Recent Progress in Modelling of Accretion Discs in AM CVn Stars

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Outline

★ Modelling of NLTE Accretion Discs
★ Model Grid for AM CVn Systems
★ Model vs. CE 315
★ Summary
Modelling of NLTE Accretion Discs

Assumptions:
- geometrically thin $\alpha$-disc  (Shakura & Sunyaev 1973)
- axial symmetry

Divide disc into set of concentric rings
Each ring: plane-parallel radiating slab
Calculate detailed vertical structure and synthetic spectrum with AcDc (Accretion Disc code, Nagel et al. 2004)
Modelling of Accretion Discs

- **hydrostatic equilibrium**
  (gas and radiation pressure)

- **radiative equilibrium**
  (full line blanketing, no convection)

- **NLTE rate equations**

- **radiation transfer equations**
  (irradiation by primary can be considered)
Modelling of Accretion Discs

- Vertical structure and spectrum for each disc ring

- Integration of all disc ring intensities, rotational broadening
  ⇒ NLTE accretion disc spectra for different inclinations

- Disc spectrum can be used as input for our accretion disc wind models
Modelling of Accretion Discs

Input parameters

- mass and radius of central object
- mass accretion rate
- radial extension of accretion disc
- Reynolds number
- chemical abundances (→ donor star)
- irradiation: temperature/spectrum of central object and irradiation angle
- atomic data
AM CVn stars

- Helium cataclysmic variables
- Orbital periods 5 - 65 minutes
- Helium dominated spectra, no hydrogen
- Absorption- or emission-line spectra
- 26 systems known
- Nature of donor star still debated
Model grid for AM CVn stars

- mass of primary: 0.6, 0.8, 1.0, 1.2 and 1.4 M☉
- mass accretion rate: $10^{-8}$, $10^{-9}$, $10^{-10}$, $10^{-11}$ M☉/yr
- variation of C, N, O, Si abundances
- radially extended to the tidal radius (if possible)
- five inclination angles

(Nagel et al. 2009)
Model grid for AM CVn stars

![Graph showing model grid for AM CVn stars. The graph plots effective temperature ($T_{\text{eff}}$) against distance from the center of the white dwarf (in km). The horizontal axis is labeled as distance from the center of the white dwarf in units of 1000 km. The vertical axis represents $T_{\text{eff}}$ in kelvins (K). Three distinct lines are shown for different masses ($M_1$): $0.6 M_\odot$, $1.0 M_\odot$, and $1.4 M_\odot$. Each line represents a different mass, with the effect of mass on the effective temperature and distance relationship being illustrated.]
Variation of primary mass

$\dot{M} = 10^{-11} \, M_\odot/\text{yr}$, inclination $i=18^\circ$

$M_1 [M_\odot]: \quad 1.4 \quad 1.0 \quad 0.6$

$\dot{M} = 10^{-8} \, M_\odot/\text{yr}$, inclination $i=18^\circ$

$M_1 [M_\odot]: \quad 1.4 \quad 1.0 \quad 0.6$
Variation of mass-accretion rate

\[ M_1 = 1.4 \, M_\odot, \text{ inclination } i=18^\circ \]
\[ \dot{M} [M_\odot/yr]: \ 10^{-8} \ 10^{-9} \ 10^{-10} \ 10^{-11} \]

\[ M_1 = 0.6 \, M_\odot, \text{ inclination } i=18^\circ \]
\[ \dot{M} [M_\odot/yr]: \ 10^{-8} \ 10^{-9} \ 10^{-10} \ 10^{-11} \]
Variation of chem. abundances

$M = 1.2 \, M_\odot$, $\dot{M} = 10^{-8} \, M_\odot/\text{yr}$

C, N, O Si solar
N 10 solar, Si solar, C, O 0.001 solar
N 10 solar, C, O, Si 0.001 solar
Variation of chem. abundances

- $M_* = 0.6 \, M_\odot$, $\dot{M} = 10^{-10} \, M_\odot$/yr
- C, N, O Si solar
- N 10 solar, Si solar, C, O 0.001 solar
- N 10 solar, Si 0.1 solar, C, O 0.001 solar
- N 10 solar, Si 0.001 solar, C, O 0.001 solar

$F_\lambda [\text{erg/(sterad s \AA)}]$

6000 6200 6400 6600

$\lambda [\text{\AA}]$
Variation of inclination

\[ \log F_\lambda \text{ [erg/(sterad s Å)]} \]

\( \lambda [\text{Å}] \)

\( M_1 = 0.6 \, M_\odot \)

\[ \log F_\lambda \text{ [erg/(sterad s Å)]} \]

\( \lambda [\text{Å}] \)

\( M_1 = 1.4 \, M_\odot \)

\[ \log F_\lambda \text{ [erg/(sterad s Å)]} \]

\( \lambda [\text{Å}] \)

\( M_1 = 0.6 \, M_\odot, \dot{M} = 10^{-10} \, M_\odot/\text{yr} \)

inclination: 87° 77° 60° 40° 18°
Influence of irradiation by primary

$M_1 = 0.8 \, M_\odot, \ T_{\text{eff}} = 80 \, 000 \, K$

$\dot{M} = 10^{-8} \, M_\odot/\text{yr}$

irradiated

(1)

(2)
Influence of irradiation by primary

\[ \log F_{\lambda} \text{ [erg/(sterad s Å)]} \]

\[ \lambda [\text{Å}] \]

\[ M_i = 0.8 M_\odot, \text{ inclination } i = 18^\circ \]

\[ M = 10^{-11} M_\odot/\text{yr} \]

\[ \log F_{\lambda} \text{ [erg/(sterad s Å)]} \]

\[ \lambda [\text{Å}] \]

\[ M_i = 0.8 M_\odot, \text{ inclination } i = 18^\circ \]

\[ M = 10^{-11} M_\odot/\text{yr} \]
Spectroscopic detection of primary
Models vs. Observation: CE 315

\[ M_* = 0.8 \, M_\odot, \quad \dot{M} = 10^{-11} \, M_\odot/\text{yr} \]

\[ \lambda \, [\text{Å}] \]

\[ \log F_\nu \, [\text{erg cm}^{-2} \, \text{s}^{-1} \, \text{Å}^{-1}] \]

\[ \lambda \, [\text{Å}] \]

Si II

Si II
Models vs. Observation: CE 315

\[ \log F_{\lambda} \text{ [erg cm}^{-2}\text{s}^{-1}\text{Å}^{-1}] \]

\[ M = 0.8 \, M_\odot, \quad \dot{M} = 10^{-11} \, M_\odot/\text{yr} \]

\[ \lambda [\text{Å}] \]

\[ \log F_{\lambda} \text{ [erg cm}^{-2}\text{s}^{-1}\text{Å}^{-1}] \]

\[ \lambda [\text{Å}] \]

Si II

Si II
Models vs. Observation: CE 315
New Developments

- Accretion disc wind with *Wompat* (D. Kusterer 2008, PhD Thesis) and *Waccabi* (D. Semionov, work in progress)

- Non-axialsymmetric discs or spiral arms, applied to metal-rich discs around single white dwarfs (Hartmann et al., in prep)

- Radiative transfer with velocity field vs. RT in static disc and rotational broadening applied to the emergent spectrum (Korcakova et al., in prep)

- Iron group elements (Krausz et al., in prep)
Summary

- grid of accretion disc models: $0.6 - 1.4 \ M_\odot, \ 10^{-8} - 10^{-11} \ M_\odot/\text{y}$

- reproduction of absorption and emission line spectra for high and low state

- irradiation by the primary seems to have almost no effect onto the spectrum

- indication of underabundance of Si in CE315 (also no Si found in X-ray [Ramsay et al. 2006] and UV [Gänsicke et al. 2003])