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Suzaku observations of Fe Kα line in some Magnetic Cataclysmic Variables

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HIGHLIGHTS

- We resolved the 6.4 keV, 6.7 keV and 7.0 keV lines in 19 mCVS.
- The 6.7 keV and 7.0 keV lines are created by collisional excitation.
- The 6.4 keV line is formed by irradiation of the neutral iron by a hard X-ray source.
- Absorption induced fluorescence is dominant in 14 mCVs.
- Reflection of hard X-rays from the white dwarf surfaces were detected in 5 mCVs.

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ABSTRACT

We resolved the 6.4 keV, 6.7 keV and 7.0 keV Fe Kα lines in 19 Magnetic Cataclysmic Variables (mCVs) observed with the Suzaku satellite. The 6.7 keV and 7.0 keV emission lines are typically created by collisional excitation in the vicinity of the white dwarf arising from the shock front. The 6.4 keV iron emission line in contrast is formed in equilibrium by irradiation of the neutral (or low ionized) iron by a hard X-ray source, as a collisional origin would lead to rapid ionization. We study the emission of these lines in the 19 mCVs and found that the 6.4 keV line emission is likely created by a combination of reflection of hard X-rays from the white dwarf surfaces and absorption-induced fluorescence. Specifically, while absorption-induced fluorescence is dominant in 14 mCVs, there are significant hints that the 6.4 keV line emission arise from the reflection of hard X-rays from the white dwarf surfaces in 5 mCVs. This reflection suggests there could be relevant information about the geometry of the WD in the system encoded in the Fe Kα line.

1. Introduction

Magnetic Cataclysmic Variables (mCVs) are interacting binaries formed by a magnetic white dwarf and a low-mass main sequence star. Matter flowing from the Roche Lobe filled main-sequence star is magnetically funneled onto the magnetic poles of the white dwarf (WD), resulting in accretion of matter at the poles. The accretion flow is usually highly supersonic as it approaches the white dwarf producing a strong steady shock close to the white dwarf surface, hence turning the accreting matter into hot plasma with $T \sim 10^8$ K at the shock front, which radiates hard X-rays (Ezuka and Ishida, 1999). There are two types of mCVs, the polars (AM Herculis type) which are characterized by strong magnetic field and intermediate polars (DQ Herculis systems) with a weaker magnetic field. The production of hard X-ray in mCVs is by the magnetically channelled accretion column, whose impact on the WD poles is followed by thermal bremsstrahlung cooling by free electrons with kT of the order of 10 keV and above (Cropper, 1990; Warner, 2003). The emission is assumed to be through the post-shock region, which is below the shock front created from the impacting accretion column. The observed soft X-rays from mCVs are created from the absorption and reprocessing of the hard X-rays in the plasma close to the surface of the WD.

The mCVs have been observed to emit Fe Kα lines, which can be resolved into fluorescence (6.4 keV) and He-like (6.7 keV) and H-like (7.0 keV) lines (Ezuka and Ishida, 1999; Mukai et al., 2003; Hellier and Mukai, 2004; Yuasa et al., 2010). Ezuka and Ishida (1999) also suggested that the reflection from the white dwarf surface makes a significant contribution to the observed Fe Kα fluorescence line. However, the origin of these lines in mCVs, in particular

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the 6.4 keV emission line is yet to be completely addressed. The 6.4 keV iron emission line is typically created by irradiation of the neutral (or low ionized) material (iron) by a hard X-ray source. Nandra et al. (1997) and references therein discussed in details previous observations of the Fe Kα line in the Seyfert galaxies, AGN, quasars and other galaxies.

The Fe Kα line of the mCVs had been observed to be similar and contributes to Fe Kα line of the Galactic X-ray emission (GRXE, Bleach et al., 1972; Worrall et al., 1982; Iwan et al., 1982; Koyama et al., 1996; Kaneda et al., 1997; Ebisawa et al., 2001; Tanaka, 2002; Revnivtsev and Sazonov, 2007; Revnivtsev et al., 2009) (see Eze et al., 2012). This makes the study of the Fe Kα line of the mCVs significant beyond simply providing a better understanding of these systems themselves.

Previous work done on mCVs was mainly on estimating the mass of the white dwarf companion using the X-ray spectra of mCVs, especially Intermediate Polars (IP), (see e.g. Rothschild et al., 1981; Ishida, 1991; Cropper et al., 1999; Ezuka and Ishida, 1999; Ramsay, 2000; Suleimanov et al., 2005; Brunschweiger et al., 2009; Yuasa et al., 2010). This is based on the dependence of the temperature of the postshock region on the mass of the WD. The mass of white dwarf is one of the most fundamental parameters in cataclysmic variables (CVs), which is used to determine the accretion flow, the dynamics of the orbital motion and in characterizing the emission from the accretion region (see Brunschweiger et al., 2009).

There is a claim that if the fluorescent line is mainly due to reflection, then the strength of this line should depend on the inclination angle of the system. It will follow that for a system having a large inclination angle, the fluorescent line is expected to be weak because it prevents the observation of any reflection from the inner edge of the disk (Ramsay et al., 2001). In the study to justify this claim, by Rana et al. (2006), it was shown that there is no clear cut correlation between the inclination angles and the EWs of the fluorescent lines. However, only very few sample (seven) sources were used in the study. Hellier and Mukai (2004) were of the view that the fluorescent line from the GK Per arises from preshock material, falling at near the white dwarf escape velocity and are photon Compton-down scattered by up to two Compton wavelengths. They also note that the fluorescent line of GK Per has an equivalent width of more than a factor of 2 greater than those seen in the other systems and is directly related to the size of the scattering targets, the white dwarf surface.

We present here the Suzaku observations of Fe Kα line in 19 mCVs and discuss the possible origin of the components of this line. We discuss data selection and analysis in Section 2, results in 3, and 4 is our discussion and conclusions.

2. Data selection/analysis

The mCVs were selected and analyzed following the method used by Eze (2014a). A total of 19 sources were thus selected

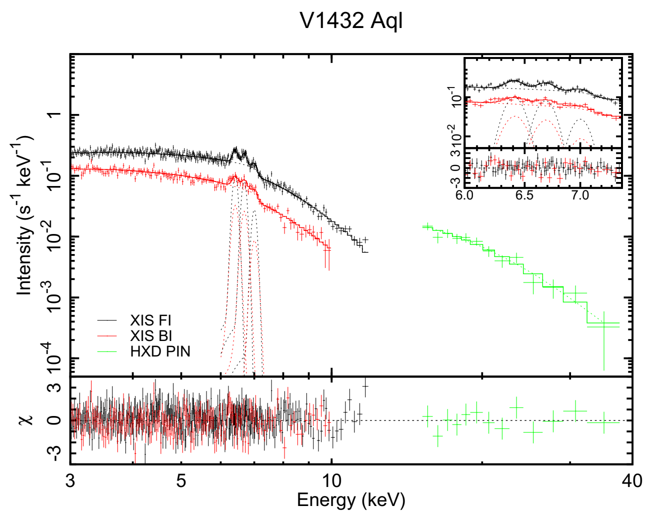

Fig. 1. Spectrum of the polar. In the upper panel, the data and the best-fit model are shown by crosses and solid lines, respectively. Each spectral component is represented by dotted lines. In the lower panel, the ratio of the data to the best-fit model is shown by crosses. The inset in the upper panel is an enlarged view for the Fe Kα complex lines.

Table 1
The reduced χ^2 (R χ^2), full χ^2 (F χ^2) and degree of freedom (dof) for the absorbed bremsstrahlung and an absorbed bremsstrahlung plus XSPEC reflect model, F-test probability and reflection normalization (for details, see Eze, 2014a).

Source name	BM Rχ^2/Fχ^2/dof	BRM R χ^2/Fχ^2/dof	FP	RN
Polars				
V1432 Aql	1.04/486.5/469	1.02/477.5/468	0.003	–
Intermediate polars				
NY Lup	1.06/1239.2/1175	1.04/1218.4/1174	8.31×10^{-6}	0.04
RX J2133.7+5107	1.12/850.9/759	1.05/797.4/758	2.32×10^{-12}	0.10
EX Hya	1.45/3338.2/2300	1.45/3336.2/2296	0.85	–
V1223 Sgr	1.15/2256.6/1963	1.08/2117.9/1962	8.10×10^{-29}	0.28
MU Cam	1.08/295.7/275	1.00/273.2/274	3.28×10^{-6}	0.04
V2400 Oph	0.97/1963.9/2019	0.95/1909.9/2018	6.38×10^{-14}	0.13
YY Dra	1.04/450.3/433	1.04/444.8/432	0.02	–
TV Col	1.15/836.5/727	1.14/829.5/726	0.01	–
V709 Cas	0.97/629.1/649	0.97/626.5/648	0.10	–
IGR J17303−0601	1.02/342.9/338	0.96/321.4/335	7.44×10^{-5}	0.04
IGR J17195−4100	1.05/598.4/568	1.04/585.8/566	0.002	–
BG CMi	0.93/417.1/449	0.93/416.9/448	0.64	–
PQ Gem	1.08/516.3/480	1.08/516.1/479	0.67	–
TX Col	1.18/406.3/345	1.11/381.7/344	3.62×10^{-6}	0.04
FO Aqr	1.22/918.2/751	0.95/709.1/750	4.98×10^{-44}	0.54
AO Psc	1.23/983.4/803	1.10/884.3/802	2.79×10^{-20}	0.30
IGR J00234+6141	1.00/296.9/298	0.99/295.0/297	0.17	–
XY Ari	1.01/790.3/786	1.00/781.3/783	0.30	–

Parameters are the absorbed bremsstrahlung model (BM), an absorbed bremsstrahlung plus XSPEC reflect model (BRM), F-test probability of null result for the BRM (FP) and reflection normalization (RN).