High Resolution Spectroscopy of the Super-saturated Contact Binary, VW Cep.

(or, How to Map Binary Star Coronae with the Chandra HETGS)

David P. Huenemoerder (MIT), Paola Testa (MIT), & Derek Buzasi (USAFA)
Abstract

Short-period binaries represent extreme cases in the generation of stellar coronae via a rotational dynamo. Such stars are important for probing the origin and nature of coronae in the regimes of rapid rotation and activity saturation. VW Cep ($P = 0.28$ d, 24 ks) is relatively bright, partially eclipsing, and very active object. Light curves made from Chandra HETGS data show flaring and rotational modulation, but no obvious eclipses. Velocity modulation of emission lines indicates that the larger, more massive component dominates the X-ray emission. The emission measure is highly structured, having three peaks. Helium-like triplet lines give electron densities of about $3 \times 10^{10}$ to $3 \times 10^{11}$ cm$^{-3}$. The modulation, emission measure, and densities together suggest that the emitting structures are compact.
VW Cep Spectrum (120ks)
VW Cep X-ray Light Curve

Rotational modulation

Flares

Bin size = 2 ks
1.5–26 Å
1.5–8.3 Å (h)
12–26 Å (s)

Count Rate [cts/s]

(h-s)/(h+s)

Time [ks]

0 20 40 60 80 100 120
VW Cep: W UMa Type (contact) binary

Period: 0.278 days (6.67 hr)

Mass Ratio: 0.39 (0.457 / 1.157)

Spectral Types: K0 V, G5 V

(Stepien 2001)

(Randich, 1998)
Contact Binaries

VW Cep schematic photospheric geometry and temperature (from nightfall).

Typical W-type W UMa optical light curves. (Hendry & Mochnacki 2000 ApJ 531, 467)
VW Cep Phased X-ray Light Curve

NO X-Ray eclipse!

Scaled optical*

X-rays (flare-filtered)

*Pribulla; http://www.astro.sk/~pribulla/lc.html
Plasma Volume, Density, & Geometry

Fit Line Fluxes:  \[ \rightarrow \]
Emission measure
\[ N_e^2 \times Volume \]
(\( \sim 5 \times 10^{52} \text{cm}^{-3} \))

Fit Line Ratios:
Helium-like lines
(\( \text{O VII}, \text{Ne IX}, \text{Mg XI} \))
\[ \rightarrow N_e \]
(\( \sim 3 - 18 \times 10^{10} \text{cm}^{-3} \))

Geometry:  \((N_e, V) \rightarrow R(\text{corona})/R_\ast < 0.2\)
Emission Measure

binsize: \( \Delta \log T = 0.1 \)

Integrated VEM: \( 4.6 \times 10^{52} \)
He-like Line Ratio Fits

HEG Ne IX

LETGS O VIII

MEG Mg XI
Velocity Modulation

Composite Line Profile: In each phase bin, transform several lines to velocity scale and sum. Measure centroid of core.

The Primary Dominates; Simulations imply ≤ 20% of the flux from the secondary at some phases (0.7–0.9).
Composite Profile Simulations

Primary/Secondary weights

1.0 : 0.0

0.8 : 0.2

0.7 : 0.3
A Consistent View

Polar/asymmetric corona: no eclipses;
Compact corona: some modulation; density & volume arguments;
Primary Star Dominates: velocity + light curves

Supersaturation is manifested in compact, near polar, and few coronal emitting regions (why is still TBD).
Another W UMa Case: 44 Boo

- Flares
- Rotational Modulation
- X-Ray eclipse!

- X-rays (flare-filtered)
- Scaled optical

- HEG
- MEG
Acknowledgements

- Standard data products and responses were made with CIAO software, version 3.2 (http://cxc.harvard.edu/ciao/). Analysis and custom programming was done with ISIS (http://space.mit.edu/cxc/isis).

- Contact binary geometry images were made with the program nightfall (Rainer Wichmann et al., http://www.lsw.uni-heidelberg.de/~rwichman/Nightfall.html).

- Photometric data for VW Cep are from T. Pribulla et al (2000 IBVS 4847, 2002 IBVS 5341) and on the web from the same epoch as the X-ray data. (http://www.astro.sk/~pribulla/lc.html).


- Thanks to John Houck for ISIS support and help.

- Thanks to John Davis for use of his S-Lang xfig module, with which the line-profile images were made.

- Thanks to Nancy Brickhouse (CfA) for tables of theoretical He-like line ratios.

- This research was supported by NASA grant G03-4005A and by NASA through the Smithsonian Astrophysical Observatory (SAO) contract SV3-73016 for the Chandra X-Ray Center and Science Instruments.