X-shooter Science Verification Proposal

Observing the IR excess of Small Magellanic Cloud Be/X-ray Binary Systems

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Abstract:

The abundant numbers of Be/X-ray binaries in the Small Magellanic Cloud (SMC) represent an exciting opportunity to observe a homogeneous group of objects which have arisen as a direct result of tidal interactions between galaxies. In particular, we propose to study the broadband spectroscopic properties of a subsample of these systems with the main goal of separating out the contribution of the circumstellar disk flux from that of the B star. The geometric, radiative and dynamic properties of the circumstellar disks obtained from this study will allow a more detailed understanding of the effect of the neutron star companion on the circumstellar disk and, as such, will clarify our concepts of the accretion processes in these complex systems.

Scientific Case:

A Be star is an early type luminosity class III–V star, which has at some time shown emission in the Balmer lines. The Balmer emission, along with a significant infrared excess is believed to originate in the circumstellar material surrounding the Be star, probably in the form of an equatorial disk. The mechanisms leading to the formation of this disk are as yet undetermined, but the radiative forces, and the rapid rotation of Be stars appear to be important factors.

Be stars are pervasive in X-ray binaries, with 72% of all high mass X-ray binaries (HMXBs) harbouring Be donors (Liu et al. 2000). In the SMC the situation is even more extreme, with all but one of the HMXBs being Be/X-ray binaries. Despite their prevalence, a good understanding of the accretion process in these systems is still not forthcoming. Decades of detailed X-ray monitoring programs, of which our ongoing RXTE program (Galache et al. 2008; Laycock et al. 2005) is an example, have been extremely fruitful in both timing analysis and identification of new sources. Detailed optical coverage of the SMC has also been possible largely due to the OGLE project (Udalski, Kubiak and Szymanski, 1997), from which there are ~ 10 years of data for these sources; many of which show oscillations on the order of 0.5–1 magnitudes over periods of 100s of days. In most cases this periodic optical brightening is due to the perturbation of the circumstellar disk, an idea supported by X-ray outbursts roughly coinciding with epochs of optical maxima. However, although the link between optical and X-ray luminosity exists, we do not yet know the intricacies of the disk dynamics that underpins this correlation, or indeed the differences between individual systems that lead to the variation in X-ray activity.

The viscous disk model (Lee, Saio & Osaki, 1991) predicts that Be stars which occur in binaries have their circumstellar disks truncated by resonant torques from the orbiting neutron star (Okazaki & Negueruela, 2001). These changes in the donor star and its associated disk, coupled with the eccentricity of the neutron star orbit, are key factors in influencing the mass accretion rate onto the neutron star. Free-free emission in the circumstellar disk (Gehrz et al. 1974) means the disk is most luminous at infrared wavelengths and also shows a number of recombination lines across the red and infrared spectrum.

The aim of these observations is to fit the spectra of a sample of SMC Be/X-ray binaries with the stellar models (Kurucz, 1979) based on the spectral type of the companion star together with a component accounting for flux from the circumstellar disk. Current interferometric observations (Tycner et al. 2006) and simulations (Sigut & Jones, 2007) suggest the circumstellar disk to have a steep temperature gradient along its equatorial axis, and so we expect the excess flux to be modelled as a complex superposition of blackbody curves. Accurate measurement of the flux in these blackbody curves would allow the determination of a radial temperature profile of the disk.

In addition, the line emission from Hα, Hβ, Brγ and the Paschen lines, would allow us to explore the distribution of density in the disk through the violet to red line ratios in the various emission lines, and to measure the velocity in the disk through peak separation of double-peaked emission lines.

Our sample comprises 12 well known Be/X-ray binary systems in the Magellanic Clouds, chosen for their recurrent X-ray activity, periodic-like optical lightcurves, and the fact that the donor stars show double-peaked emission lines. This sample forms a preliminary study in using this broadband spectral technique to quantifying the characteristics of Be/X-ray binary circumstellar disks and compare these with the features predicted through simulations.

Calibration strategy:

All of these targets must be done under photometric conditions as it is important to flux calibrate the spectra. All of our targets are of reasonable brightness and so we require no particular constraints on lunar phase. A red and a blue standard star will be used during calibration.

Targets and number of visibility measurements

Target (SXPname)	**Other Name**	**RA**	**DEC**	**V** mag	**Mode** (slit/IFU)	**Remarks**
6.85	XTE J0103-728	01 01 24.0	-72 43 30.0	14.60	slit	High priority
8.80	RX J0051.8-7231	00 51 52.0	-72 31 52.0	14.87	slit	No lunar constraints
18.3	XTE J0055-727	00 49 11.4	-72 49 39.0	15.96	slit	High priority
46.6	XTE J0053-724	00 53 53.8	-72 26 35.0	14.7	slit	No lunar constraints
59.0	RX J0054.9-7226	00 54 57.4	-72 26 40.3	15.3	slit	No lunar constraints
82.4	XTE J0052-725	00 52 55.0	-72 33 00.0	15.0	slit	No lunar constraints
91.1	RX J0051.3-7216	00 50 55.0	-72 13 38.0	15.1	slit	No lunar constraints
140	XMMU J005605.2-722200	00 56 05.2	-72 22 00.0	15.9	slit	No lunar constraints
293	XTE J0051-727	00 58 12.64	-73 30 48.0	14.6	slit	No lunar constraints
327	XMMU J005252.1-721715	00 52 52.5	-72 17 14.9	16.5	slit	No lunar constraints
342	XMMU J005403.8-722632	00 54 03.8	-72 26 32.0	15.0	slit	No lunar constraints
756	RX J0049.7-7323	00 49 42.1	-73 23 14.1	14.6	slit	High priority
-	Blue Standard	hh mm ss	dd mm ss	-	slit	standard star
-	Red Standard	hh mm ss	dd mm ss	-	slit	standard star

Using a slit width of approximately 1" will give us the resolution to measure the emission lines described above.

Time Justification:

Using the X-Shooter exposure time calculator, we would require approximately 15 minute expsoures for each of our 12 targets to achieve a S/N better than 20 at all wavelengths. This should be done in two 450s exposures at two positions in the slit to accurately background subtract the NIR spectra. In total, we would require $\sim$1500s average time per target. The 2 standard stars will be significantly less than this. Therefore, this program asks for approximately 5 hours of telescope time.

References

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