Accretion Disk Wind in AM CVn Binaries

A 3-D Monte Carlo Approach

Daniel-Jens Kusterer, Thorsten Nagel & Klaus Werner

Institut für Astronomie und Astrophysik
Kepler Center for Astro and Particle Physics
Eberhard-Karls Universität Tübingen, Germany

AM CVn systems are interacting binary systems similar to cataclysmic variables (CVs), but more compact with orbital periods of less than 80 minutes. The primary is a white dwarf, whereas the nature of the secondary is not completely clear, yet. Abundances and composition of the outer layer of the secondary can be found by analysis of the accretion disk (presented by Nagel et al. this conference). Spectra from high state AM CVn systems do not only show typical signatures of accretion disks, but also P Cygni line profiles, a sign of outflow being present in the system.

In this poster we present the first analysis of accretion disk wind in AM CVn systems. Emergent wind spectra are modeled with our 3D Monte Carlo radiative transfer code WOMPAT. We show that P Cygni profiles can be reproduced with our wind models. Despite the obvious difference in chemical composition and size of the accretion disks in AM CVn and normal, hydrogen rich, CVs, the wind lines in both cases are quite similar. This means that the dependence of the wind mechanism on these parameters has to be small.

The first detection of outflows in CVs dates back to the late 1970ies and early 1980ies when blueshifted absorption troughs and P Cygni profiles in ultraviolet (UV) resonance lines were discovered (Heap et al. 1978; Córdova & Mason 1982). More recent work shows that outflowing material has a strong influence on observations, not only in the "classical" UV wind lines, but also in other features. Not only in CVs, but also in their "smaller twins" the AM CVn systems, signatures of biconical outflow is found. As in CVs such an accretion disk wind is mainly found in high state systems. Figure 1 shows a STIS spectrum of AM CVn which shows several small P Cygni features.

Such signatures of outflows are mainly seen during outbursts and high states of CVs, as the disk is hotter and creates more radiation pressure for driving a wind. The observational evidence is such that detailed models of CVs, at least in outburst, have to include outflows. Also included in Fig. 1 is a spectrum calculated with WOMPAT for a AM CVn parameter set with $M_{\mathrm{WD}} = 0.6 M_{\odot}$ and an inclination angle of 40°. No parameter space exploration has been done for this, therefor it is just to be taken as a very rough guidance for future possibilities. As a source of radiation for the photon packets a blackbody white dwarf with $T = 18.000$ K and the accretion disc was used. The accretion disk input consisted of twelve rings calculated with AcDc (Nagel et al. 2004) and further blackbody rings to fill up the gap to the outer edge of the disk. The combined theoretical spectrum of these twelve AcDc rings is shown in Fig. 1, as well.

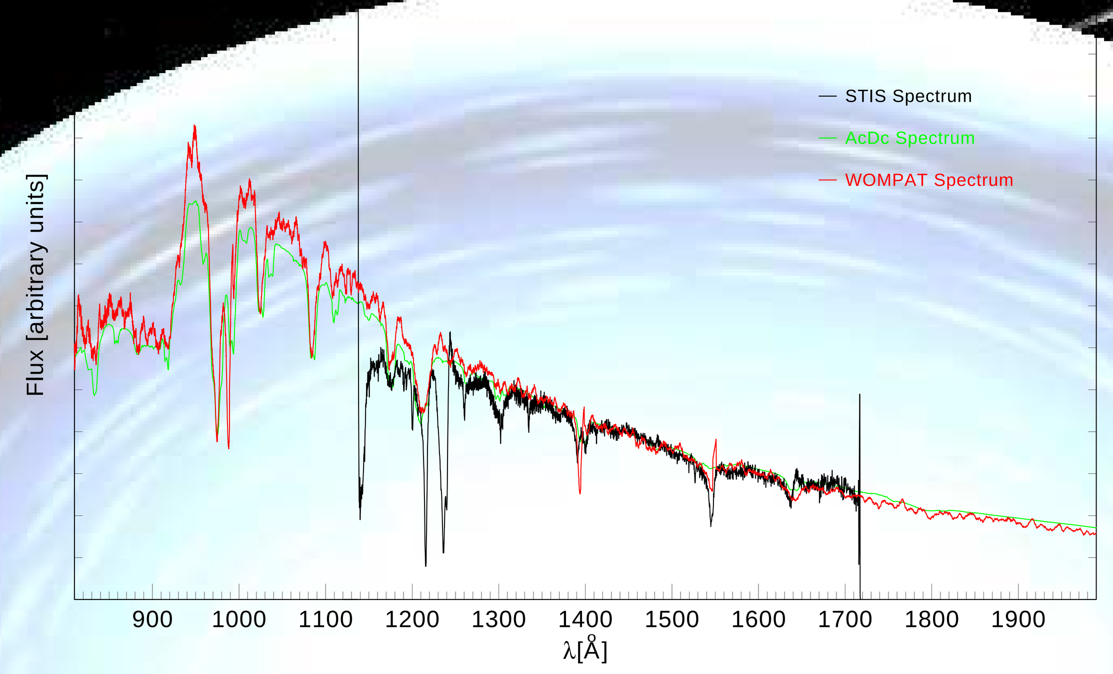

FIGURE 1: STIS spectrum of AM CVn overlaid with a theoretical disc spectrum calculated with AcDc (Nagel et al. 2004) and a Monte Carlo accretion disk wind spectrum calculated with our new code WOMPAT. Theoretical spectra are calculated for $i = 40^{\circ}$

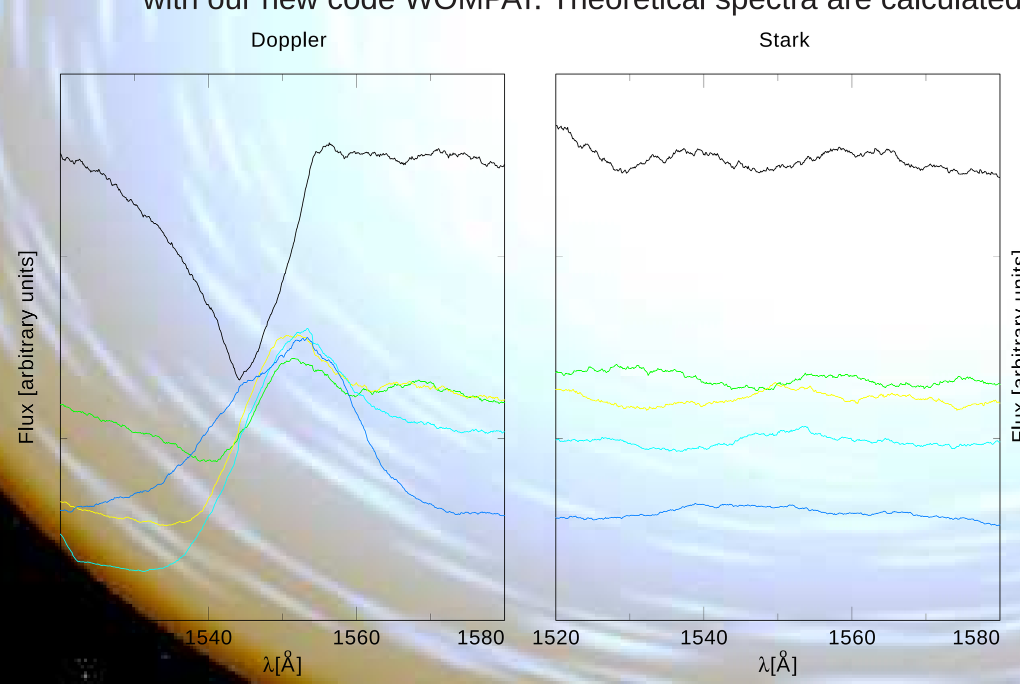

FIGURE 2: Calculated C IV 1550 Å resonance line for different inclination angles. Left panel shows calculations with Doppler broadening, right panel with Stark broadening.

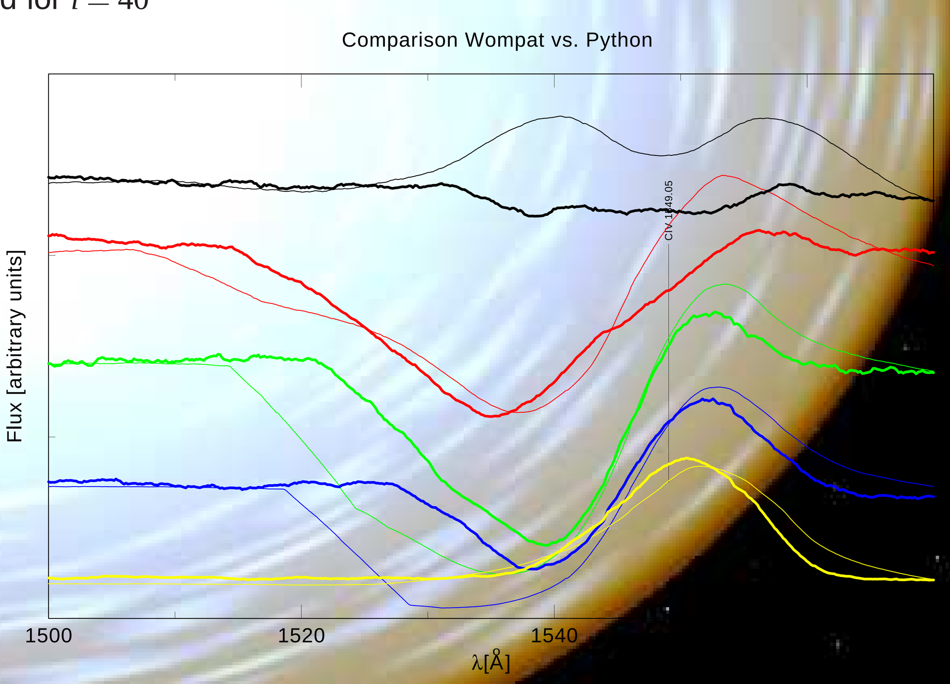

FIGURE 3: Calculated C IV 1550 Å resonance line for different inclination angles. Plotted are results from Python (Long & Knigge 2002) and WOMPAT (thick lines). Inclination angles are 10.0° (black), 27.5° (red), 45.0° (green), 62.5° (blue) and 80.0° (yellow)

One interesting point to note is shown in Fig. 2. Using the same parameters the assumption of Doppler broadening yields much stronger lines compared to the use of Stark broadening. In order to get the P Cygni profile for Stark broadening one could assume a higher abundance of C in the wind as compared to the standard solar value. Other possible solutions currently probed for this problem are different temperatures and higher accretion rates. Even clumping like in O-star winds might prove useful.

Even with the limitations WOMPAT still has a comparison with the most sophisticated CV wind code available today, Python (Long & Knigge 2002), yields acceptable results as shown in Fig. 3. Thanks to Stuart Sim for providing Python data.

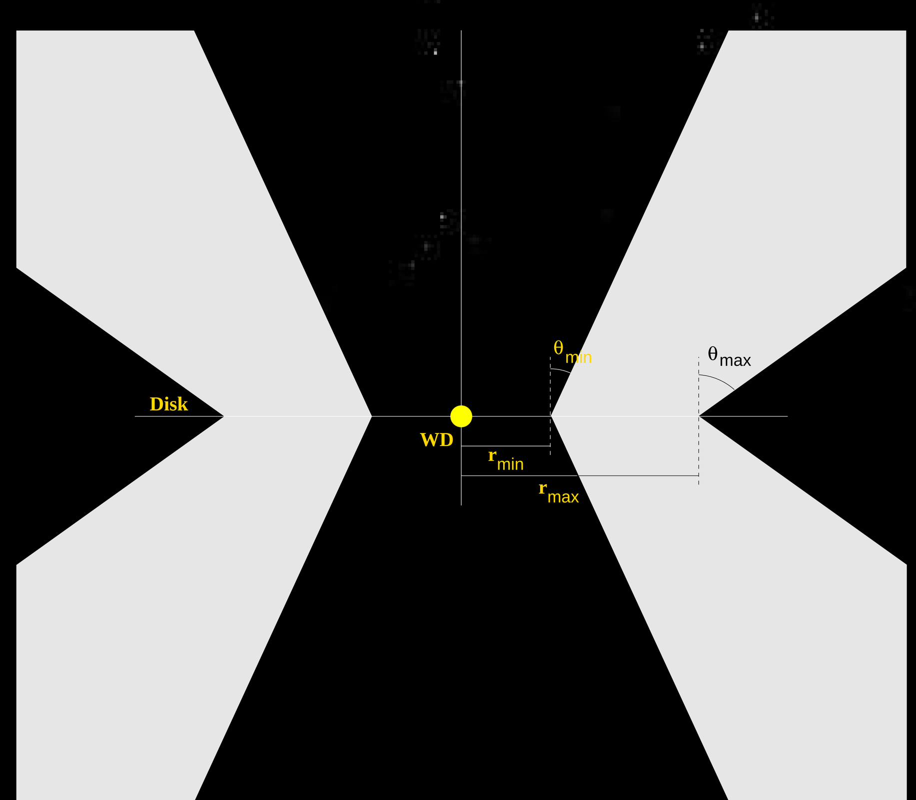

FIGURE 6: Biconical wind model according to Shlosman & Vitello (1993)

The background image is a visualisation of AM CVn
Made by D.-J. Kusterer with the BINSIM tool by Rob Hynes.

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Within the Tübingen group a code for modeling NLTE accretion disk atmospheres was developed and successfully used to model spectra of CVs, AM CVn systems and ultracompact X-ray binaries (Nagel et al. 2004, Werner et al. 2005, Kromer et al. 2007). Our goal is to develop a whole package with which we are able to model a complete CV including the accretion disk, the white dwarf and the outflow. This poster concentrates on the presentation of the radiative transfer in accretion disk winds and its application to AM CVn.

At the moment we implemented a kinematical biconical wind model by Shlosman & Vitello (1993) for the outflow structure, see Fig. 6. Monte Carlo techniques are used to do the radiative transfer in this three-dimensional wind structure. Photon packets, which represent a monochromatic family of photons, are created on the disk or the WD and are then followed through the wind. All parts of a photon packet's life, the creation, interaction points and -processes, new directions of flight, . . . are determined via probabilities. Optical depths are acquired by numerical integration of local opacities along the photon's line of flight. Thus no Sobolev approximation is needed. Furthermore line opacities can be calculated with either Doppler or Stark broadening. The spectra are determined by detecting escaping parts of photon packets in a virtual detector located at infinity.

Typical P Cygni wind lines, such as the C IV 1550 Å resonance line, see Fig. 3, as well as wider spectral features as the Lyman edge, are reproduced by our model. A whole wind spectrum calculated for a standard set of CV parameters is shown in Fig. 4. It shows nice C IV, N III and Lyα lines. Comparing this standard model to a model spectrum calculated for AM CVn parameters and abundances shown in Fig. 5 one immediately sees the missing Lyman edge, a Si IV line at 1400 Å not present in the standard model and the other lines, especially the C IV line being narrower. Note also the differences in the Monte Carlo wind spectrum calculated with a blackbody disk input or with a "real" disk input when comparing Fig. 1 and Fig. 5. The obvious edge around 900 Å is a He feature of the disk, but on the other hand the Si IV and C IV lines are features of the wind.

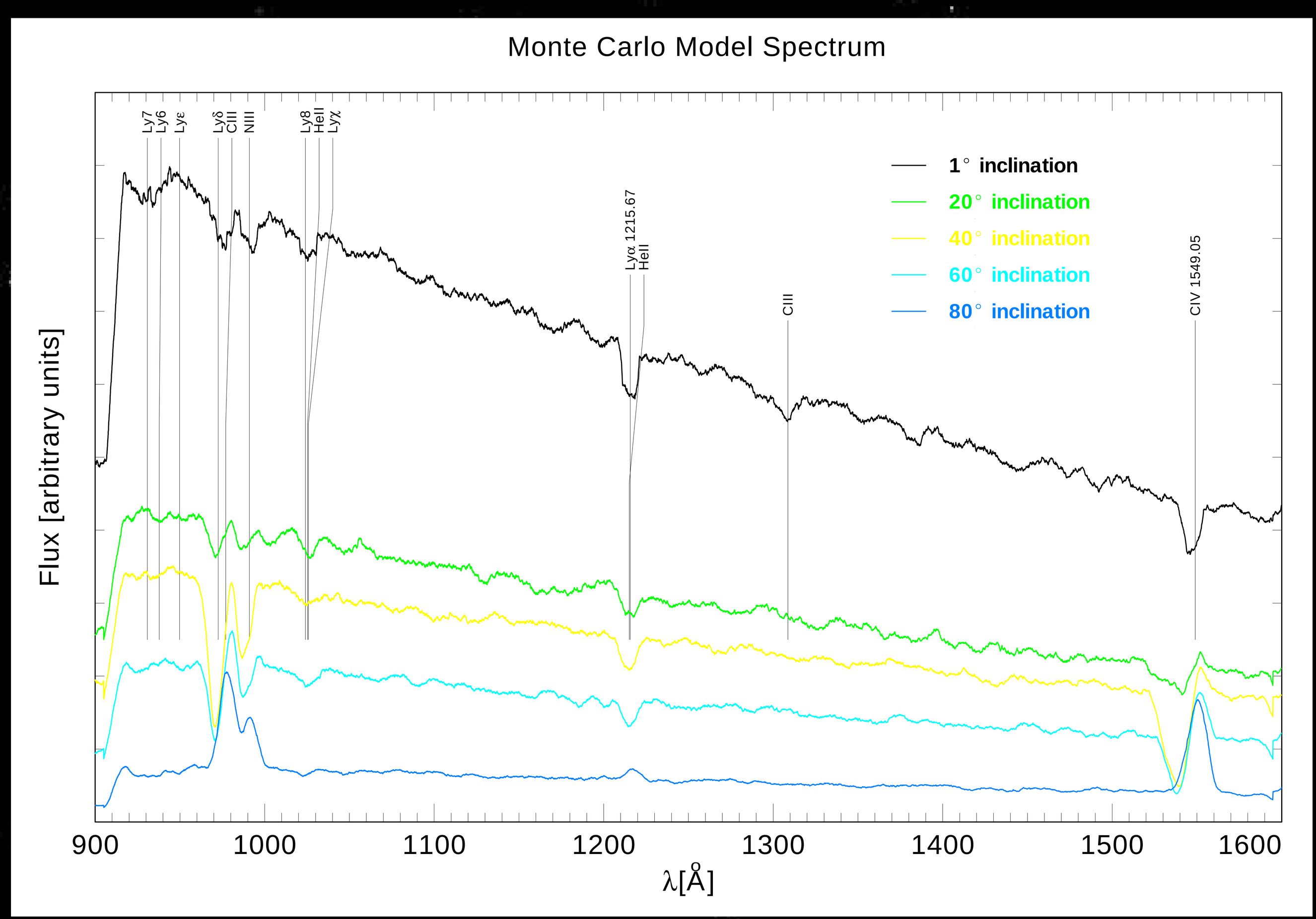

FIGURE 4: Calculated model spectrum for standard CV parameters and different inclination angles. A black-body accretion disk is used, thus all features are wind features. Solar abundances were used. Compare to Fig. 5.

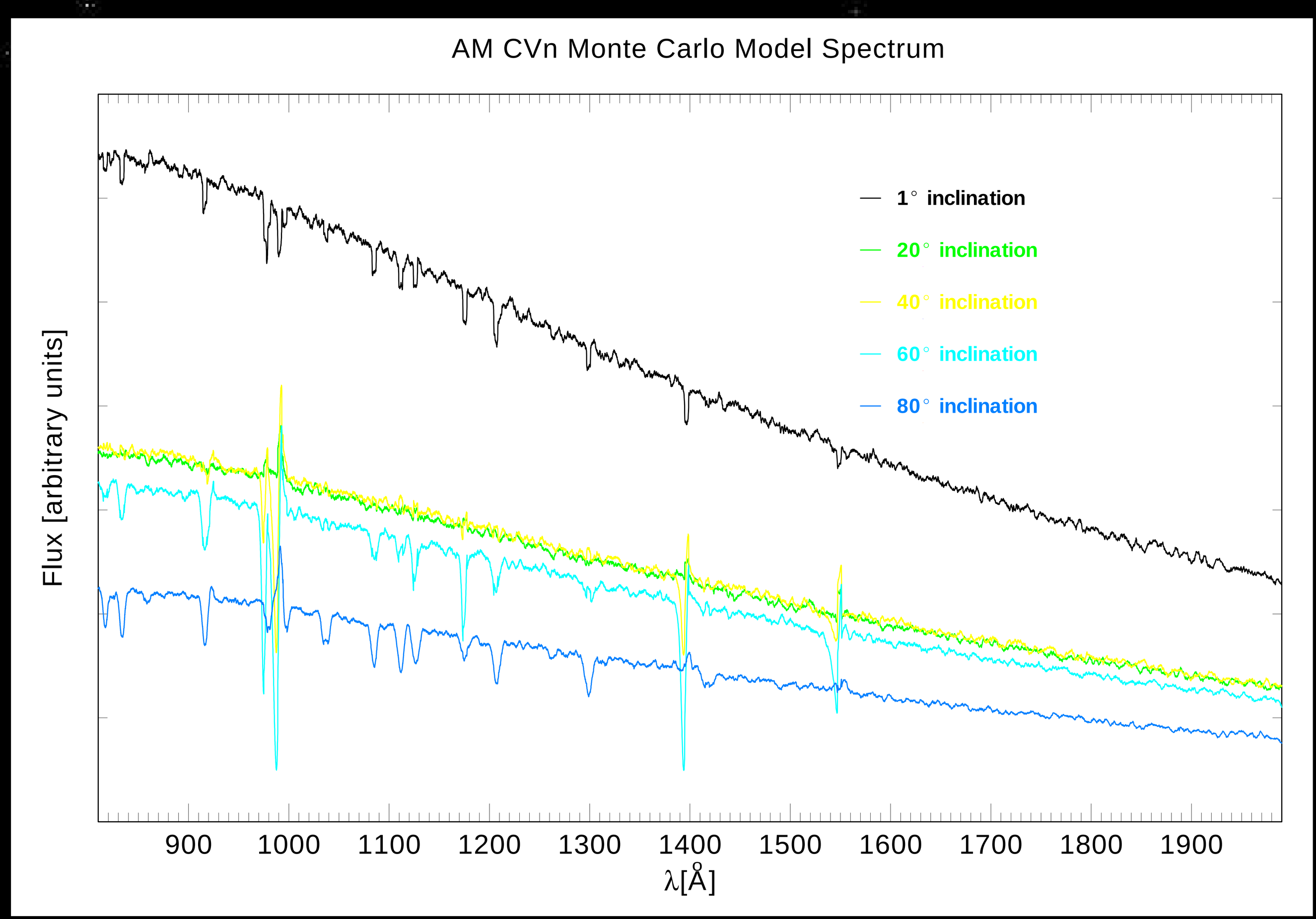

FIGURE 5: Calculated model spectrum for AM CVn parameters. A black-body accretion disk is used, thus all features are wind features. Note the differences compared to a wind model with AcDc input as in Fig. 1.