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The Origin of X-Ray Emission Lines From SS Cgy

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Abstract

SS Cyg is a dwarf nova binary star that undergoes frequent large amplitude outburst within a period of 40 days. SS Cyg was observed with the Chandra x-ray telescope in quiescence on 2000 August 24, and near the peak and early decline of a narrow outburst on 2000 September 12 and 14 (exposures of 47 and 96 ks). The spectrum of the source shows strong emission lines of O VII and O VIII in all three observations. These lines, we note, originate from the boundary layer.

Key Words: Cataclysmic Variables, emission lines, SS Cyg, dwarf novas.

1. Introduction

Cataclysmic Variables (CVs) are binary stars in which the secondary star fills its Roche lobe and starts transferring mass into the lobe of the compact primary. The transferred material has too much angular momentum to fall directly onto the surface of the white dwarf, but instead builds an accretion disk, which spirals round the white dwarf. The matter in the disk will be accreted onto the white dwarf if it losses its angular momentum. The matter in the disk losses its angular momentum gradually and moves toward the accreting star. Cataclysmic Variables (CVs) are made up of three classes: novae, dwarf novae and nova-like variables. SS Cyg is in the class of dwarf novae in which the secondary star is a red dwarf-type star while the primary star is a white dwarf. The red dwarf-type and white dwarf stars in SS Cyg are separated by about 160,900 km. The closeness of the stars made it possible for them to complete their orbital revolution in 6.5 hours. Observations show that SS Cyg is fairly close to the Sun at a distance of about 28 to 31 pc [1]. The inclination of the system has been calculated to be about 50 ° , yielding a respective component mass of $M_{wd} = 0.60$ M$_\odot$ and $M_{ms} = 0.40$ M$_\odot$ [2].

When the secondary star loses matter, it streams in the direction of the primary, forming an accretion disk around it. The observed outbursts are believed to be the result of processes that arise in the hydrogen-rich disk. It could be as a result of a sudden transfer of mass from the secondary to the primary (as postulated in the mass-transfer burst model) or it could be the product of instability with the disk (as postulated by the disk-instability model). During SS Cyg outburst, typical dwarf novae rise by 2–6 magnitudes on timescales of about 10–100 days.

It has been shown from theoretical point of view that the boundary layer of CVs is very hot due to accretion process and as a result it is the most likely source of high energy radiation in the extreme ultraviolet and x-ray bands. It is important to note that Dwarf Novae (DNs) are indeed not large producers of high-energy radiation during minimum light. However, when they undergo an outburst, the boundary layer between the accretion disk and the surface of the white dwarf becomes quickly heated to a few hundred thousand Kelvin [3]. Mauche [4] was of the view that the boundary layer is the dominant source of high-energy radiation in nonmagnetic cataclysmic variables (CVs). This implies that observation in the extreme ultraviolet and x-ray wave bands will best reveal the nature of radiations coming from the boundary layer.

In this work spectral analysis of observed data from the Chandra X-ray telescope was carried out. The emission lines of O VII and O VIII were present in the three observational data analyzed. Their line strengths were also determined and based on theoretical considerations we suggested the possible origin of these x-ray emission lines.

2. Observations

SS Cyg was observed with the Chandra x-ray telescope in quiescence on 2000 August 24 and near the peak and early decline of a narrow outburst on 2000 September 12 and 14 (exposures of 47 and 96 ks). The Chandra X-ray telescope is a NASA satellite devoted to acquiring astronomical data in the X-ray wavelength range of 1.2–175 Å (0.07–10 keV). The satellite was launched 23 July 1999. A detailed description of the science instrumentation is presented in [5]. The satellite has exquisite angular resolution, which can measure X-ray source locations to less than 1 arc second. These observations were obtained through the NASA Guest Observer Program. For each target observation, a Deep Survey image and requested data are obtained. The data is proprietary to the Guest Investigator for a period of one year following the observation, after which they are placed in the Chandra X-ray telescope Archive and become publicly available. It is from this public archive that the data used for this work was obtained.

3. Analysis Results

We used the standard pipeline-processed data to begin our analysis, after checking that no significant updates to the calibration had occurred since the data had been last processed. We examined the light curve of the data for flares due to solar radiation, and removed the flares. We then extracted the 1^{st} order spectrum from the Medium Energy Grating (MEG) of the High Energy Transmission Grating (HETG) and calculated the instrumental response using the CIAO tools mkgarf and mkgrmf. We then examined the spectrum using XSPEC, finding very strong O VII and O VIII lines (see the plots in Figure). Tables 1 and 2 show the line strengths for O VII and O VIII for the three observations.

Table 1. Line strength of O VII for the three observations.

Time of Observation.	Line Strength. Photons/cm^2
Time00	$5.36 \times 10^{-5} \pm 0.15 \times 10^{-4}$
Time45	$3.53 \times 10^{-4} \pm 0.19 \times 10^{-2}$
Time55	$4.87 \times 10^{-4} \pm 0.78 \times 10^{-3}$

Table 2. Line strength of O VIII for the three observations.

Time of Observation.	Line Strength. Photons/cm^2
Time00	$5.8 \times 10^{-5} \pm 0.43 \times 10^{-4}$
Time45	$1.18 \times 10^{-3} \pm 0.51 \times 10^{-3}$
Time55	$1.08 \times 10^{-4} \pm 1.21$

Time00 is the Time for the first observation (2000-08-24, T 10:28:23); Time45 is the time for the second observation (2000-09-12, T 17:00:58); and Time55 is the time for the third observation (2000-09-14, T 21:09:02).

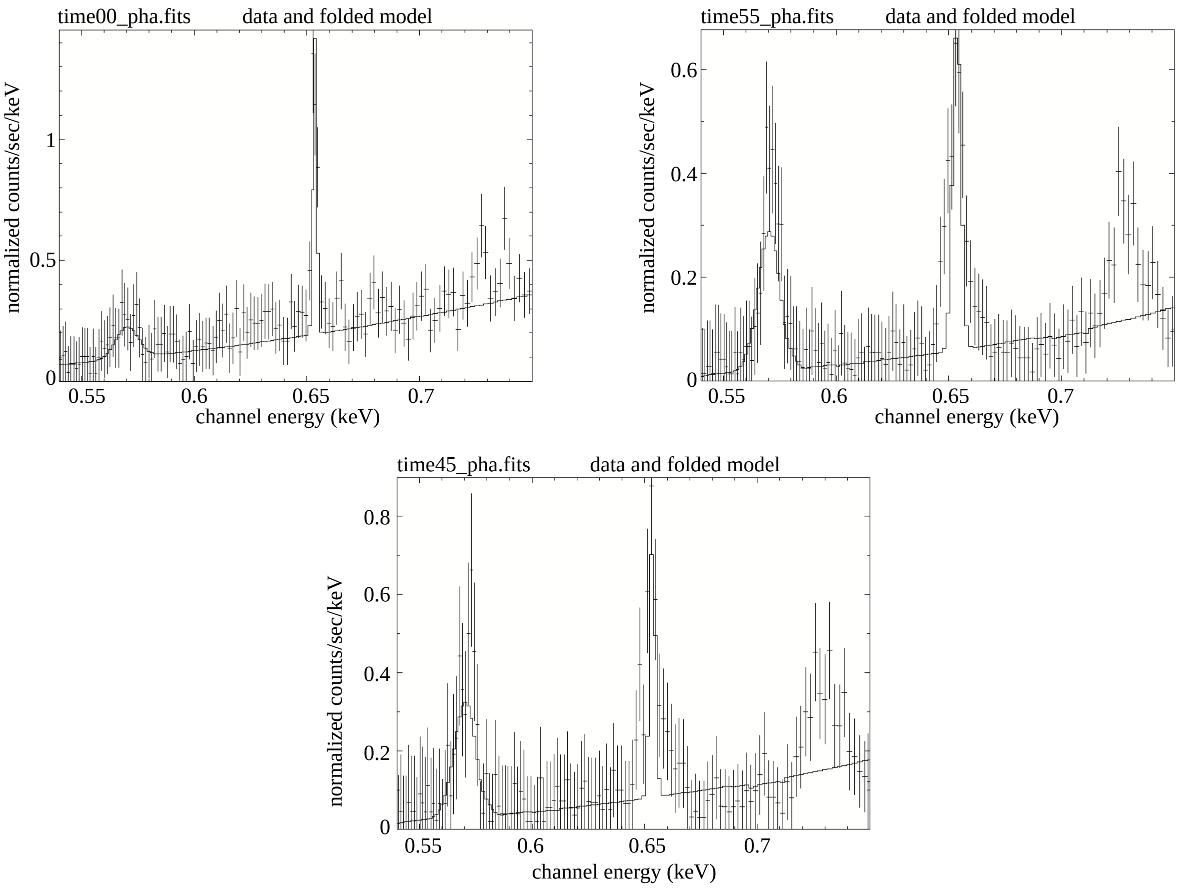

Figure 1. The spectrum of the three observation of SS Cyg.

4. Conclusion

As was noted earlier, the inner regions of dwarf nova emit ultra-violet and X-ray radiations. It is therefore reasonable to state that these observed emission lines of O VII and O VIII originated from the boundary layer.

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