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## A SIMPLE, UNIFYING MODEL OF THE EXTREME ULTRAVIOLET SPECTRA OF DWARF NOVAE IN OUTBURST

Christopher W. Mauche<sup>1</sup>

### RESUMEN

Se describe brevemente un modelo simple de la capa limítrofe y del viento del disco de acreción de novae enanas en explosión aplicándolo a los espectros de WZ Sge y SS Cyg en explosión obtenidos con la Rejilla de Transmisión de Baja Energía de Chandra.

### ABSTRACT

A simple model of the boundary layer and accretion disk wind of dwarf novae in outburst is briefly described and applied to the *Chandra* Low Energy Transmission Grating spectra of WZ Sge and SS Cyg in outburst.

*Key Words:* **BINARIES: CLOSE — NOVAE, CATAclysmic VARIABLES — STARS: INDIVIDUAL (SS CYG, WZ SGE) — STARS: WINDS, OUTFLOWS — ULTRAVIOLET: STARS**

### 1. INTRODUCTION

According to simple theory, the boundary layer between the accretion disk and the surface of the white dwarf is the dominant source of high energy radiation in nonmagnetic cataclysmic variables. When the mass-accretion rate is high, as in nova-like variables and dwarf novae in outburst, the boundary layer is optically thick and its temperature is of order the blackbody temperature  $T_{\text{bb}} = (GM_{\text{wd}}\dot{M}/8\pi\sigma f R_{\text{wd}}^3)^{1/4} \sim 100$  kK. Such a compact source of extreme ultraviolet (EUV;  $\lambda \sim 100$  Å) flux is not inconsistent with low inclination systems like SS Cyg ( $i \sim 40^\circ$ ) and VW Hyi ( $i \sim 60^\circ$ ), but the lack of EUV eclipses in high inclination systems like UX UMa ( $i \approx 71^\circ$ ; Wood, Naylor, & Marsh 1995; Pratt et al. 2004) and OY Car ( $i \approx 83^\circ$ ; Naylor et al. 1988; Pratt et al. 1999; Mauche & Raymond 2000) requires an additional extended source of EUV flux. A plausible explanation for the origin of this extended EUV flux is proposed by Mauche & Raymond (2000), who modeled the *Extreme Ultraviolet Explorer* (EUVE) spectrum of OY Car in superoutburst with a simple model, wherein EUV radiation from the boundary layer is scattered into the line of sight by the system's accretion disk wind. Characterizing the boundary layer spectrum as an absorbed blackbody and the wind as an expanding spherical shell, good fits were obtained with an assumed wind mass-loss rate  $\dot{M}_w \approx 1 \times 10^{-10} M_\odot \text{ yr}^{-1}$  and a boundary layer fractional emitting area  $f \approx 0.17$ –1 with a boundary layer temperature  $T_{\text{bl}} \approx 95$ –127 kK, an absorbing column density  $N_{\text{H}} \approx 1.6$ – $2.5 \times 10^{19} \text{ cm}^{-2}$ , and a luminosity  $L_{\text{bl}} = 4\pi f R_{\text{wd}}^2 \sigma T_{\text{bl}}^4 \approx 1$ – $10 \times 10^{34} \text{ erg s}^{-1}$ .

### 2. LETG SPECTRA OF WZ SGE AND SS CYG

Given the success of this simple model to explain the *EUVE* spectrum of OY Car, we used it to model the *Chandra* Low Energy Transmission Grating (LETG) spectra of WZ Sge and SS Cyg. The WZ Sge spectrum was obtained on 2001 July 27 during the early decline of a superoutburst that began four days earlier (Kuulkers et al. 2002), while the SS Cyg spectrum was obtained on 2001 January 16 during the plateau phase of a normal (asymmetric) wide outburst that began four days earlier. The resulting background-subtracted, fluxed spectra are shown by the black histograms in Figure 1. The LETG spectrum of WZ Sge, which is very similar to the *EUVE* spectrum of OY Car, contains numerous broad *emission* lines, the strongest of which are asymmetric, with flux missing from the blue sides of the lines. A similar asymmetry was seen in the lines in the *EUVE* spectrum of OY Car, but it is much more apparent in this higher resolution (FWHM = 0.05 Å for the *Chandra* LETG spectrometer compared to FWHM = 0.5 Å for the *EUVE* SW spectrometer) and higher signal-to-noise ratio LETG spectrum of WZ Sge. That these are P Cygni-type profiles is demonstrated clearly by the similarity of the O VI  $2s$ – $np$  ( $n = 3, 4, 5$ ) lines in the EUV to the O VI  $2s$ – $2p$  line in the FUV (Long et al. 2003). In contrast to the EUV spectra of OY Car and WZ Sge, the EUV spectrum of SS Cyg consists of a broad ( $\lambda \approx 40$ –130 Å) continuum, which we argue below is cut by a multitude of broad, blueshifted *absorption* lines.

Details of the analysis and interpretation of these spectra will be presented elsewhere (Wheatley & Mauche 2004; Mauche 2004), but we report here the

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