The disc radiates all the mechanical energy dissipated by viscous shearing between the Keplerian orbits.

Here is a summary of the basic assumptions:

- The energy balance is considered as a balance between the net radiation loss (calculated exactly, without invoking neither optically thin, nor optically thick approximations) and the dissipated mechanical energy.
- The dissipated energy is proportional to viscosity, which is given through the Reynolds number, not by means of an ad hoc scaling parameter α.
- The effects of illumination of the disc by the central star might be taken into account, using the formalism of Hubeny (1990b).
- The disc is not considered as a semi-infinite atmosphere but rather as a finite slab of gas.
- The optical thickness of the disc is a parameter that directly follows from the model.
- The total radiative flux is not constant, but increases upwards (from the central plane of the disc to its surface), its value being determined through the energy balance equation.
- Analogously, the gravity acceleration is not constant and depends on the distance from the central plane.
- The vertical structure of the disc (temperature, density, radiation field, etc.) follows from the appropriate model calculations.

The program solves the basic equations (radiative transfer, hydrostatic equilibrium, energy balance, statistical equilibrium, charge and particle conservation) by the use of a hybrid CL/ALI (Complete Linearization / Accelerated Lambda Iteration) method (Hubeny & Lanz 1995).

Not all of the basic equations have to be solved. For example, it is possible to keep the temperature fixed and skip the energy balance equation, thus calculating so-called semi-empirical model.

2.2. Models

The first step is to prepare the initial grid of disc models. Currently we have computed models with the mass transfer rates 10^{-8}, $5{\cdot}10^{-9}$ and 10^{-9} $M_\odot$/yr (hereafter model X, model Y and model Z). Models, presented in this article, were calculated with complete NLTE state evaluation in continuum and H and He I lines. He II line opacity is calculated using LTE assumptions. All discs extend from 2.0 to 9.0 $R_\star$. The central star has the mass of 1.1 $M_\odot$ and the radius of $4.6 \cdot 10^8$ cm. Disc illumination effects are neglected.

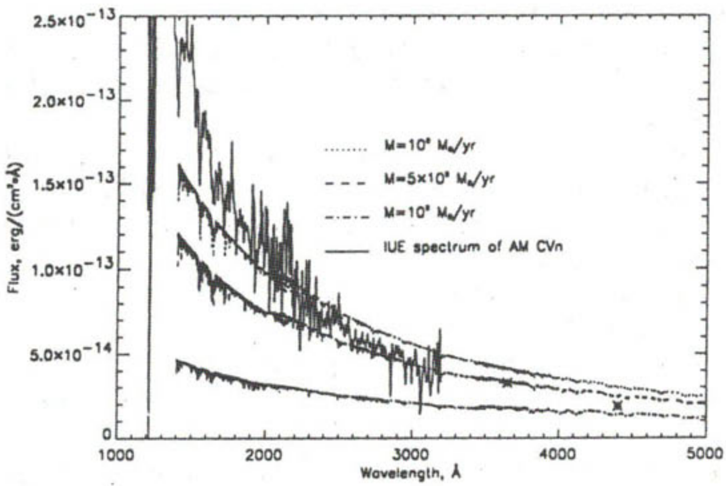

Fig. 1. Synthetic spectra for inclination $i = 40°$, compared with the IUE spectrum of AM CVn, extended by U and B band photometric observations.

Fig. 1 shows synthetic spectra of the three models for the 40° inclination, predicted for AM CVn (Solheim 1998). The IUE spectrum of AM CVn is also shown after its extension to longer wavelengths by photometric ground-based flux values. This graph shows a satisfactory fit of the observed spectrum and the models within the given mass transfer range. However, in the wavelength range below 2000 Å a hot central object needs to be added.

The models show spectral features, specific for AM CVn type stars, particularly, broad absorption lines with emission-like cores. Figs. 2 and 3 show the selected model fits of AM CVn and V803 Cen

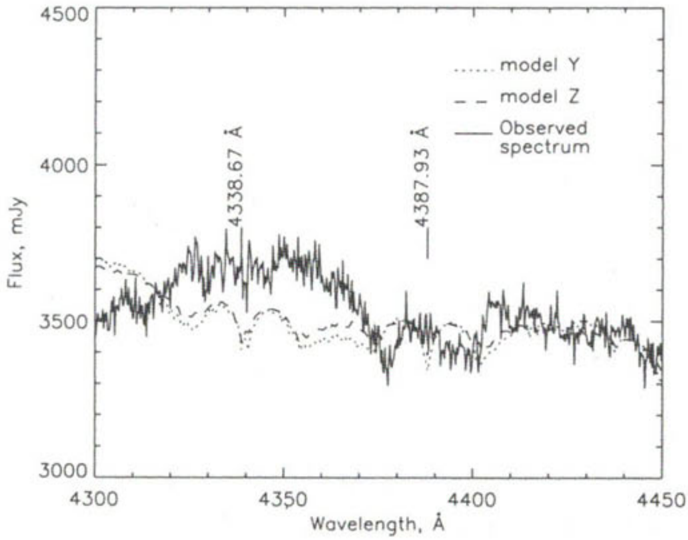

Fig. 2. The observed helium line profile of AM CVn fitted to the synthetic spectra of model Y (dotted line) and model Z (dashed line) for inclination of $i = 40°$.

spectra in the neighborhood of He I 4388 Å line. The observed spectra, plotted by solid line, are taken from Solheim (1993). They are flattened and scaled to the photometric flux value, so the exact fitting of the continuum is impossible. Better comparison spectra hopefully will be available after the completion of reduction of the spectra, obtained with the Nordic Optical Telescope in March 1997.

Fig. 2 shows a fit of the observed He I 4388 Å line of AM CVn and the models Y and Z with the inclination of 40°. Fig. 3 gives the same for V803 Cen outburst spectra but for the inclination of 5°. Profile features of the 4388 Å He I line at longer wavelengths can be fitted more closely by fine-tuning model inclination and mass transfer rate. The He II line at 4338 Å exhibits strong emission, filling absorption line and rising above the continuum level.

Next steps in our work will include the expansion of the model grid and the refinement of the models themselves. Correctness of the LTE assumption and the chemical composition of the disc is

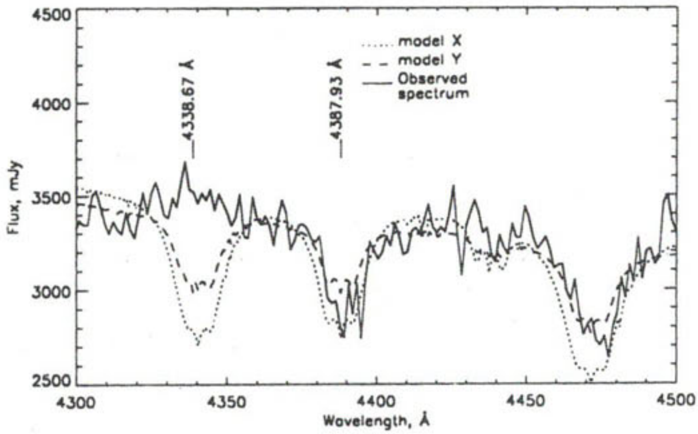

Fig. 3. The observed helium line profile of V803 Cen fitted to the synthetic spectra of model X (dotted line) and model Y (dashed line) for inclination of $i = 5°$.

of special interest. In the models already computed, low helium opacity leads to divergence in the process of solving the equation of state in outer parts of the disc. The physical conditions there deserve a careful investigation. Opacity in these relatively cool parts of the disc could be dominated by metals, which can be detected in the observed spectrum, or by hydrogen, which can be present but in undetectable amount. This maximum hydrogen abundance still has to be determined.

WET observations and the dynamic modeling suggest the presence of some specific geometric structure of the disc such as eccentricity, tidal bulges or spiral arms (Solheim et al. 1998). Such structures can significantly influence the disc spectrum and should be taken into account in the final computations.

3. CONCLUSION

The spectra of the LTE models, presented above, already provide a satisfactory fit with the observed spectra for an AM CVn type object, exhibiting some key features. The models can be improved by taking into account the possible NLTE effects, changes of chemical composition and geometric configuration. Possibly, all this will result in closer fit of the continuum slope and of the line profiles.

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