First results from the use of the relativistic and slim disc model SLIMULX in XSPEC

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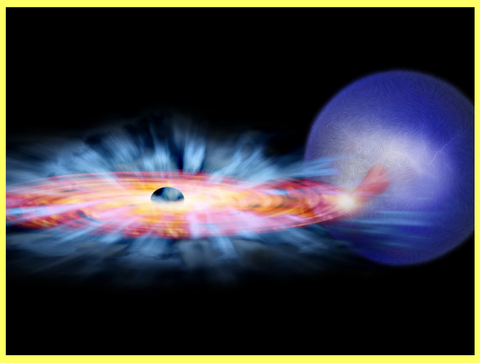
Ultra-Luminous X-ray sources (ULXs) are accreting black holes for which their X-ray properties have been seen to be different to the case of stellar-mass black hole binaries. The mass of the black hole (BH) derived from the thermal disc component is usually in the range of 100-1000 solar masses, which have led to the idea that this might represent strong evidence of the Intermediate Mass Black Holes (IMBH), proposed to exist by theoretical studies but with no firm detection (as a class) so far. Recent theoretical and observational developments are leading towards the idea that these sources are instead stellar-mass BHs/NSs accreting at an unusual super-Eddington regime. In this paper we briefly describe the model SLIMULX that can be used in XSPEC for the fit of thermal spectra of slim discs around stellar mass black holes in the super-Eddington regime. This model consistently takes all relativistic effects into account. We present the obtained results from the fit of the X-ray spectra from NGC 5408 X-1.

The Ultra-Luminous X-ray source paradigm



Stellar-mass Black Hole (BHB)

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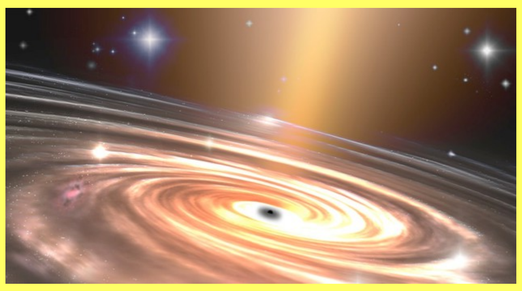


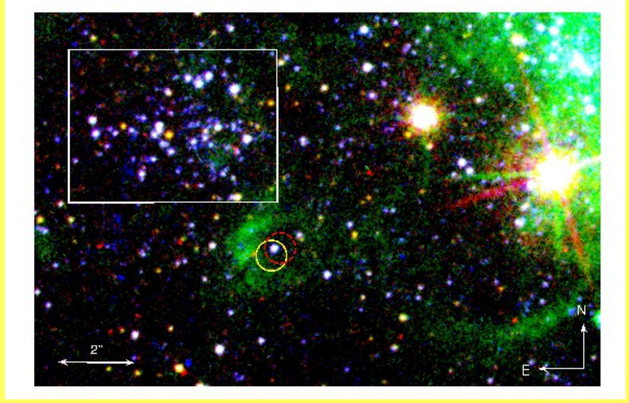
Supermassive Black Hole (AGN)

InterMediate Mass Black Hole (IMBH)

- Ultra-Luminous X-ray (ULX) sources are point-like, off-nuclear sources observed in other galaxies, with ***total observed*** luminosities greater than the Eddington luminosity **for a stellar mass black hole** ($L_X \sim 10^{38}$ erg/s).
- Therefore either the accretion is supper-Eddington, or emission *is not isotropic* or the black hole has a higher mass ($M_{BH} \geq 20\ M_\odot$).
- This *opens a real possibility to the existence of the InterMediate-Mass Black Holes* (IMBHs; $M_{BH} \geq 10^2$-$10^4\ M_\odot$; Colbert & Mushotzky, 1999) but only a few cases recently confirmed (ESO 243-49 HLX1; Farrell et al. 2011).
- Our goal is to obtain the mass of the compact source using X-ray spectroscopy of ULXs through the use of a proper code able to deal with extreme General Relativity conditions and accretion rates higher than Eddington (SLIMULX).

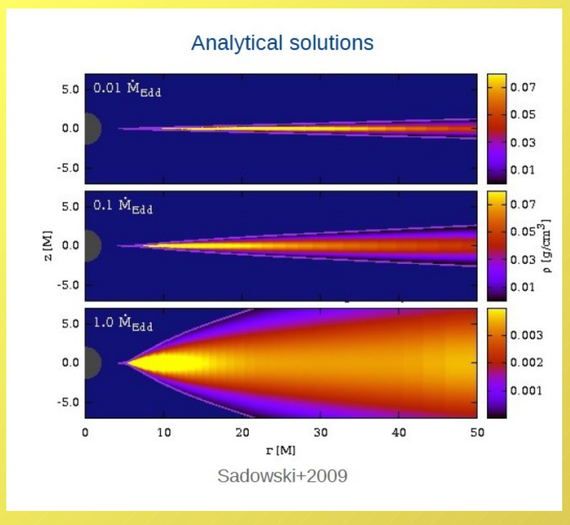
The Ultra-Luminous X-ray source NGC 5408 X-1

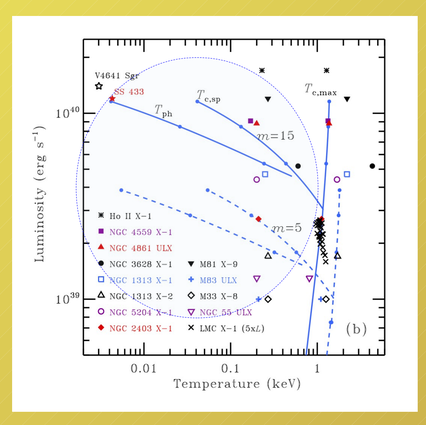
- NGC 5408 is a nearby (D=4.8 Mpc) ULX with a peak (*RXTE*, 0.3-10 keV, 2008-2009) X-ray luminosity of $L_X = 2 \times 10^{40}$ erg/s (Strohmayer, 2009)
- Quasi-Periodic Oscillations (QPOs) were discovered at 0.01 Hz in the X-ray light curve which *suggested the presence of an IMBH* (Strohmayer & Mushoztky, 2009).
- We studied the 6-Long 100 ks observations with XMM-Newton performed in 6 years (2006-2011).



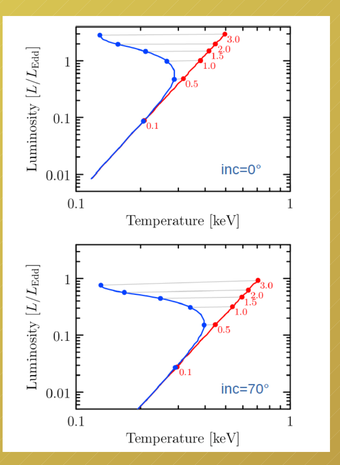
HST image (blue - F225W, green - F502N, red - F845M) of ULX NGC 5408 X-1 (circled), the surrounding field and a nearby stellar association (box) (from Grise et al. 2012)

L-T Plot in near Eddington case





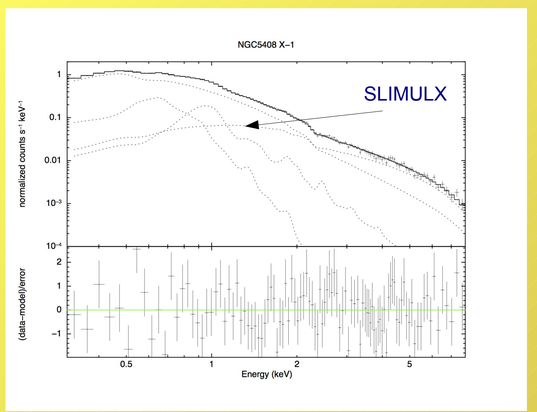
(Upper-left)X-ray luminosity versus inner disc temperature inferred from X-ray spectral fits for a sample of ULXs and of BHBs.Figure taken from Poutanen et al. (2007).



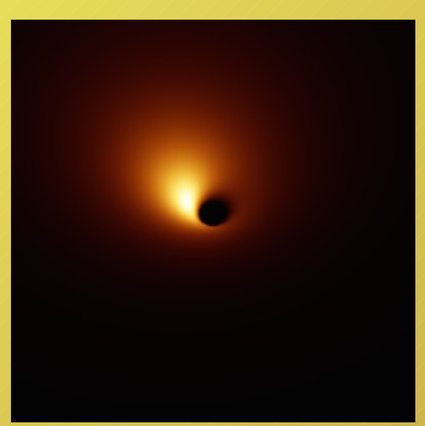
(Upper-right) X-ray luminosity versus inner disc temperature for the standard (red) and the slim accretion disc (blue). Figure taken from Bursa (2016).

SLIMULX model

- Standard (thin) disc follows $L \sim T^4$ relation.
- Advection and obscuration effects cause *significant deviations from that relation in super-Eddington regime*.
- The effect is strong inclination dependent.
- Observed luminosity *can stay around Eddington* if mass accretion rate is high.



(Upper-left) EPIC-pn XMM-Newton spectrum (top) and chi-square residuals (bottom) of NGC 5408 X–1 fitted with the spectral model TBabs(apec + apec+ slimulx + powerlaw) in XSPEC.



(Upper-right) Accretion disc as seen from an observer located at infinity (credits: M. Bursa).

Results and Conclusions

- Standard (thin) disc model is inaccurate for $L_{disc} > 0.3\ L_{EDD}$.
- Such models tend to give incorrect values for BH masses and for accretion rate (luminosity).
- Standard (thin) accretion disc theory is not enough → need to move on to *slim-discs*.
- For the case of NGC 5408 X-1 ***a maximally rotating, of 5 $M_\odot$ BH*** is inferred.
- No need of IMBH for NGC 5408 X-1 (prototype of the ULX classification).

Related publications:

"First results from the use of the relativistic and slim disc model SLIMULX in XSPEC", Caballero-Garcia, M. D., Bursa, M., Dovčiak, M., Fabrika, S., Castro-Tirado, A. J., Karas, CAOSP (2017)