Magnetic CVs studied with Fe XXV triplet lines

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Introduction: Post-shock region of magnetic CV

Some white dwarfs (WDs) in cataclysmic variables (CVs) are magnetic enough that accretion proceed along field lines. The accretion flow in such cases is nearly vertical with respect to the WD surface. A strong stand-off shock forms just above the WD surface; the post-shock plasma must cool and further slow down before settling onto the WD. They often do so primarily by emitting optically thin, thermal X-rays. For a 0.6 Msun WD, the free-fall velocity is ~4,300 km/s, and the shock temperature is ~22 keV (6,900 km/s and 57 keV for a 1.0-Msun WD).

The region filled by the cooling and falling multitemperature plasma is called a post-shock region (PSR), and X-ray emission from there contains many characteristics that can be used study physical conditions/parameters of accreting WDs, such as WD mass, accretion rate, and accretion geometry.

Although many numerical approach have been reported to model the PSR, by e.g. Cropper+1998, Suleimanov+2005, Yuasa+2010, the **f** parameter which denotes **fractional area of PSR to the WD surface area** remains a free parameter which largely affect numerical solution, and is not precisely measured (some upper limits, e.g. <0.2% or <0.7% are reported for particular objects). If we can constrain **f** from ASTRO-H/SXS observations, we will be able to directly solve the PSR model, precisely obtaining temperature, pressure, density, and velocity profiles in the PSR. **This leads to detailed understanding of magnetic CVs, the low-luminosity hard-X-ray source population in the Galaxy** (Revnivtsev+2009, Yuasa+2012).

Density diagnostics using He-like Fe Kα triplets

Astrophysical plasmas with a density above the critical density of Fe XXV (10^{17-18} cm^{-3}) together with plasma temperature that is high enoug to ionize Fe to He-like are rather rare. However, PSRs of magnetic CVs with high accretion rates are believed to reach this extreme condition (Figure 2 and Table 1) over a plausible range of **f** (Figure 3). Therefore, by studying the Fe XXV triplet lines with the SXS, plasma density in a PSR could be directly measured, and it will be possible to constrain the physical condition of a PSR further deepening our understanding on accretion physics.

Figure 4 shows X-ray spectral model of Ka emission lines from Fe XXV using the SPEX/CIE model (Kaastra+1996) and PSR structure calculed using a model of Yuasa+2010. The spectra clearly shows decrease of the forbidden line intensity in smaller **f** vaues (i.e. higher PSR densities), and therefore forbidden/intercombination line ratio, or equivalently R=z/(x+y) ratio, can be used as a density diagnostic tool.

V1223 Sgr as a PV target candidate

In the white paper draft, we picked up a particular MCV, V1223 Sgr, as a candidate of PV targets proposed by the white dwarf team. This is because the CV is one of the brightest MCV in the sky (~5 mCrab in the 2-10 keV band), and previous studies have revealed that it has the highest accretion rate in known MCVs. These aspects are favorable when accumulating enough photon statistics within an affordable exposure, and study structure of a PSR by means of He-like Fe triplet lines.

Figure 5 shows simulated V1223 Sgr observation with the SXS. With an assumed exposure of 100 ks, we will be able to determine intensities of each of triplets with relative errors of ~10-30%. Fit results and calculated R=z/(x+y) values are tabulated in Table 2. Figure 6 shows correlation of **f** and R. From these resulst, we expect that we can clearly distinguish **f**=0.0002 and 0.001 cases, but for 0.001 and 0.005 cases, discrimination may be possible only marginally within the errors with the 100-ks exposure.

Table 2: Results of the Gaussian fits to the simulated spectra of a100-ks observation of V1223Sgr.

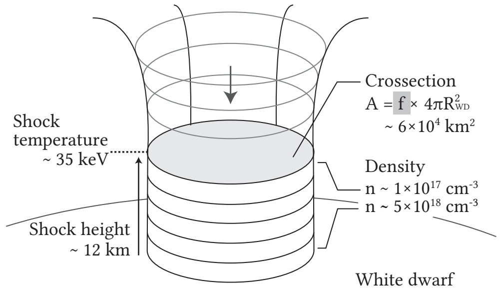
f	Intensity (10^{-5} photons s^{-1} cm^{-2})				R
	w	x	y	z	
0.005	$4.80^{+0.25}_{-0.37}$	$1.00^{+0.18}_{-0.30}$	$1.29^{+0.11}_{-0.31}$	$1.54^{+0.22}_{-0.19}$	0.68 ± 0.12
0.001	$4.72^{+0.30}_{-0.37}$	$0.99^{+0.19}_{-0.27}$	$1.38^{+0.20}_{-0.19}$	$1.20^{+0.11}_{-0.21}$	0.51 ± 0.10
0.0002	$4.77^{+0.26}_{-0.33}$	$1.29^{+0.22}_{-0.18}$	$1.68^{+0.23}_{-0.18}$	$0.67^{+0.17}_{-0.18}$	0.23 ± 0.06

Summary

1. Plasma density diagnostics using Fe XXV triplet can be performed with SXS spectra of bright magnetic CVs. Simulation results of a 100-ks V1223 Sgr observation is presented as an example.

2. From derived R=z/(x+y) ratio, we will be able to constrain f value, by inversely correlating them using Figure6. Numerical model can be re-solved with derived f value, much increasing accuracy compared to results obtained with assumed f values.

3. The solved numerical model can be re-used to constrain WD mass and other physical parameters in, e.g., broad-band SXS+SXI+HXI analyses.



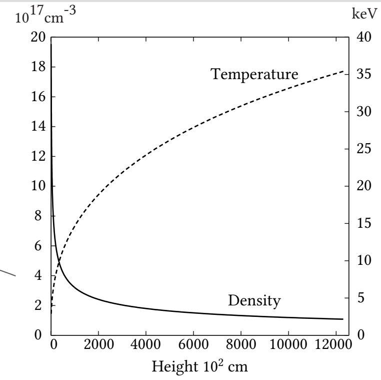


Figure 1 (left): Schematic view of a PSR of a magnetic CV. Typical physical values are shown for WD mass of 0.79 Msun (equivalent to that of V1223 Sgr). Note **f** parameter in the crosssection equation. **Figure 2 (right)**: Plasma temperature and density profiles of PSR plasma calculated along the height from the WD surface. White dwarf mass of 0.79 was assumed (see Yuasa et al. 2010 for details of the numerical model).

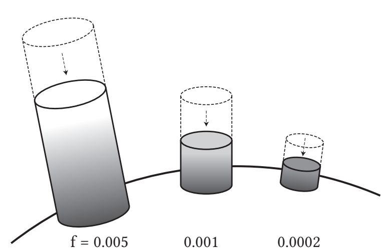
Table1: ResultofthePSRstructuremodelcalculation for V1223 Sgr with different covering fraction **f**.

Result	f		
	0.0002	0.001	0.005
h_s cm	2.52×10^5	1.25×10^6	6.14×10^6
kT_s keV	35.7	35.7	35.4
ρ_s cm^{-3}	5.42×10^{17}	1.08×10^{17}	2.18×10^{16}
v_s cm s^{-1}	1.36×10^8	1.36×10^8	1.36×10^8

* h_s, kT_s, ρ_s, and v_s are shock height measured from the WD surface, plasma temperature, density, and falling velocity directly below the shock.

Shock temperature is not sensitive since gravitational potential depth of shock is almost constant over these f values.

Well match critical density of Fe XXV triplet lines. I.e., density diagnostics using f/i ratiio will be applicable.



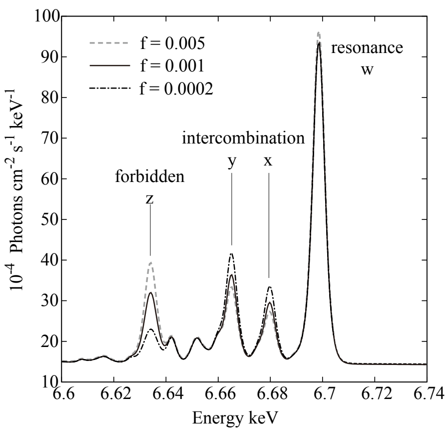


Figure 3 (left): Schematic view of PSR for different typical **f** values. As f increases, plasma density immediately below the shock decreases (as the volume of PSR expands).
Figure 4 (right): Spectral model of 0.79-Msun MCV with three different f values.

Simulation of V1223 Sgr for 100-ks SXS observation

Figure 5 (right): Simulated spectra of V1223 Sgr. Each panel shows results for f=0.005, 0.001, and 0.0002 from top to bottom. Note the apparent change of intensity of the z (forbidden) line.
Figure 6 (bottom): R=z/(x+y) ratio calculated from intensities derived from Gaussian fits to the simulated spectra.