2022 PhD Project

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Student may register at any South African university

Multi-wavelength studies of jets and accretion in low mass X-ray binaries

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Low-mass X-ray binaries (LMXBs) are compact binary systems in which a neutron star or stellar-mass black hole accretes material from a low-mass stellar companion, via an accretion disc. In many LMXBs, the average accretion rate subjects the discs to a thermal-viscous instability, causing transient behaviour. Matter builds up in the disc until a sharp rise in viscosity triggers an outburst, temporarily increasing the luminosity and draining the disc of material, until it drops back into the quiescent, low-viscosity state. These outbursts are observed as X-ray transients, and typically lead to transient jets, detected in the radio band.

How jets (the collimated bipolar outflows commonly associated with accreting compact objects) form is an unsolved mystery. Their fundamental properties, such as bulk velocity and power, are still poorly constrained. This means that key aspects of the theoretical models of jet formation are essentially untested by observations.

Radio and X-ray data indicate that the mechanisms responsible for jet formation are the same not only in all stellar-mass black holes, but also in super-massive black holes. While accretion state transitions in AGN are too slow to be observable, state transitions in LMXBs occur over just days. The study of jets in the easily observed black hole LMXBs is therefore very important to the understanding of AGN jets. The ThunderKATs Large Survey Project on MeerKAT, with the help of data from e.g. the *Swift* X-ray telescope, is greatly increasing our sample of simultaneous radio and X-ray observations of LMXBs. This dataset has the potential to revolutionize our understanding of jet formation in black holes. MeerKAT is also able to extend the correlation between radio and X-ray flux of black hole LMXBs to the lower luminosities of neutron star systems. While the jets in neutron star LMXBs are very similar to those in black hole systems, there are also a few striking differences in their radio emission properties. Observations of neutron star systems may therefore give insight not only into the general properties of jets, but in particular into the role of a solid surface, or rotation of the compact object.

Project goals This project will involve multi-wavelength studies of accretion and outflows in LMXBs. The details of the research to be undertaken will be defined by the successful applicant, with guidance from the supervisor. It will likely include detailed follow-up of at least one new transient black hole LMXB, using MeerKAT, X-ray observatories such as *Swift* and *Chandra*, as well as SALT and the small SAAO telescopes. A second component may use ongoing MeerKAT monitoring observations of persistent neutron star LMXBs. The overall goal is to test the universality of jets and their properties. The student will work with me at SAAO, and with collaborators at UCT, Oxford, and Toulouse.

Skills Basic programming skills and demonstrated research ability are required. Experience in observational astrophysics, in particular radio interferometry, will be an advantage.

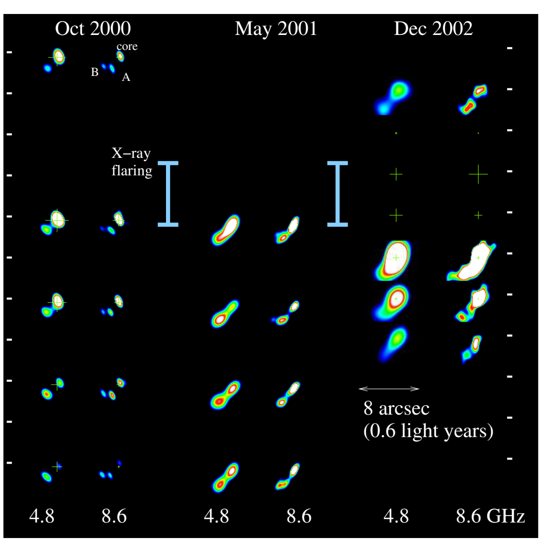

Figure 1. The ultra-relativistic jets from the neutron star system Cir X-1, imaged at 4.8 and 8.6 GHz. White tickmarks indicate time steps of one day, and the blue bar indicates the time of the X-ray flaring (near periastron passage). The brightening of the X-ray source indicates an increased rate of accretion onto the central neutron star. At this time, the entire length of the radio structure brightens, so that a projected apparent expansion velocity $\gtrsim 15\times$ the speed of light can be inferred, implying an ultra-relativistic flow aligned very closely with the line of sight. (From Fender et al. 2004b.)