Suzaku observation of the intermediate polar V1223 Sagittarii

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Abstract

We report on analysis of the intermediate polar V1223 Sagittarii observed with the *suzaku* satellite. Owing to good energy resolution of the XIS and high sensitivity of the HXD above 10 keV, we determined plasma parameters with unprecedented accuracy, taking into account a reflection component from the white dwarf. Finally we estimated the mass and the radius of the WD in V1223 Sgr at $0.76^{+0.08}_{-0.07} M_\odot$ and 7.3±0.06 $\times 10^8$ cm respectively with the maximum temperature.

Key words: cataclysmic variables(CV), intermediate polars(IPs), white dwarf(WD), V1223 Sagittarii

1. Introduction

An intermediate polars is a subclass of magnetic cataclysmic variables (mCV) binaries composed of a Roche Lobe-filling low-mass main-sequence star or a red giant and a magnetized white dwarf (WD) whose magnetic field strength is in the range 0.1-230MG. Matter spilled over the Roche Lobe is funneled into so-called accretion column by the magnetic field of the WD and accretes preferentially onto magnetic poles almost at free-fall velocity. Since the flow becomes highly supersonic as it approaches the WD surface, a strong steady shock occurs close to WD surface, and the accreting matter turns into hot plasma with $T \sim 10^8$ K at the shock front that radiates hard X-rays. Hence the temperature of the plasma reflects the depth of gravitational potential of the WD and can be written as

$$kT = \frac{3}{8}\frac{GM_{\rm WD}}{\rm R}\mu m_{\rm H} = 16\left(\frac{M_{\rm WD}}{0.5M_\odot}\right)\left(\frac{R}{10^9{\rm cm}}\right)^{-1}{\rm keV} \quad (1)$$

(Aizu 1973), where $M_{\rm WD}$ and $R_{\rm WD}$ are the mass and the radius of the WD, μ is the mean molecular weight, whose value is 0.615 for solar-abundance plasma, and $m_{\rm H}$ is the mass of hydrogen atom. Below the shock front, the plasma is cooled by optically thin thermal plasma emission in the hard X-ray band.

Since the shocked plasma is formed close to the WD surface, its reflection component from the WD surface also emerges mainly above 10 keV. Note that, therefore we can't obtain the correct temperature of the plasma unless estimate exactly the reflection component. With the aid of the mass-radius relation of the WD obtained by Nauenberg (1972)

$$R_{\rm WD} = 0.78\times 10^9\left[\left(\frac{1.44M_\odot}{M_{\rm WD}}\right)^{2/3} - \left(\frac{M_{\rm WD}}{1.44M_\odot}\right)^{2/3}\right]^{1/2}{\rm cm}. \quad (2)$$

Therefore, we can evaluate the mass and the radius of the WD separately from equations (1) and (2) by measuring the shock temperature.

V1223 Sagittarii is one of the most famous IPs, in which a WD rotating at a period of 745.5 sec (Osborne et al. 1985) and a secondary star revolve at an orbital period of 3.36 hr (Jablonski & Steiner 1988). The mass of the WD in V1223 Sgr was estimated, we summarized these results in table 1.

Table 1. Mass of the WD in the V1223 Sgr estimated in past.

Satellite	$M_{\rm WD}(M_\odot)$
HST	$0.93 \pm 0.12^\dagger$
RXTE & *INTEGRAL*	$0.71 \pm 0.03^\ddagger$
RXTE	$0.95 \pm 0.05^\S$
XMM-NEWTON	$1.046^{+0.049}_{-0.012}\|$
Swift	$0.65 \pm 0.04^\sharp$

† K.Beuermann et al. 2004
‡ J.Revnivtsev et al. 2004
§ Suleimanov et al. 2005
‖ Evans & Hellier 2007
♯ Brunschweiger et al. 2009

2. Observation

We observed V1223 Sgr with *suzaku* satellite (OBSID 402002010) from 11:31:40 13th Apr. 2007 to 22:36:12

14th and achieved net exposures of about 60ks and 46ks with the XIS (Koyama et al. 2007) and the HXD (Takahashi et al. 2007), respectively. The observation was performed at the HXD nominal position, in order to collect more photons over 10 keV and estimate exactly reflection component which stands out in the energy band.

3. Analyses and Results

The X-ray spectra of IPs are composed of the multi-temperature optically thin thermal plasma from post shock matter in the accretion column (Hōshi 1973, Aizu 1973), its reflection from the WD and the fluorescent iron emission at 6.4 keV. The spectra of the thermal plasma component can described by cooling flow model (named `cevmkl` in XSPEC) adopted a power-law type differential emission measure (DEM) as

$$d(EM) \propto \left(\frac{T}{T_{\rm max}}\right)^{\alpha} d(\log T) \propto \left(\frac{T}{T_{\rm max}}\right)^{\alpha-1} dT \quad (3)$$

where $T_{\rm max}$ is the maximum temperature of the plasma. On the other hand, we adopt the model `reflect` in xspec which is a convolution type model representing reflectivity of neutral material. can be described by the reflect of neutral material model named `reflect` (Magdziarz & Zdziarski 1995).

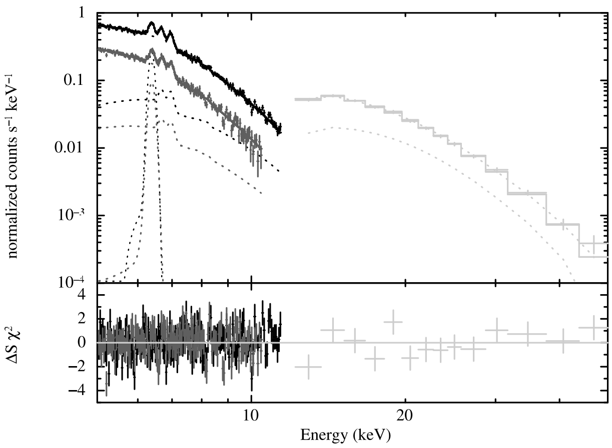

Fig. 1. Result of simultaneous fit of the CEVMKL plus reflection model to the 5-50keV band with the parameters listed in the table 2. The black ,red and green crosses show the FI-CCD (XIS0, 3), the BI-CCD (XIS1) and the HXD, respectively, from which the NXB and CXB have been subtracted.

In figure 1, we show the result of the fit to an averaged spectrum of V1223 Sgr by *suzaku*. In mCVs, the X-rays generally undergo multicolumn absorption. In order to avoid the complexity associated with the absorption, we fit the model to the spectra in the 5-50 keV band in which the absorption can be approximated by a single column density. We fixed an angle between the normal of the reflection surface and the line of sight at 24 deg (Beuermann et al. 2004), which is the inclination of the white dwarf.

Table 2. Best-fit parameters. A simultaneous fit of the cevmkl plus reflection model to *suzaku* spectrum.

Parameter	Value
$N_{\rm H}$	$8.87^{+1.8}_{-1.7} \times 10^{22}{\rm cm}^{-2}$
${\rm T_{Max}}^{*}$	$33.5^{+7.1}_{-5.4}$ keV
$\alpha^{\dagger}$	$0.58^{+0.20}_{-0.15}$
$\Omega/(2\pi)^{\ddagger}$	$0.95^{+0.34}_{-0.27}$
$i^{\S}$	24deg (fixed)
${\rm Z_O}^{\parallel}$	$1.07^{+0.71}_{-0.38}$
${\rm Z_{Fe}}^{\parallel}$	$0.29^{+0.03}_{-0.02}$
χ^2(d.o.f.)	350.78(313)

*Maximum temperature of the optically thin thermal plasma.
†Power of DEM as $d(EM) \propto (T/T_{\rm max})^{\alpha-1}dT$.
‡Solid angle of the reflector viewed from the plasma.
§Angle between the reflection surface and the line of sight.
$^{\parallel}$Solar abundances by Anders and Grevesse (1989) is adopted.

We summarized the best-fit parameters in table 2. DEM are consistent with 0.5. The solid angle of the reflector ($omega/2pi$) viewed from the plasma is consistent to 1 which indicates the shock height is negligibly smaller than the radius of the WD. These results are consistent with theoretically expected consistent with theoretically expected the accretion column in IPs. We found $T_{\rm max}$ to be $33.5^{+7.1}_{-5.4}$ keV. According to eq. (1) and (2) we estimated the mass and the radius of the WD in V1223 Sgr at $0.76^{+0.08}_{-0.07}M_{\odot}$ and 7.3±0.06 × × 10^8 cm respectively. with unprecedented accuracy, owing to accurate evaluation of the reflection component with *suzaku*.

4. Reference

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