Timing properties and X-ray lags of an ultraluminous X-ray source

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Soft time lags

P. Uttley's talk + review [Uttley et al. 2014]

"soft excess"-dominated band lagging behind primary power law dominated band



FeK reverberation: see E. Kara's and A. Zoghbi's talk + Dovciak's poster K01 More on soft lags in AGN: see E. Gardners's talk

Soft time lags in AGN



Emmanoulopoulos et al. 2011]

Soft time lags in GBHs

GX 339-4



[Uttley et al. 2011]

Soft time lags in neutron stars



[Vaughan et al. 1998, Kaaret et al. 1999, deAvellar et al. 2013, Barret et al. 2013, Mendez et al. 2013, deAvellar poster B03]

Soft time lags vs BH mass



Overview of the talk

• Do ULXs have soft lags as well?



• Can we link the variability properties of ULXs to those of GBHs?



Ultraluminous X-ray sources: NGC 5408 X-1



NGC 5408 X-1



NGC 5408 X-1



Energy dependence qualitatively similar to high frequency lags in other sources



NGC 5408 X-1



No secure estimate of the BH mass (unknown companion star orbiting parameters) Current estimates go from 50M $_{\odot}$ to 10⁴M $_{\odot}$

No complete understanding of the origin of the spectral components

What we know about NGC 5408 X-1

- 1. X-ray luminosity $\gtrsim 10^{40}$ erg/s
 - a) Isotropic emission, sub-Eddington \longrightarrow IMBH (>100 M $_{\odot}$) b) Beamed L

c) Isotropic emission, super-Eddington \longrightarrow stellar mass (<50 M $_{\odot}$) [e.g. Roberts 2007, Feng & Soria 2011]

[e.g. Strohmayer 2009]

 \longrightarrow stellar mass (<50 M_o)

2. Significant high-frequency X-ray variability (unusual for ULXs) [Heil et al. 2009, Middleton et al. 2011]

3. mHz QPO always detected [Strohmayer et al. 2007, Strohmayer & Mushotzky 2009, Pasham & Strohmayer 2012]

What we don't know about NGC 5408 X-1

1. Mass

No detection of companion star [Kaaret & Corbel 2009]

- 2. Physical origin of X-ray spectral components Soft excess + turn over at \sim 4-6 keV (cool-optically thick corona?) [e.g. Gladstone et al. 2009]
- 3. Accretion state Canonical state or ultraluminous state? [e.g. Roberts 2007, Gladstone et al. 2009, Sutton et al. 2013 + T. Roberts' talk tomorrow]

4. Identification of the mHz QPO with known QPOs from GBHs and NS

[e.g. Strohmayer et al. 2007, Casella et al. 2008, Strohmayer & Muschotzky 2009]

BH mass estimates



1. Fractional rms



2. Fractional rms spectrum



3. Total rms vs flux



[Muñoz-Darias et al. 2011, Heil et al. 2012]

4. QPOs



Variability and accretion state



Hard Intermediate state



Hardness



IMBH: the lag fits in the correlation (may require truncated disc) **Stellar mass:** the lag is too long to be due to reverberation [e.g. Gladstone et al. 2009, Middleton et al. 2011]

winds? [see C. Silva's poster (F-32) on the response of outflowing gas in AGN]

Conclusions

• Does some ULX have soft lags?

Yes! If the soft lag in NGC 5408 X-1 is due to reverberation, it requires an IMBH

• Can we link the variability properties of ULXs to those of GBHs?

Analogies between NGC5548 X-1 and hard intermediate state GBHs