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DERIVING THE DYNAMICAL MASSES OF ULTRA-LUMINOUS X-RAY SOURCES WITH OSIRIS

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RESUMEN

Las ULXs (del acrónimo inglés Ultra Luminous X-ray sources) son fuentes de rayos X puntuales extragalácticas con $L_X \sim 10^{39}-10^{41}$ erg s^{-1} descubiertas en los 80 con el satélite *Einstein.* En la última década se ha confirmado que son binarias de rayos X con agujero negro. Hay mucha controversia sobre la naturaleza del objeto compacto. Podría tratarse de un agujero negro de masa estelar acretando en el régimen super-Eddington, o un agujero negro de masa intermedia. El único método para poder dilucidar la naturaleza de dichos objetos es mediante la determinación de las masas dinámicas de estos sistemas, tarea que se puede realizar con OSIRIS.

ABSTRACT

Ultra Luminous X-ray Sources (ULXs) are extragalactic X-ray point sources with $L_X \sim 10^{39} - 10^{41}$ erg s^{-1} discovered in the 80s with the *Einstein* satellite and confirmed as black hole X-ray binaries during the last decade. The nature of the compact object is highly controversial. They could be super-Eddington stellar-mass black holes or intermediate mass black holes. Deriving dynamical masses of the brightest ULXs, which can be done with OSIRIS, is the only way to find out the nature of the compact object.

Key Words: accretion, accretion disks — black hole physics — X-rays: binaries

1. INTRODUCTION

Ultra Luminous X-ray sources (ULXs) are extragalactic X-ray point-like objects with $L_X \gtrsim 10^{39}$ erg s^{-1} in the energy range 0.3–10 keV.

These objects were discovered in the 80s with the *Einstein* satellite as non-nuclear X-ray point sources in nearby galaxies, particularly in star-forming galaxies (e.g. Stocke et al. 1991; Long & van Speybroeck 1983). Over the last two decades, thanks to the improvements in the capabilities of X-ray satellites such as *XMM-Newton* or *Chandra*, the X-ray timing and spectral properties of ULXs have been studied in detail, leading to the general agreement that ULXs are Black Hole (BH) X-ray binaries (e.g. Strohmayer & Mushotzky 2003; Feng & Kaaret 2005; Winter et al. 2006; Feng & Kaaret 2007; Berghea at al. 2008).

BH X-ray binaries are believed to have an upper limit on the X-ray luminosity given by the Eddington limit (Frank et al. 2002)

$$L_{\rm Edd} \simeq 1.3 \times 10^{38} \left(\frac{M}{M_\odot}\right) {\rm erg\ s^{-1}}, \qquad (1)$$

our Galaxy BHs have stellar masses ($\sim$5–10 $M_\odot$), therein, an upper limit of $L_X \sim 10^{39}$ erg s^{-1}.

Therefore, ULXs could be super-Eddington accretors (e.g. King et al. 2001), being excellent laboratories to study accretion physics in these regimes. ULXs could also be X-ray binaries with Intermediate Mass BHs (IMBHs) of $10^2 - 10^4$ $M_\odot$ (e.g. King & Dehnen 2005), representing an exciting possibility: they could be important targets to search for gravitational waves, they could have played a key role in the formation of supermassive BHs, etc.

The nature of the compact object and the existence or otherwise of IMBHs is the key uncertainty driving the study of ULXs. The only way to solve this puzzle is an independent measurement of the masses of the BHs in these systems. Doppler shifts of the optical spectra due to the orbital motion of the optical counterpart around the BH, giving as a result a radial velocity curve, and hence the semi-amplitude velocity (K_0) and the orbital period (P_0), provide an independent measurement of a lower limit of the mass on the BH (the mass function),

$$f\left(M_X\right) = \frac{P_0 K_0^3}{2\pi G}, \qquad (2)$$

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GTC, with its large collecting area and frontline instruments such as OSIRIS, offers a unique opportunity to obtain an important result and make significant impact in the field.

2. HOLMBERG II X-1 AND OSIRIS

The selected target is the ULX located in the irregular galaxy Holmberg II at a distance of 3.05 Mpc (Hoessel et al. 1998). This ULX has a $L_X \sim 10^{40}$ erg s^{-1} (Zezas et al. 1999), is located in a star-forming region (Lehmann et al. 2005), and has colors consistent with an O4V-B3Ib companion (Kaaret et al. 2004).

Spectra obtained during the 2010B campaign using OSIRIS with grating R2000B, covering the wavelength range λ4000–5600 Å, are presented in Figure 1.

As expected, several strong nebular emission lines are observed in these spectra due to contamination from the star-forming region surrounding the ULX. No Doppler shifts have been found in the He II emission lines of these spectra, consistent with a nebular origin for these lines.

We plan to subtract the nebular emission lines during the reduction process, which is ongoing, to find absorption lines of the optical counterpart. With an analysis of these absorption lines, we will classify the spectral type and luminosity class of the optical counterpart. We expect to obtain Doppler shifts from the combined analysis of the stellar and nebular spectra and the mass function of the BH. It would be the first orbital solution of a ULX.

These nebular emission lines seem to have variability in their intensities that could be due to the X-ray ionization. Simultaneous X-ray and optical observations would be very useful to look for correlations between the variability of these emission lines and X-ray fluxes.

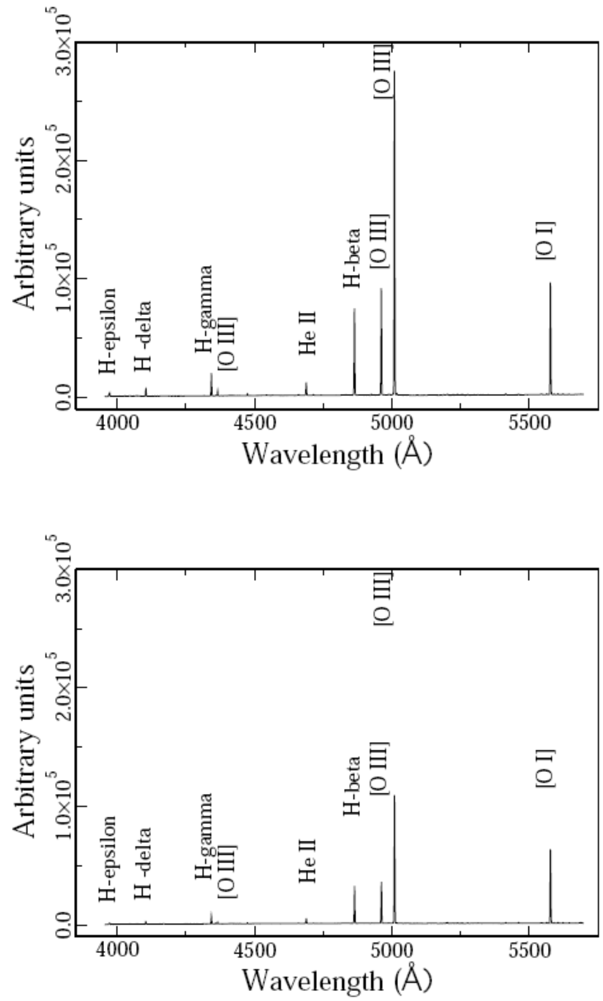

Fig. 1. GTC+OSIRIS (R2000B) spectra of Holmberg II X-1 obtained during the 2010B campaign. The upper spectrum was obtained on November 11th, 2010, while the lower spectrum was obtained on February 2nd, 2011.

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