X-shooter Science Verification Proposal

Dissecting an eclipsing X-ray binary in a single shot

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Abstract:

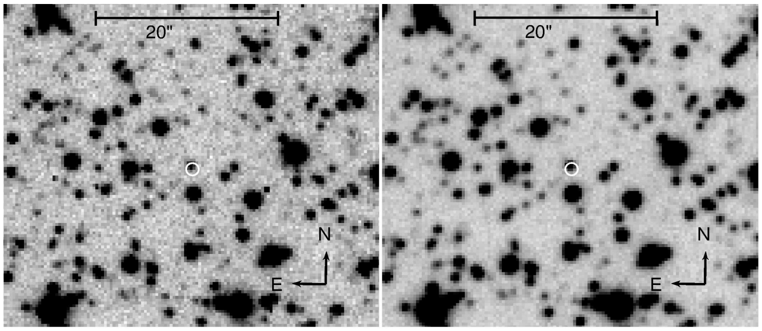
We propose to use X-shooter to acquire spectra of the shortest period (3.28 hours) eclipsing X-ray binary, XTE J1710-281. This source displays a wide variety of variability: sharp eclipses, intensity dips and type I X-ray bursts. We recently discovered the fairly bright optical counterpart of this enigmatic source, making it an ideal target for X-shooter: the continuum (UV, optical and nIR) will provide an accurate view of the disk, jet and possibly even the companion star, while the bright disk emission lines (H, He) will enable us to calculate temperature structure, geometry and composition of the disk. We aim to obtain 1.5 hours of spectroscopy, effectively covering half an orbital period, exploiting the eclipsing nature of the system. This will not only help us understand this individual binary, but also serve as a testcase of the capabilities of X-shooter to probe systems like this in a novel, broad wavelength range, way.

Scientific Case:

Introduction – The accreting X-ray binary systems (XRBs) are amongst the best studied Galactic X-ray sources. They consist of a compact object (a neutron star or black hole) and a "normal" star orbiting one another while the compact object accretes matter from its companion. These systems show a rich phenomenology, displaying spectral state changes, dramatic outbursts and complex temporal behaviour on a wide range of temporal and spectral scales. In optical and near-infrared wavelengths a wealth of phenomena can be seen: the accretion disk is bright in blue light, the secondary star can be seen in the red, and a relativistic jet contribution may be seen as a seperate spectral component as well. A particularly attractive laboratory for the energetics, disk/corona morphology and stellar evolution of XRBs are the eclipsing XRBs: their nearly edge-on inclinations offer a unique view of the components of these systems.

XTE J1710-281 – This source is of particular interest, as it exhibits nearly every possible type of variability commonly seen in different low mass X-ray binaries: it shows clear, sharp eclipses, intensity dips and flares as well as bright type I X-ray bursts. From these X-ray bursts (runaway burning of accreted material on a neutron star surface) it is clear that the accretor is a neutron star, and that the source has a distance of $\sim$ 13 kpc. This source shows pronounced X-ray eclipses with a period of 3.28 hours and a duration of 410 seconds, making it the shortest period eclipsing/dipping X-ray binary known, and therefore an important object to help understand the class of eclipsing X-ray binaries as a whole. The dipping behaviour seems to suggest this source has a complex accretion disc - corona geometry. From the eclipses we estimate the donor star to be a $\sim 0.3M_{\rm sun}$ star. As part of a survey of faint persistent X-ray sources (Wiersema et al in prep; Wiersema et al 2009, MNRAS Letters in press arXiv:0902.3002) we discovered its optical counterpart using *Chandra* and *EFOSC2* on the ESO 3.6m (see figure).

Why X-shooter – In the UV-VIS-NIR continuum we expect the signatures of the accretion disk, jet, and the companion star. This XRB has blue V,R,I colors, showing that over that wavelength it is disk-dominated. Our narrowband H α data shows it to be a likely H α emitter. The disk will therefore likely show bright emission lines of hydrogen (Paschen, Brackett, Balmer), as well as bright He I and He II. Metal absorption lines and CO bands are expected from the secondary star. With X-shooter we will be able to get all these diagnostics in a single shot, at the same orbital phase in the same orbit, avoiding problems with short timescale variability. We will use the absorption features to pinpoint the donor star type, and use the emission lines to probe disk structure and temperature, combining data with our X-ray data. This will give us one of the most complete optical/nIR spectroscopic dataset of a eclipsing XRB to date.



H α narrowband and V band exposures of the field around XTE J1710-281 (*EFOSC2*, Wiersema et al in prep; Wiersema et al 2009, MNRAS Letters accepted). A clear optical counterpart is detected in the *Chandra* error circle (white).

Targets and observing mode

Target	RA	DEC	V mag	Mode (slit/IFU)	Remarks
XTE J1710-281	17:10:12.589	-28:07:51.34	20.4	slit	Crowded field

Time Justification:

We aim to get sufficient signal-to-noise in the continuum to study the slope of the accretion disk continuum, the jet contribution and the type of the secondary star. We propose for 9 exposures of 600 seconds (1.5 hours total exposure excluding (telluric) standards), which will cover nearly half an orbital period, with a preference of having an eclipse in the data taking (we have the ephemerides from our RXTE data). We will be able to co-add the spectra to study the continuum properties, and use the bright emission lines to study the geometry of the system by studying the changes in line fluxes and profiles as a function of phase. In the following we assume seeing 0.8 arcsec, airmass 1.2 and slit widths 1, 0.9 and 0.9 for the UVB, VIS and NIR arm respectively.

We know the optical magnitudes from our *EFOSC2* campaign (R = 20.0, V = 20.4, I = 19.7; leading to continuum S/N $>$ 5 per bin for the entire range of the vis arm). The secondary is likely around 0.3 solar masses which will contribute to the near-infrared light (an M2 star would have $J \sim 19$), but that value has a sizeable uncertainty. The infrared magnitude is further constrained by the local 2MASS upper limit of $J > 16$ (due to the crowded field this limit is only rough). Extrapolating a disk-like spectrum (as seen in the optical) predicts an infrared magnitude 1 to 2 magnitudes brighter than the secondary star (note the highly uncertain reddening towards this Galactic plane target), this gives a S/N of the continuum above 10 per bin below 2 micron in the NIR arm. The brightness in U and B band is difficult to estimate due to the large uncertainties in the extinction. However, even for a worse case scenario of B$\sim$21.3 the UV arm will give continuum S/N $>$ 5 per bin for the entire range.

We expect (very) bright emission lines to dominate the spectra at all wavelengths (e.g. Bandyopadhyay et al 1999, MNRAS 306, 417), also when the continuum is very faint. Scaling the spectra of Bandyopadhyay et al shows that the brightest Paschen and Brackett lines will be detected with sufficient signal to noise to study their flux and profile variablity as a function of orbital phase, and be able to solve for disk structure as the secondary covers different parts of the disk. In order to maximise the science return, we will perform quasi-simultaneaous hard- and soft X-ray and UV observations with Swift (using *XRT*, *BAT* and *UVOT*).