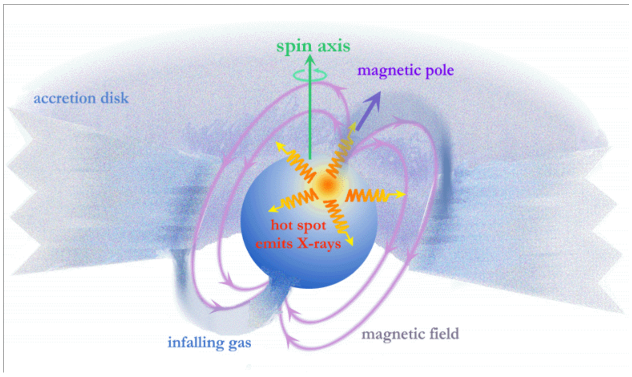
Spectral and Temporal studies of BeXRB outbursts



A unique laboratory for the study of radiation processes in extreme accretion are X-ray pulsars. These are found typically in high-mass X-ray binaries (HMXBs), while the brightest and most variable ones are those where the donor is a Be star (i.e. BeXRBs). Their environment combines some of the strongest magnetic fields (> 10^{12} G) and effects of strong gravity, while also gives us the opportunity to gain insight onto the Neutron Stars (NS) equation of state. Bright outbursts of BeXRBs have also helped us understand the most bright binary systems, the so called Ultra-luminous X-ray sources. In this Meteor project we will work with observational data of bright outbursts of BeXRBs (e.g. SMC X-2, SMC X-3) and constrain some of the fundamental properties of the binary via spectral and temporal studies. (Illustration Credit: CXC/S. Lee)

Theory

by GEORGIOS VASILOPOULOS & MARIA PETROPOULOU

X-ray pulsars (XRPs) are systems composed of a highly magnetized neutron star (NS) that accretes from a donor star (see review [1]). Typically a Keplerian accretion disk may be formed around the NS, however due to the high magnetic field of the NS the disk is truncated at ∼100 times the NS radius, where the magnetic pressure is balanced by pressure from accreting gas. X-rays are produced as the dynamic energy of the infalling material is converted to radiation. Particles travel (almost free falling) towards the NS magnetic poles following the magnetic lines, until near the NS surface their fall is halted by radiation pressure. Depending on parameters like the NS magnetic field and mass accretion rate, a shock might form just above (a few meters or even Km high) the accreting poles, and almost all radiation we observe from X-ray pulsars come from this area that we commonly call accretion column. Since the bulk of the observed X-ray radiation is produced near or on the NS surface, we tend to observe X-ray pulsations as the NS rotates (due to misalignment of rotation and magnetic axis). However, the story goes on; the disk itself can produce soft X-rays, or reprocess the pulsating emission. This is confirmed by the presence of a a non pulsating soft component in the X-ray spectrum of many XRPs.

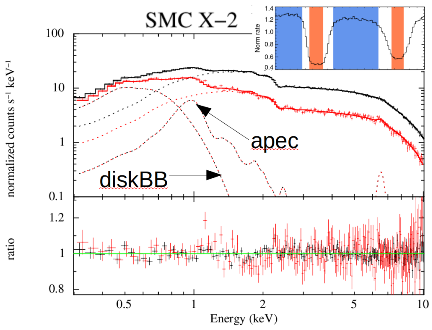


Fig. 1: Spectral fit to spin-phase resolved data of SMC X-2.

Applications

by GEORGIOS VASILOPOULOS

In order to better understand the properties of the BeXRBs we need to perform detailed spectral and temporal analysis of data collected during outbursts where the sources are bright (e.g. [2],[3],[4]). In Fig. 1 we see the spin period phase-resolved X-ray spectrum of SMC X-2 obtained with XMM-Newton at a super-Eddington outburst, i.e. $L_{\rm X} = 7 \times 10^{38}\ erg\,s^{-1}$. On-pulse (blue) and off-pulse (orange) are shown in the inset. The pulsating component dominates the high-energy part of the spectra and may be fitted by a phenomenological model. At low energies we can identify non pulsating components that resemble an accretion disk and emission from hot plasma from material trapped within the magnetosphere.

For the Meteor project you will be given the opportunity to work on either archival data, or data from new outbursts that were obtained within 2023 from telescopes like XMM-Newton, NuSTAR, NICER and Swift.

References

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[2] Koliopanos, F. & Vasilopoulos, G. 2018 A%A, 614A, 23

[3] Vasilopoulos et al. 2020, MNRAS, 494, 5350

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