Time-variable Fe K emission lines from accreting white dwarf binaries

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Accretion of gas from a normal star in a binary system onto a compact star liberates a vast amount of gravitational potential energy. This often results in heating of the gas and high-energy electromagnetic radiation. By observing the emission, properties of the compact star can be studied because the emission occurs from regions close to the star.

We have been studying the mass-accreting white dwarf system that is considered to be an important candidate of type Ia supernovae. In particular, our focus has been on measuring the mass of a white dwarf in a binary system by modeling of X-ray spectra of heated gas. For details of the modeling and initial results, see our previous publication (Yuasa et al. 2010).

To further improve the accuracy of the mass measurement, it is crucial to understand the geometry and profiles of density, temperature, and bulk velocity of the X-ray emitting plasma. In April 2014, we were awarded a 180k-second observation of the magnetic accreting white dwarf V1223 Sgr by using the Japanese Suzaku X-ray telescope. The aim of the observation is to assess the geometry assumed in the model calculation based on precise measurement of time variation of Doppler energy shifts and intensities of the Fe atomic lines after the previous marginal report (Hayashi et al. 2011).

After the standard data selection, we obtained high-photon-statistics spectrum as presented in Fig. 1. To disentangle Doppler energy shifts of lines caused by in-falling bulk velocity of the X-ray emitting gas and other effects such as white dwarf spin and subsequent line-of-sight viewing angle variation, we performed phase resolved spectral fitting by splitting the total observation time into four phase bins with a period of 754 s (corresponding to the spin period of the white dwarf in V1223 Sgr). No statistically significant time variation was observed for the centroid energies of the lines, in contrast to the previous report (Hayashi et al. 2011), due to long-term degradation of the energy resolution of the instrument. On the other hand, as shown in Fig. 2, the line intensities varied over spin phases although statistical fitting errors are still large due to phase resolving (resulting shorter integration time per phase bin).

These time variations can be interpreted to be caused by the resonance-trapping beaming effect (Terada et al. 2001) where the optical thickness of the X-ray emitting hot plasma becomes greater than unity only for resonance line photons and trapped within the plasma while continuum photons exit the plasma region almost freely (i.e. the plasma is optically thin for continuum photons). In this scheme, the optical thickness is sensitive to the plasma density, the geometrical shape, and the white dwarf mass. Therefore, we are continuing to perform detailed analyses and comparison with Monte Carlo radiation transfer simulation results to utilize this resonance-beaming feature as an alternative constraint for measuring the white dwarf mass and related physical quantities of the binary system such as the mass accretion rate.

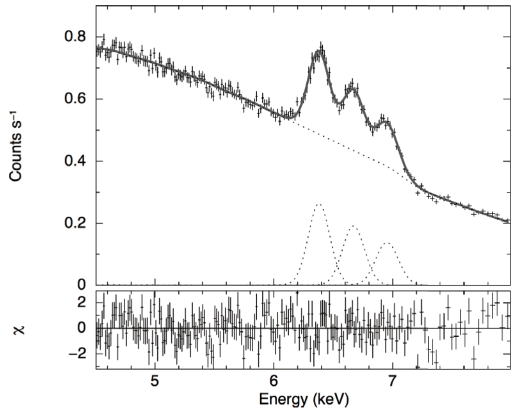

Fig. 1. Time-average X-ray CCD spectrum of V1223 Sgr. Thermal bremsstrahlung continuum and three atomic emission lines from neutral Fe (6.4 keV) and highly ionized Fe ions (6.7 and 6.9 keV).

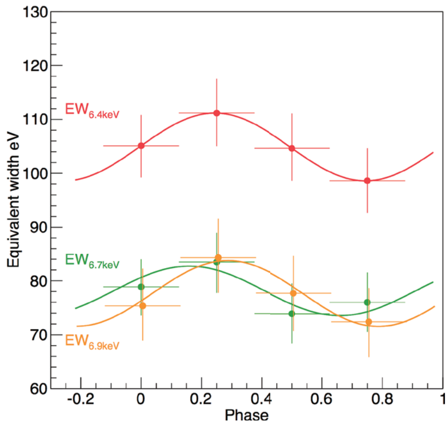

Fig. 2. Crosses are intensities of the three Fe emission lines over white dwarf spin phases (ordinate presents the equivalent width, which is a measure of the line intensity). Solid curves are the best-fit sinusoidal functions.

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References

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