The spectral state transitions of ESO 243–49 HLX-1 [1]

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Key points

➪ The extreme **ultra-luminous X-ray source HLX-1** in the galaxy ESO 243-49 reaches a luminosity of 10^{42} erg s^{-1} (0.2-10 keV) **[2]**

➪ Strongest evidence for the existence of **intermediate mass black holes ($10^2 – 10^5\ M_\odot$) [3,4,5,6]**

[see talk by S. Farrell and poster by N. Webb]

Methods

➪ X-ray spectral and variability study of the source based on XMM-Newton (3 epochs), Chandra ACIS-S and **Swift XRT** monitoring data **[1]**

Results

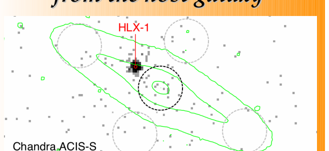
➪ HLX-1 showed three states: a **thermal state** at high luminosity, a **hard state** at low luminosities, and a **steep power law state**

➪ Typically observed for **Galactic stellar-mass black hole binaries**, but HLX-1 luminosities are 3 orders of magnitude higher

➪ Low disk temperature (0.2 keV) in the thermal state suggests an intermediate mass black hole

➪ The bolometric luminosity (hence the X-ray luminosity) of the source in the thermal state should always be lower than the Eddington luminosity for the system, giving a limit on the mass of the black hole of **> 9 000 $M_\odot$**

Annex: contamination from the host galaxy



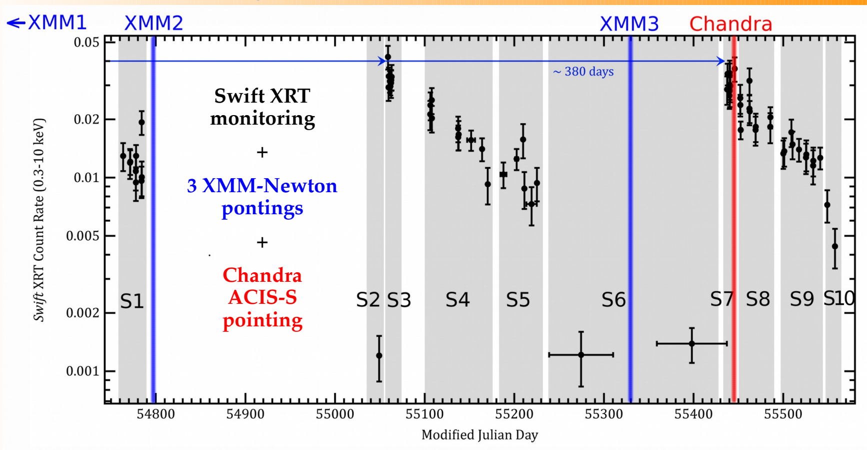
➪ ~9 counts **excess** aligned with the bulge (central dashed circle)

➪ ~5x10^{39} erg s^{-1}, as expected for a spiral galaxy **[7]**

➪ Soft: **mekal** with kT=0.4 keV

➪ Could contribute about **15% of the XMM3 flux**

Variability and hardness: reminiscent of Galactic stellar mass black hole binaries



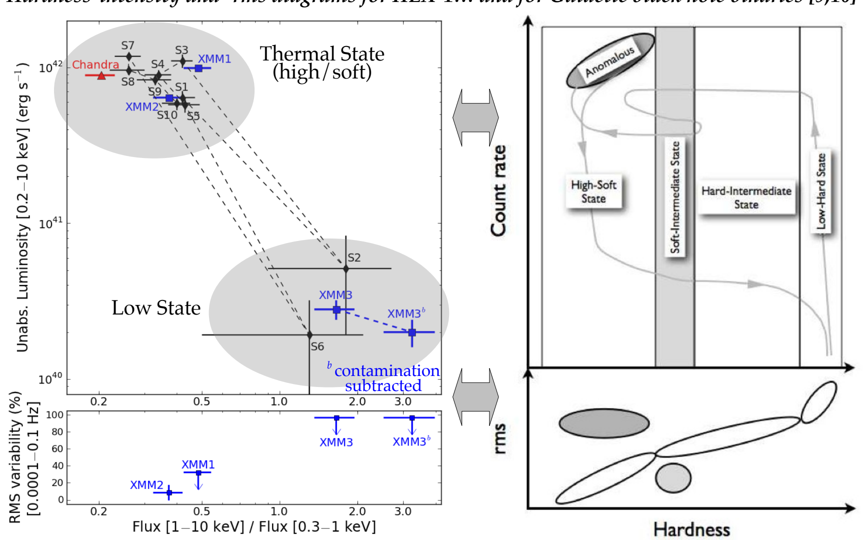
➪ Unabsorbed luminosities ranged from **2.1×10^{40} to 1.25×10^{42} erg s^{-1}**

➪ Possible **recurrence**/periodicity of ~380 days... next early September 2011? **[see also 8]**

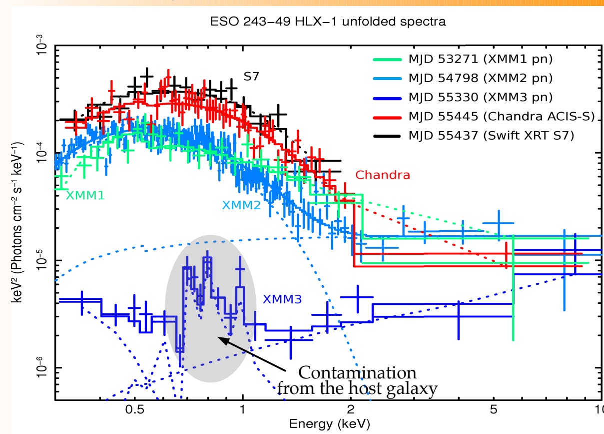
➪ XMM3 and Chandra **triggered** to obtain spectra at **low** and **high** luminosity states

➪ **Swift data stacked** over different periods (S1-S10) to estimate hardness ratios **[as in 5]**

Hardness-intensity and -rms diagrams for HLX-1… and for Galactic black hole binaries [9,10]



Spectral evolution of HLX-1: clear spectral states and transitions



	power law	diskbb [keV]	χ^2/d.o.f.	State
XMM1	3.3±0.2	...	66.7/65	steep pow. law
XMM2	2.1±0.2	0.18±0.01	391.4/344	thermal
XMM3	1.6±0.4	(0.07±0.04)	57.5/56	hard
Chandra	...	0.22±0.02	57.0/49	thermal

➪ Thermal states showing a $L_{disk} \propto T_{in}^{\ 4}$ relation

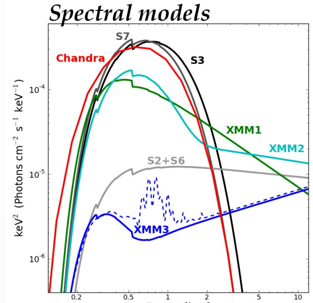
➪ Inconsistent with models of **milli-blazars** / **beaming [11]**

➪ Different from spectra of sources proposed to be in an *ultra-luminous state* with **super-Eddington accretion [12]**

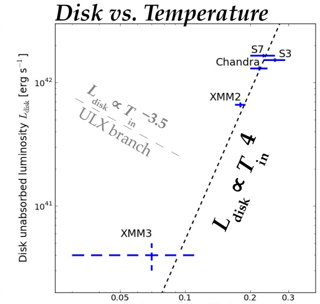
➪ Homologous to Galactic black hole binaries **[9,10]**, which have **non-beamed** and **sub-Eddington** emission, implying

$$M_{black\ hole} > 9\ 000\ M_\odot$$

Spectral models



Disk vs. Temperature



References: **[1]** Servillat et al 2011., ApJ, submitted **[2]** Farrell et al. 2008, Nature, 460, 73 **[3]** Webb et al. 2010, ApJL, 712, 107 **[4]** Wiersema et al. 2010, ApJL, 721, 102 **[5]** Godet et al. 2009, ApJL, 705, 109 **[6]** Davis et al. 2011, ApJ, 734, 111 **[7]** Fabbiano 1989, ARA&A, 27, 87 **[8]** Lasota et al. 2011, ApJ, 735, 89 **[9]** Belloni et al. 2010, AIPC, 1248, 107 **[10]** Remillard & McClintock 2006, ARA&A, 44, 49 **[11]** King 2009, MNRAS, 393, L41 **[12]** Gladstone et al. 2009, MNRAS, 397, 1836