Acquisition of radial velocity curves for ULXs with GTC

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Abstract. The nature of Ultra-luminous X-ray sources (ULXs) in nearby galaxies is highly controversial: are they the long-sought intermediate mass black holes or a new state of stellar-mass black hole X-ray binary? Only radial velocity studies can unambiguously solve this puzzle. We have granted and guaranteed time to observe two of the brightest ULXs (*B*<*22* mag) accessible to GTC: NGC 5204 X-1 and Holmberg II X-1. The radial velocity curves of the ULXs companion stars obtained through long-slit spectroscopy with OSIRIS can settle the debate on whether ULXs contain a ~100-1000 $M_\odot$ black hole or not.

NGC 5204 X-1.

Liu et al. (2004) combined Chandra X-ray positioning with HST images to identify the optical counterpart (Figure 1) of this ULX (L_X~3×10^{39} erg s^{-1}). The multi-band optical photometry (see Table 1) and a STIS far-ultraviolet spectrum, suggest that the optical counterpart of this ULX is a B0Ib (supergiant) star (Figure 2). In addition, some of the spectroscopic features seen in the low-resolution ultraviolet spectrum point towards an X-ray-illuminated accretion disk with the optical companion filling the Roche lobe. The derived properties would imply a binary system with an orbital period of ~10 days.

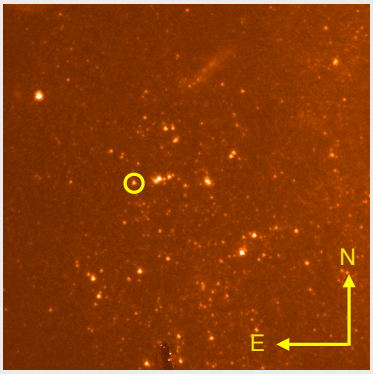

Figure 1. HST image with the optical counterpart of NGC 5204 X-1 (yellow circle).

Table 1. HST magnitudes reported by Liu et al. (2004).

Filter	STMAG [mag]
F220W	19.99 ± 0.05
F435W	21.92 ± 0.05
F606W	22.97 ± 0.09
F814W	24.03 ± 0.08

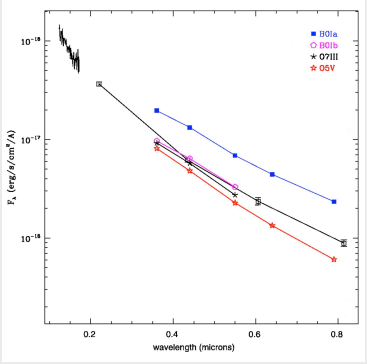

Figure 2. Spectral energy distribution of the optical counterpart of NGC 5204 X-1 derived with FUV spectrophotometry and multiband photometry (black lines). The spectral energy distributions for four stardard stars are also shown for comparison (adapted from Liu et al., 2004).

Holmberg II X-1.

This ULX (L_X~10^{40} erg s^{-1}) is placed in an emission line nebula. Kaaret et al. (2004) combined Chandra, XMM-Newton and HST images to identify the optical counterpart as a blue (O4V-B3Ib) star (Figure 3). Their derived HeII (λ4686 Å) luminosity suggests that the X-ray flux of the ionizing source is larger than 4×10^{39} erg s^{-1} and supports the hypothesis of an ultra-luminous X-ray source. In addition, Lehmann et al. (2005) obtained a low resolution spectrum around the ULX position, confirming the presence of strong emission lines and forcing the use of medium-resolution spectroscopy to derive the expected radial velocity variations.

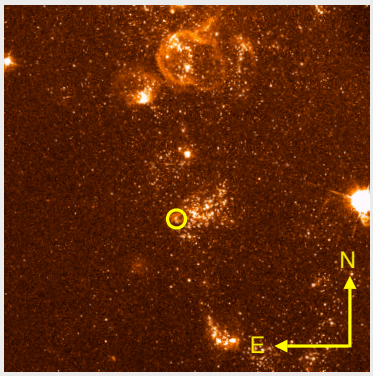

Figure 3. HST image with the optical counterpart of Holmberg II X-1 (yellow circle).

Table 2. HST magnitudes reported by Kaaret et al. (2004).

Filter	STMAG [mag]
F459M	22.04 ± 0.08
F550M	21.35 ± 0.10

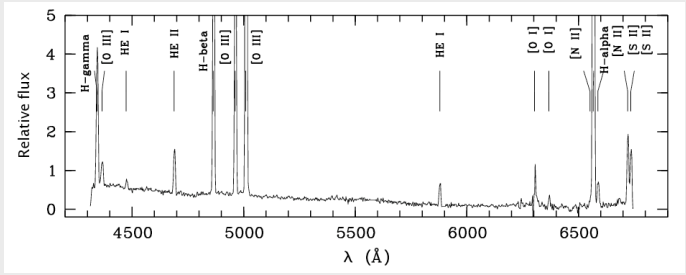

Figure 4. Combined spectrum of Holmberg II X-1 region, obtained with the 6 m BTA telescope by Lehmann et al. (2005).

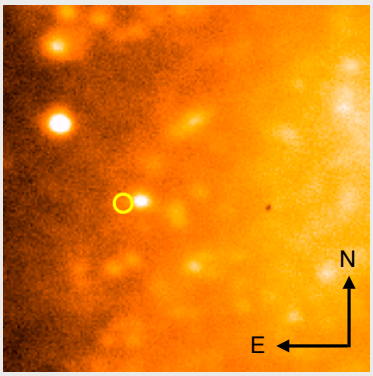

Figure 5. Preliminary GTC image of the region around NGC 5204 X-1. With an exposure time of 90 sec, only the nearby cluster HST-1 (Liu et al., 2004) is visible. The position of the ULX is marked with a yellow circle.

Observations.

The faintness of the optical counterparts, together with the need of medium-resolution spectroscopy, implies the use of a 10m class telescope (like GTC). The guaranteed time awarded to this project is expected to provide the first radial velocities of ULXs with an uncertainty of ~15 km s^{-1}. The preliminary images of NGC 5204 X-1 (Figure 5) have confirmed the good angular resolution achievable with GTC (0.85 arcsec). The radial velocities derived with the OSIRIS R2000B grism will be used to determine the minimum mass (i.e., mass function) of the compact object in both ULXs. With the proposed instrumental setup, the minimum mass for most of the confirmed stellar mass black holes could be determined (Figure 6). Therefore, the proposed observations represent a major step to confirm or reject the existence of intermediate mass black holes in ULXs.

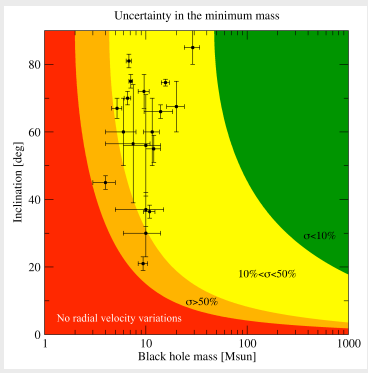

Figure 6. Expected uncertainty (σ) in the minimum mass of the black hole in NGC 5204 X-1. Properties for several black holes in Charles & Coe (2006) and Crowther et al. (2010) are also shown (black circles).

References

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