Multi-wavelength Observations of the Black Widow Pulsar 2FGL J2339.6–0532 with OISTER and Suzaku

YATSU, Y. (Tokyo Institute of Technology)
KATAOKA, J., TAKAHASHI, Y. (Waseda University)
TACHIBANA, Y., KAWAI, N. (Tokyo Institute of Technology)
SHIBATA, S. (Yamagata University)
PIKE, S. (Brown University)
YOSHII, T., ARIMOTO, M., SAITO, Y. (Tokyo Institute of Technology)
NAKAMORI, T. (Yamagata University)
SEKIGUCHI, K. (NAOJ)
on behalf of OISTER team

A millisecond pulsar (MSP) is believed to evolve from a dead pulsar in a binary system via mass accretion from a companion star that has spun up the pulsar for billions of years. Indeed, most MSPs are discovered in binary systems; however, isolated MSPs also exist. The missing link between the isolated MSPs and binary MSPs is black widow pulsars in which a sufficiently spun up pulsar is evaporating its companion with its powerful pulsar wind. In this study we focus on the newly found black widow pulsar 2 FGL J2339.6$-$0532 discovered by the Fermi gamma-ray observatory to clarify the intermediate stage between the accretion-driven phase and the rotation-powered phase utilizing optical and X-ray telescopes.

In optical we utilized the *Optical and Infrared Synergetic Telescopes for Education and Research: OISTER* for covering wide wave band from K_S to B-band and the entire orbital motion. The target was observed from 22 Sep to Oct 7 2011 with 14 telescopes. The resultant light curves folded with the orbital period of 4.63 hr are shown in Fig. 1—Left. Fig. 1—Right shows the SED at various orbital phases, indicating that the surface temperature varies from 3200 K to 8000 K coincident with the orbital motion. Assuming a simple geometry, we constrained the range of the inclination angle of the binary system to $50° < i < 59°$, which enables us to discuss the interaction between the pulsar wind and the companion in detail.

In X-rays the target was observed with the Suzaku X-ray observatory for 96 ks. The obtained X-ray spectrum was well fitted with a two component model function consists of a black body with a temperature of T_{BB} 0.15 ± 0.06 keV and a power law function with a photon index of $\Gamma = 1.14^{+0.14}_{-0.15}$. Fig. 2 shows X-ray light curves as functions of orbital phase for 3 energy bands. In low energy band below 1 keV, the intensity of the target seems uniform. Taking into account the size of black body emitter of $R \sim 0.28$ km, the soft and steady component can be originated in the surface of pulsar. While in the Hard X-rays, the intensity shows periodic variation synchronized with the optical light curves, indicating that the hard X-rays are from the shocked pulsar wind covering the companion surface rather than the pulsar itself. Assuming a thin emitting region covering the companion, we constrained the magnetization parameter to $\sigma < 0.1$. This result means that the pulsar wind from the central MSP is already in the particle-dominant stage at 10^{11} cm from the pulsar. This may critically constrain the acceleration mechanism of the pulsar wind.

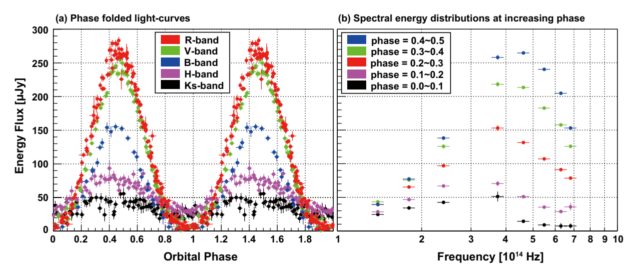

Figure 1: Left—Multi-color light curves from K_S to B-band. Right—SEDs for various orbital phases.

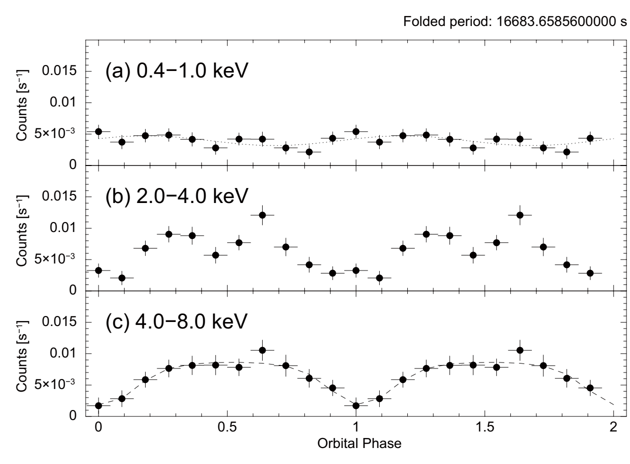

Figure 2: X-ray light curves at various energy band.

Reference

[1] Yatsu, Y., Kataoka, J., Takahashi, Y., et al.: 2015, *ApJ*, **802**, 84.