論文題目要旨

学位申請者：Marina Yoshimoto

論文題目：Observational Studies of Ultraluminous X-ray Sources in Supercritical Accretion

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Ultraluminous X-ray Sources (ULXs) are point-like X-ray sources in galactic off-nuclear regions with a luminosity of $> 10^{39}\,\mathrm{erg\,s^{-1}}$, exceeding the Eddington luminosity of $10\,M_{\odot}$ black holes (BHs). ULXs are the most favorable nearby laboratories for studying the formation of supermassive BHs because they are interpreted as stellar-mass compact objects in supercritical accretion or intermediate-mass BHs (IMBHs) in sub-Eddington accretion. The objectives of our studies are to 1) Determine the nature of a ULX in an environment with the lowest metallicity among ULXs, similar to conditions in the early universe, 2) Reveal long-term variability of radiation in supercritical accretion, and 3) Facilitate observations of faint X-ray transients from such as ULXs and other sources.

We present an analysis of X-ray observations of the ULX in I Zw 18 based on archival data taken with Chandra, XMM-Newton, and Suzaku from 2000 to 2014 and new XMM-Newton data we observed in 2024. This ULX is considered to be an IMBH candidate because it is in the lowest-metallicity environment among ULXs, where the formation of heavy BHs is facilitated. However, actual study of the ULX based on observations spanning for a long period has been too limited to determine its nature. In this study, we confirm that the spectra changed from hard to soft between 2000 and 2002. Furthermore, we find that the spectra were in a hard state in 2024, which indicates that at least one soft-to-hard transition had occurred by 2024. We derive a positive correlation of $L \propto T_{\mathrm{in}}^{2.1\pm0.4}$ between the bolometric luminosity L and inner-disk temperature T_{in} on the basis of the multicolor disk blackbody model, where we exclude the data in the hard state. The nominal relation for the standard disk is rejected at a significance level of 1.5%. These results suggest that the ULX was in the slim-disk state during these observations. Moreover, we find a radial dependence of the disk temperature of $T(r) \propto r^{-p}$ with $p < 0.75$, which also supports the hypothesis that the ULX has a slim disk. Therefore, the I Zw 18 ULX is most likely to be powered by not an IMBH in sub-Eddington accretion but a stellar-mass compact object in supercritical accretion.

We present the long-term spectral and timing evolution of the ULX pulsar NGC 7793 P13 from 2011 to 2023 based on archival data from XMM-Newton,

Chandra, NuSTAR, and NICER, including unpublished data after 2020. This dataset enables us to investigate the observational properties across a long modulation of $\sim 10\,\mathrm{yr}$. Although previous studies suggested an increasing trend in flux in 2020, we find that the pulsar decreased its flux to $2.6^{+0.6}_{-0.7} \times 10^{-14}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$ in 2021, and re-brightened to $6.4^{+1.3}_{-1.1} \times 10^{-12}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$ by 2023. The pulsation reappeared in the re-brightening epoch after the pulsation nulling in 2020. Moreover, in the subsequent two years, the spin-up rate was twice as large as that before 2020. However, the pulsed fraction was roughly as expected from an anti-correlation with the flux confirmed before 2020. Furthermore, we perform systematic phase-resolved spectroscopy to investigate the spectral evolution. The result shows that, during the flux-decaying epoch, spectral hardness in the off-pulse phase softened while that in its on-pulse phase remained almost unchanged. This could result from a change in the size of the accretion column as the flux varies.

We present development and implement the system of searching for transients and reporting them through the Astronomer's Telegram, utilizing XRISM/Xtend. This project is called "XRISM/Xtend Transient Search (XTS)". XRISM/Xtend has one of the largest field-of-view ($38' \times 38'$) among pointing observatories and high sensitivity. Therefore, it is expected to detect faint X-ray transients. We reported 17 transients through XTS in the performance verification phase by September 2024. The transients are flares on stars, a supergiant fast X-ray transient on a high-mass X-ray binary, and a supernova by follow-up observation, with fluxes of $> 10^{-13}\,\mathrm{erg\,cm^{2}\,s^{-1}}$.