Black Holes from Stars to Galaxies – Across the Range of Masses
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The K-correction for LMXBs: an application to X1822-371 and GX339-4

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Abstract. We model the K-correction for emission lines formed on the irradiated face of companion stars in compact binaries. We compute this K-correction in a general approach as function of the mass ratio and the disc flaring angle. Our results, combined with the detection of high excitation emission lines arising from the donor star, can be used to set constraints to the masses of neutron stars and black holes in persistent Low Mass X-ray Binaries (LMXBs).

The application of our model to X1822-371 (Muñoz-Darias, Casares & Martínez-Pais 2005) lends strong support to the presence of a massive neutron star in this LMXB (i.e. $M_{\rm NS} > 1.6 M_{\odot}$). Here, we also present the K-correction for the Black Hole binary GX339-4, where we obtain a solid lower limit to the black hole mass of $M_{\rm BH} > 5.8 M_{\odot}$.

Keywords. Accretion, accretion disks – binaries: close – X-rays: stars

1. The K-Correction for LMXBs

Low mass X-ray binaries (LMXBs) are interacting binaries where a low mass donor star transfers mass onto a Neutron Star (NS) or Black Hole (BH). If the accretion rate is high enough the X-ray luminosity remains above $\sim 10^{36}$ erg s^{-1} resulting in persistent systems. In these sources the companion star is usually undetectable and thus dynamical studies have been restricted to transients where the companion dominates the optical spectrum of the source. The situation has recently changed thanks to the discovery of narrow emission components within the Bowen blend at $\lambda\lambda$ 4634-50 arising from the donor in the prototypical LMXB Sco X-1 (Steeghs & Casares 2002). Fortunately, this property is not peculiar to Sco X-1 and this technique has successfully been applied also to others LMXBs (e. g. X1822-371: Casares *et al.* 2003, GX339-4: Hynes *et al.* 2003; hereafter H03, V801 Ara and V926 Sco: Casares *et al.* 2006). However, these high energy emission lines are excited on the inner hemisphere of the donor and only provide a lower limit to the true K_2 velocity which corresponds to the center of mass of the companion. In Muñoz-Darias *et al.* (2005; hereafter MCM05) we model the deviation between the reprocessed light center and the center of mass of a Roche lobe-filling star (i.e. the so-called K-correction). To do this, we integrate a Gaussian profile over the Roche lobe geometry which is divided in $\sim 10^5$ resolution elements. We find that the K-correction depends on:

(i) Mass ratio, $q = M_2/M_1$;
(ii) Disc flaring angle, α, which obscures the companion;
(iii) Orbital inclination, i.

Therefore, we have computed the K-correction as function of q and α for the cases of low and high orbital inclination. The K-correction is well fitted by fourth-order polynomials and we report the coefficients of the fits in MCM05.

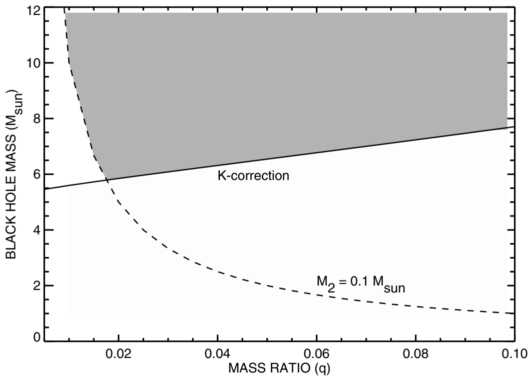

Figure 1. Black Hole mass determination in GX339-4. Dashed line represents the constraint $M_2 = 0.1M_\odot$. Solid line shows the lower limit to $M_{\rm BH}$ obtained through the K-correction by using $\alpha = \alpha_M$. The possible BH mass range is restricted by the grey region.

2. The mass of the neutron star in X1822-371

To date, the accretion disc corona X1822-371 is the best candidate to apply the K-correction since we know with high accuracy the following system parameters:

(i) Orbital period = 5.57 hr (Hellier & Mason 1989);

(ii) Orbital inclination = $82.5 \pm 1.5°$ (Heinz & Nowak 2001);

(iii) Radial velocity of the NS, $K_1 = 94.5 \pm 0.5$ km s^{-1} (Jonker & van der Klis 2001);

(iv) α constrained between 12–14° (Hellier & Mason 1989, Heinz & Nowak 2001);

(v) Doppler tomography of the NIII emission line at λ4640 reveals a compact spot at the position of the companion with $K_{em} = 300 \pm 15$ km s^{-1} (Casares *et al.* 2003).

As we show in MCM05, the application of the K-correction strongly suggest that X1822-371 harbours a heavy neutron star of 1.6–2.3$M_\odot$.

3. The Black Hole binary GX339-4

GX339-4 was proposed as a BH candidate by Samini *et al.* (1979). However, this transient LMXBs has a high level of X-ray activity and the features of the companion are undetectable even during quiescent epochs. Only during the 2002 outburst H03 discovered narrow NIII emission likely arising from the companion star. These authors obtained a best fit orbital period of $P_{\rm orb} = 1.7557 \pm 0.0004$ days and measured a NIII radial velocity of $K_{em} = 317 \pm 10$ km s^{-1}. Moreover, the small motion in the wings of the HeII λ4686 emission line suggests $q \lesssim 0.08$. Here, we apply the K-correction for $0.05 < q < 0.1$ by assuming $\alpha = \alpha_M$ for each value of q, where α_M is the highest value of the flaring angle for the companion to be irradiated. The absence of X-ray eclipses sets an upper limit to the orbital inclination for each q. We use these constraints to derive a lower limit to the mass of the BH. Assuming that $M_2 \geqslant 0.1M_\odot$ we obtain $M_{\rm BH} > 5.8M_\odot$ (see figure 1).

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