（別紙様式２）

フォトンサイエンス国際卓越大学院プログラム（XPS）

光科学特別実習　報告書

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X-ray emission mechanism of high mass X-ray binaries (HMXBs)

Neutron stars are a class of compact objects with extreme physics such as strong gravity and strong magnetic fields. They are ideal and unique laboratories in the universe to demonstrate physical processes under such extreme environments. X-ray astronomy has played an important role in unveiling high energy physics surrounding neutron stars, since its energy band covers thermal and non-thermal emission of neutron stars (about 0.1–100 keV). Among many classes of neutron stars, HMXBs are a subclass which consists of a neutron star and high mass star. They are characterized by accretion flow which comes from high mass star and falls onto neutron star surface. By observing emission from the accretion flow, one can investigate physical processes taking place under strong magnetic fields.

Due to the strong magnetic fields in HMXBs (~10^{12} G), the accreting matters are prevented from directly falling onto the neutron star surface by magnetic pressure. Alternatively, they move along with the magnetic field lines, forming the “accretion columns” on the magnetic poles of the neutron star (Becker & Wolff, 2007, Fig. 1). The accretion column is an optically thick region in which seed photons from the neutron star surface are fueled by inverse Compton scattering. Therefore, the X-ray spectroscopy directly reflects physical processes taking place around the neutron star.

The spectral and temporal properties of HMXBs in the X-ray band are very complicated since they are highly time-variable. The time fluctuation is originated from various factors such as self-rotation of the neutron star, binary moves in orbit, and non-uniform plasma surrounding the system. However, the interpretation of spectral variation is still phenomenological, far from understanding in terms of physical processes. The aim of this work is to interpret the spectral fluctuation based on physical processes by applying time-resolved spectroscopy.

Phase resolved spectroscopy of Centaurus X-3

In this work, we focused on Centaurus X-3, which is one of the brightest HMXBs in our galaxy. We utilized observation data of NuSTAR, which is an X-ray satellite with good timing resolution (2 μs) and wide coverage of energy band (3–78 keV). The source is under periodic motion with an orbital period of 2.1 days and self-spin period of 4.8 s. We divided the observation data with respect to both its orbital phase and spin phase. The orbital-phase resolved spectroscopy showed that the low energy photons are responsible for the spectral fluctuation, which suggests that the spectral variability is due to the different degrees of absorption by surrounding photo-ionized plasma. The spin-phase resolved spectroscopy, on the other hand, showed that the high energy photons above 10 keV fluctuate a lot. This is due to the difference of effectiveness of inverse Compton scattering inside the accretion column. The cyclotron resonance scattering feature also varies along the spin phase, which also supports the different degree of inverse Compton scattering.

Presentation in IAU Symposium 363

I attended IAU Symposium 363 via online and presented our results of time-resolved spectral analyses. I had a poster presentation and showed my poster in Fig. 2. In addition to the poster session, we also had chance of short oral presentation, in which I was asked a few questions about my spectral analyses. The conference itself was held for 5 days and a lot of talks including theoretical and observational studies were available. Most parts of the presentations were about magnetars, which are neutron stars with the strongest magnetic fields in the universe. The presentations were interesting and useful in that I can extend those stories into the HMXB studies. I also learned a lot about the observation and simulation of gravitational wave, which is completely different field from my major. After all, the attendance to IAU Symposium 363 was a valuable experience for me as I learned many things of other fields and they could be further taken into my future research. I would like to thank everyone to give me a chance to present my research and learn from other studies.

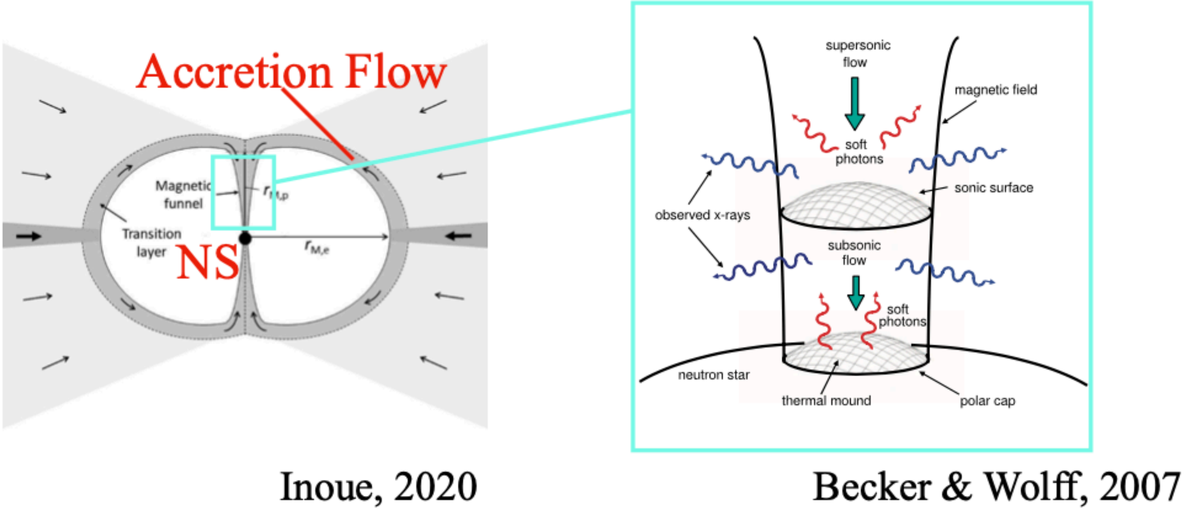

Fig. 1. Accretion flow of a neutron star (left) and an accretion column on the magnetic pole (right).

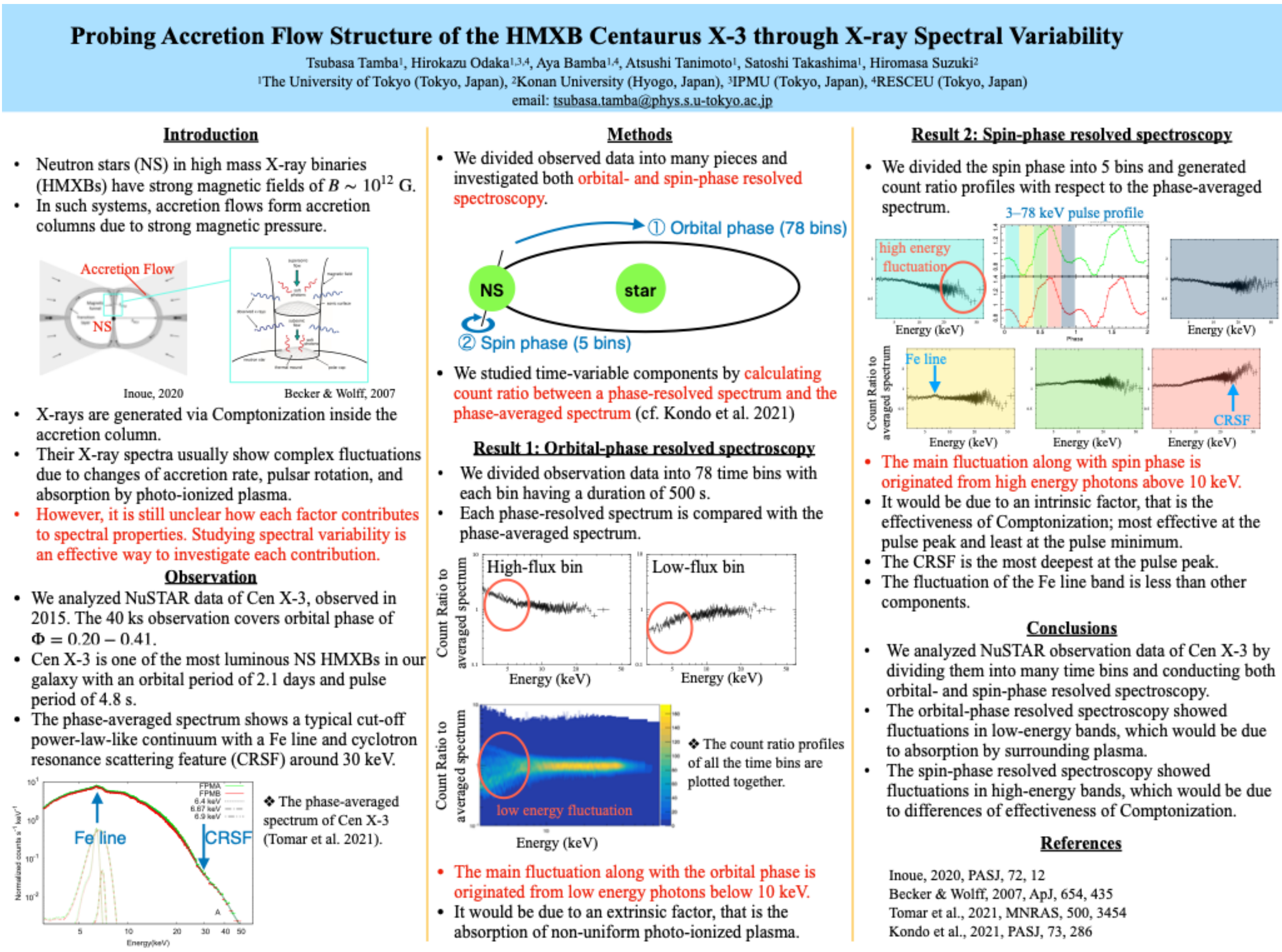

Fig. 2. Poster presented in IAU Symposium 363.