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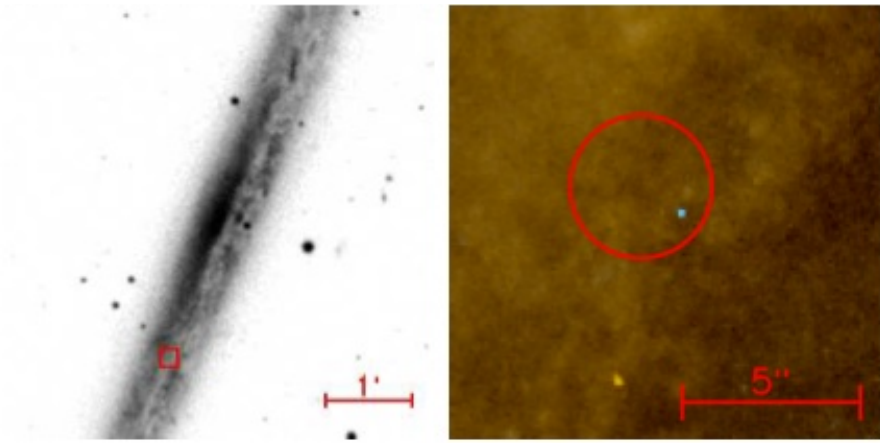
The most luminous ULXs: evidence for IMBHs?



Tim Roberts

Andy Sutton (Durham), Jeanette Gladstone (Alberta), Dom Walton (Cambridge), Amy Scott (Leicester)

With contributions from:

Matt Middleton, Chris Done, Floyd Jackson (Durham)

Lucy Heil, Simon Vaughan, Silvia Mateos, Victoria Heard (Leicester)

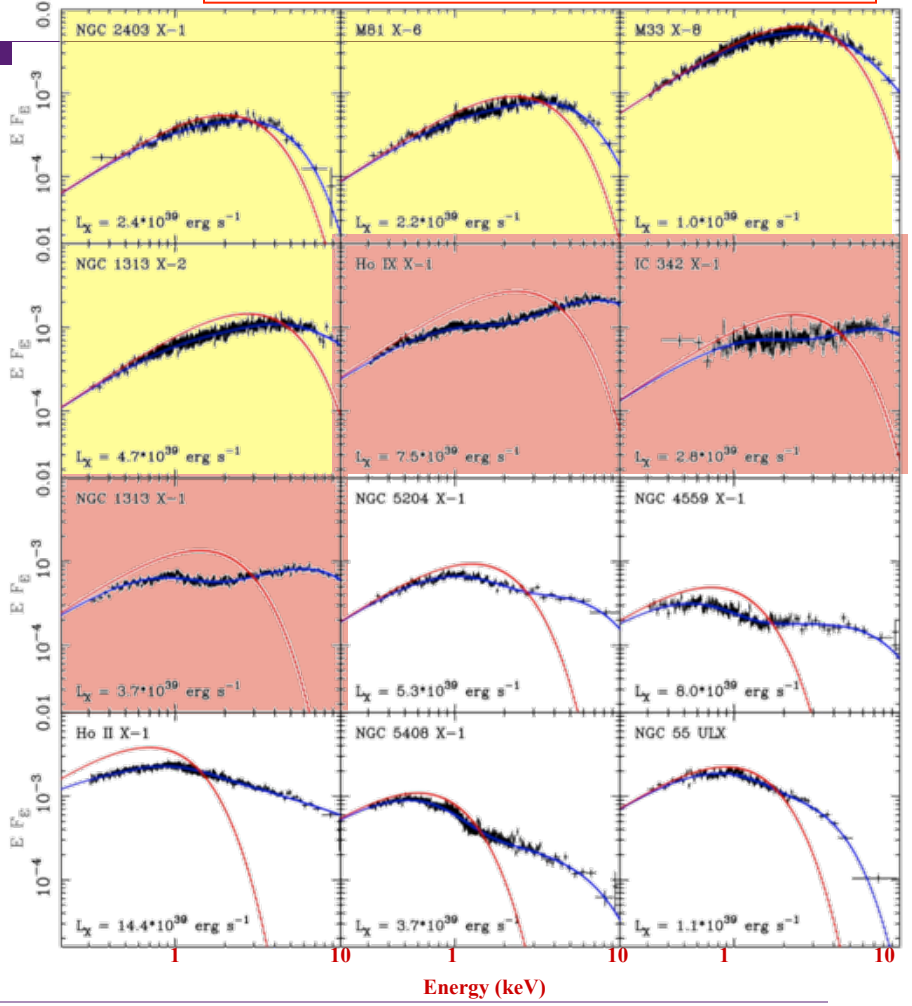
Why care about ULXs?

- > 10^{39} erg s^{-1} definition: this is ~ Eddington limit for a 10 $M_\odot$ black hole
- Which implies either a new ~ 10^2 – 10^4 $M_\odot$ class of intermediate-mass black holes…
  - Remnant seeds of SMBHs?
- …or stellar mass (< 100 $M_\odot$) black holes that exceed the Eddington limit
  - Most extreme accretion environments

ULX spectral sequence

Gladstone, Roberts & Done 2009

- Need highest quality data
- IMBH model: cool disc + power-law, sub-Edd
- **But data is unlike sub-Edd states: not IMBH**
- Broad disc at lower L_x
- Cool disc plus optically thick comptonisation at higher L_x: *ultraluminous state*

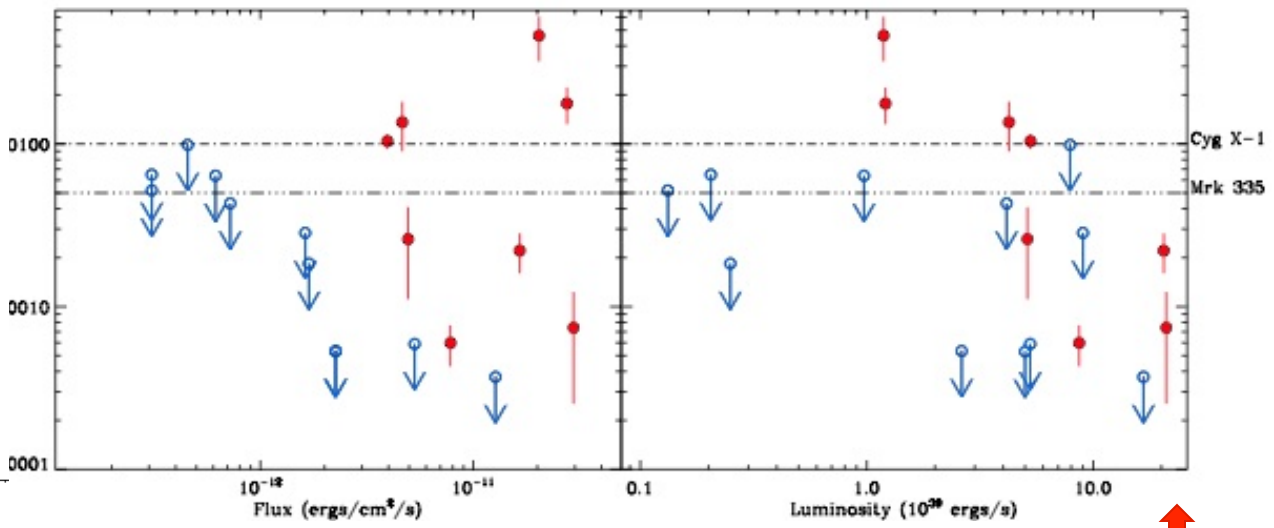


What about X-ray timing?

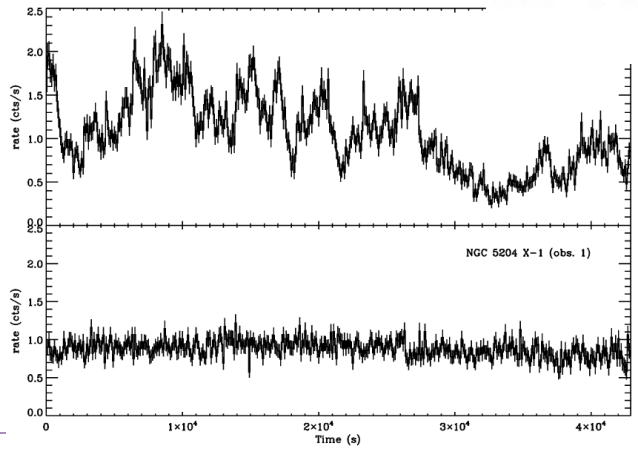
Heil, Vaughan & Roberts 2009

Majority of ULXs have suppressed variability

Again – unlike corona-dominated sub-Edd states (as would be case if IMBH present)



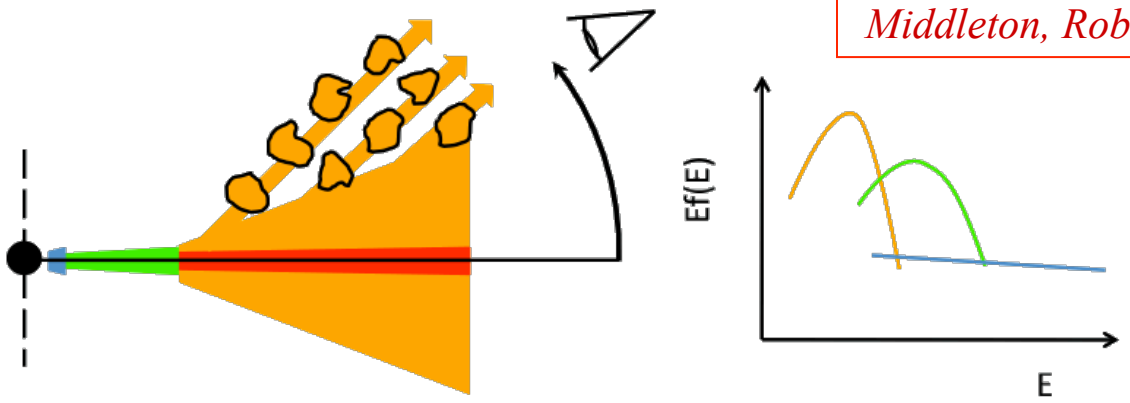
Variability of ULXs, modelled by constraining PSD shape & normalisation



Variability of NGC 5204 X-1 compared to the AGN, NGC 4051. The count rate of NGC 4051 is scaled to that of NGC 5204 X-1

ULXs and radiatively-driven winds

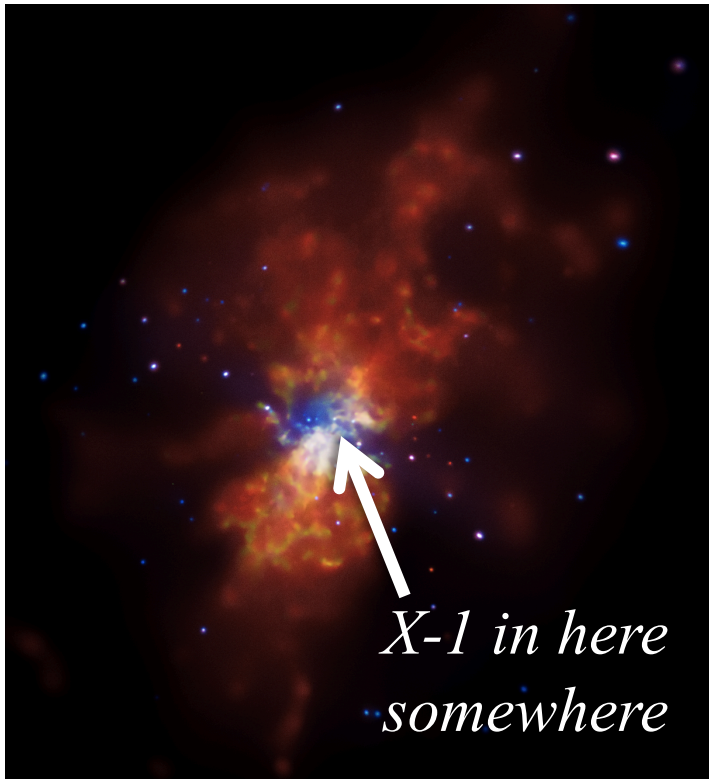
Middleton, Roberts, Done & Jackson 2011



See Middleton talk @ 17.50

- Theory predicts a key characteristic of super-Eddington accretion is a radiatively-driven wind (e.g. Poutanen et al. 2007, Ohsuga & Mineshiga 2011), driven from photospheric radius
- Emergence of this optically-thick component provides 'cool disc'; becomes increasingly important with accretion rate
- Both components invariant: where variability present, could be extrinsic from clumpy wind in line-of-sight (e.g. NGC 5408 X-1)

Are there any ULX-IMBHs?



0.5 Ms Chandra LP data

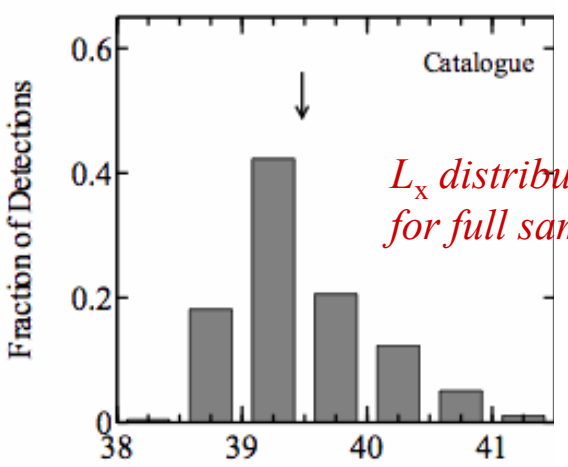
- Difficult to exceed L_{Edd} by factor > 10
- But tail of high L_x (> 2 × 10^{40} erg s^{-1}) ULXs – IMBH candidates?
- Particularly HLXs (L_x > 10^{41} erg s^{-1})
- Famous objects e.g. M82 X-1, ESO 243-49 HLX-1

See Farrell talk next

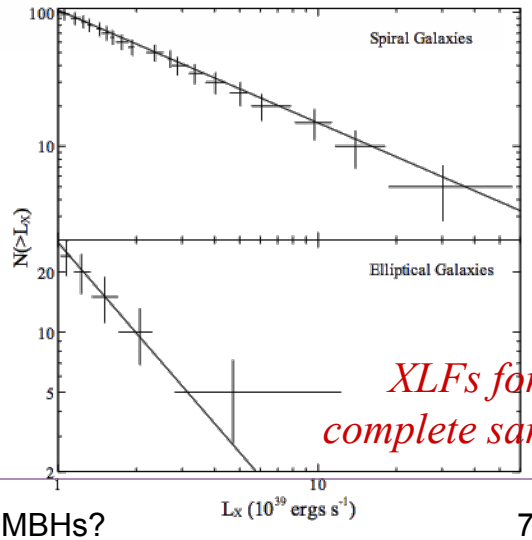
A new 2XMM sample

Walton, Roberts, Mateos & Heard 2011

- New 2XMM-DR1 + RC3 catalogue: 650 observations of 470 candidate ULXs
- Low contamination (~20% QSOs)
- But ~60 detections of ~45 objects with $L_x > 2 \times 10^{40}$ erg s^{-1}
  - ~ 30% contamination



L_x distribution for full sample

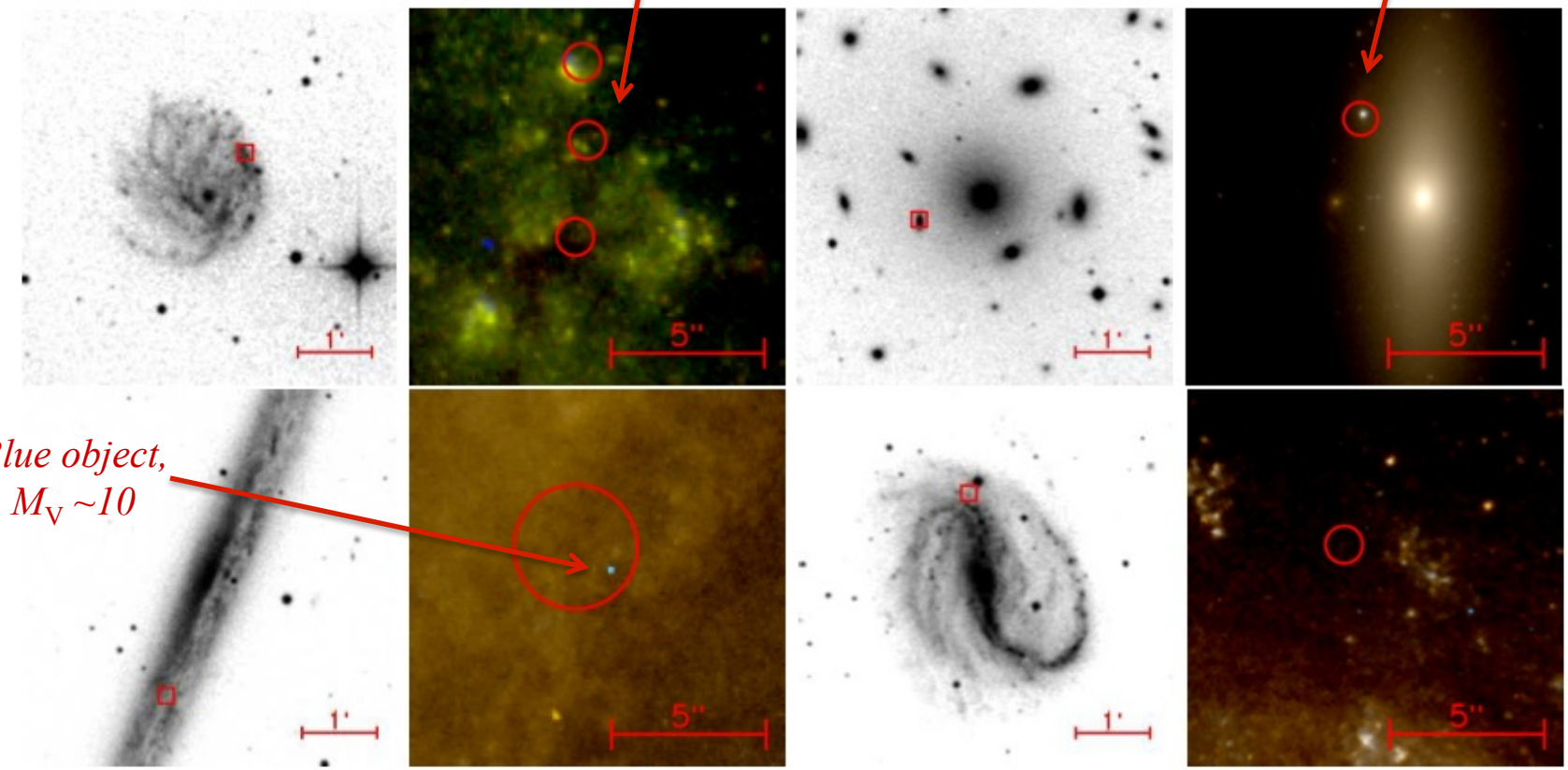


XLFs for complete sample

A sample of the most luminous ULXs

- Select good detections with $L_x > 5 \times 10^{40}$ erg s^{-1}, $d < 100$ Mpc (excluding M82 X-1)
  - 10 objects, including 3 candidate HLXs
  - > 40 observations (at least 2 per object), including *Chandra* data for 8 objects
  - Data quality moderate (100s of counts on average per observation)
- Expect ~3 QSO contaminants; one HLX candidate newly ID'ed by SDSS as QSO

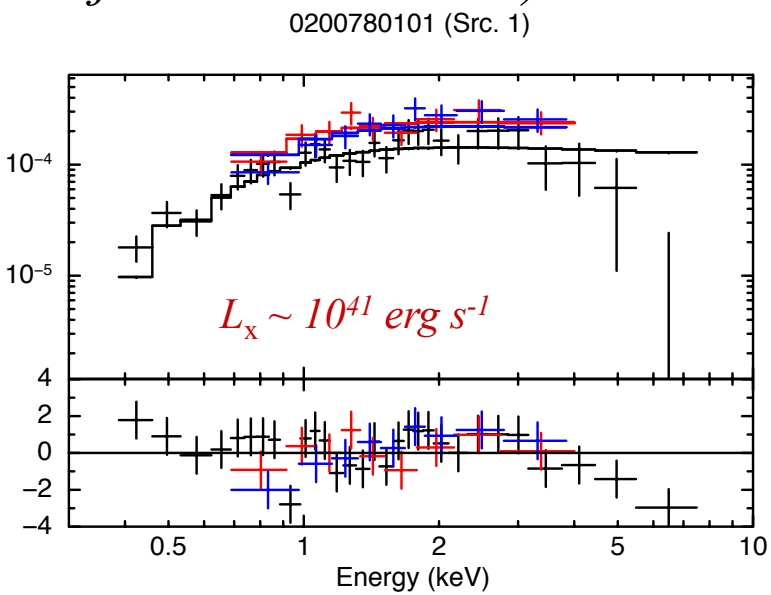
Locations

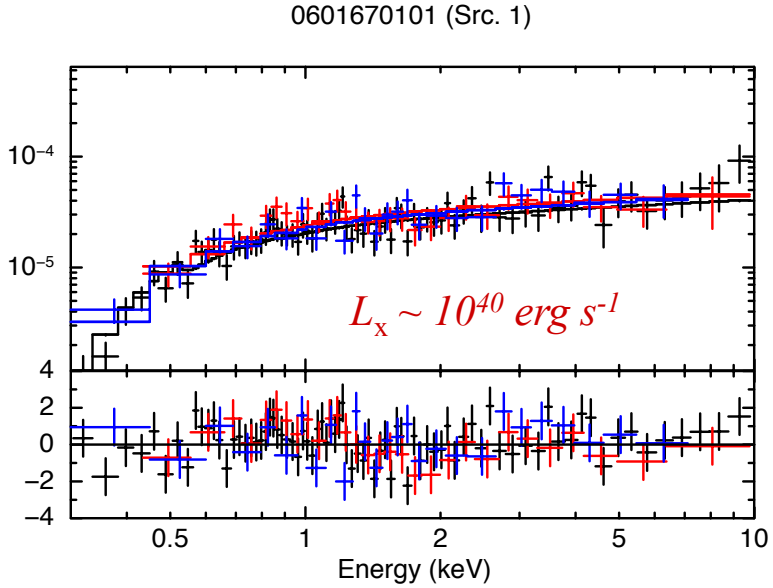


7/10 found in spiral galaxies; 3/10 around ellipticals (includes 2 QSOs)

X-ray spectra

Spectra fit with simple power-law or multi-colour disc models, majority better fitted by power-law (although few datasets reject either model)



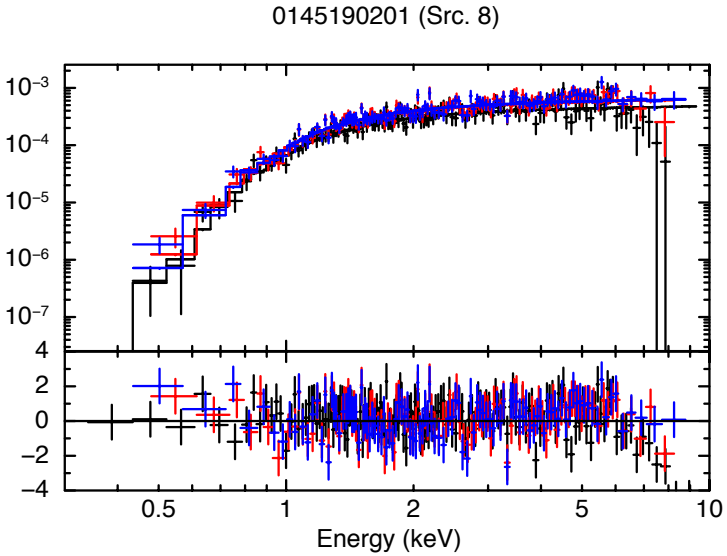


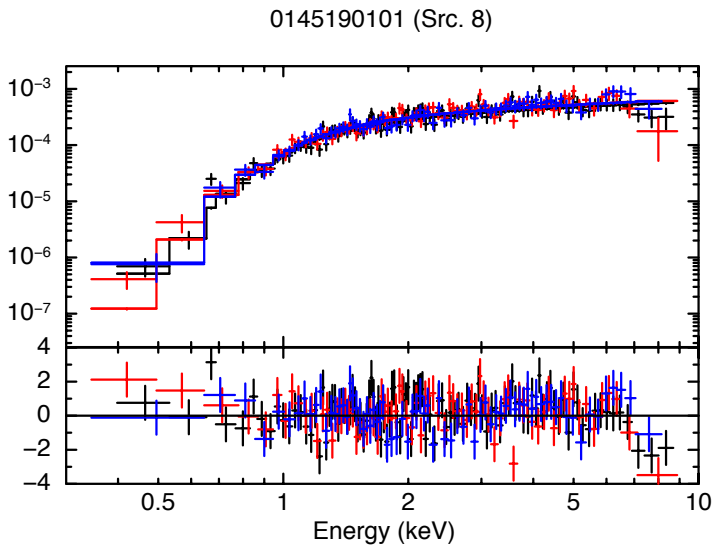
Observations of NGC 470 HLX candidate, model is best-fitting power-law

NGC 5907 ULX

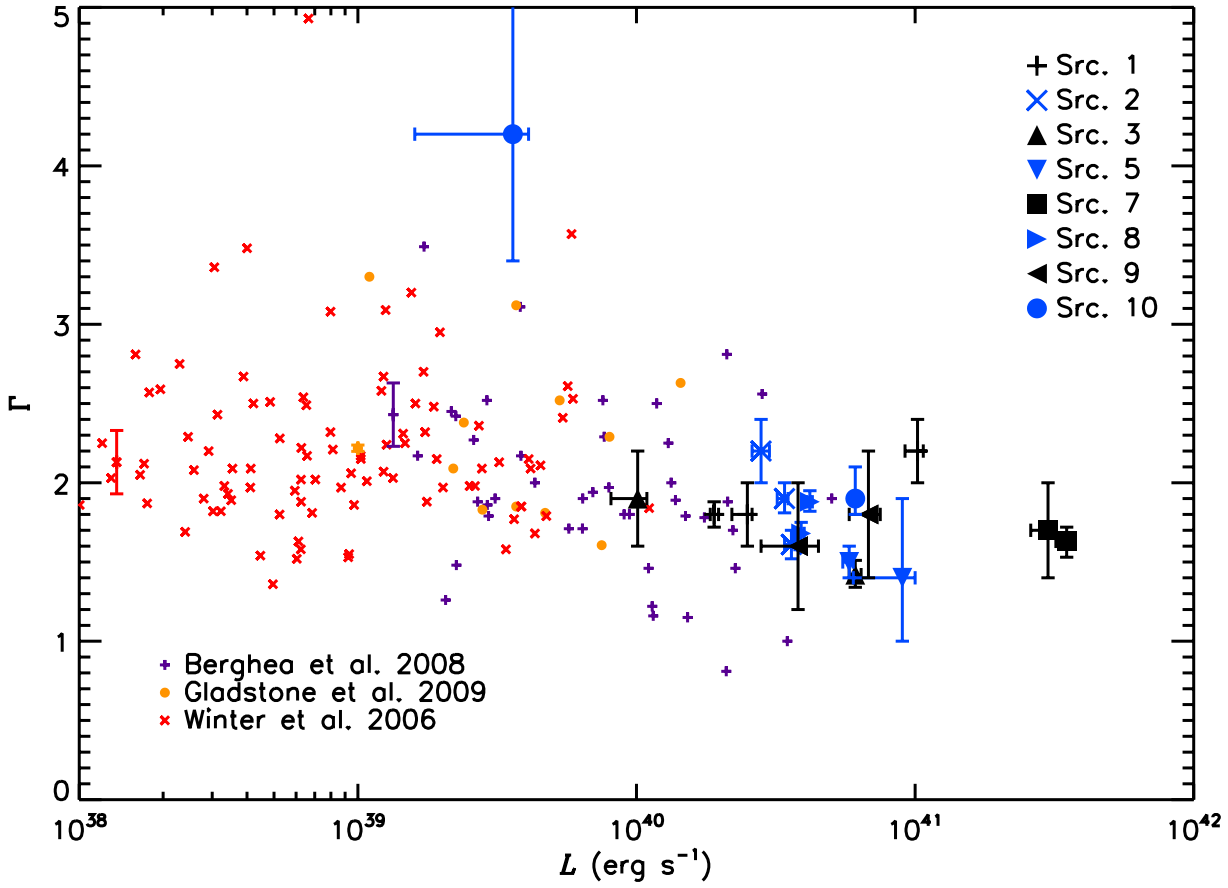
Best quality data (> 5000 counts per observation): find break characteristic of ultraluminous state

***BUT**: distance uncertain; $L_X \sim 2 \times 10^{40}$ erg s^{-1} for $d \approx 10$ Mpc, this is probably an 'ordinary' ULX...*



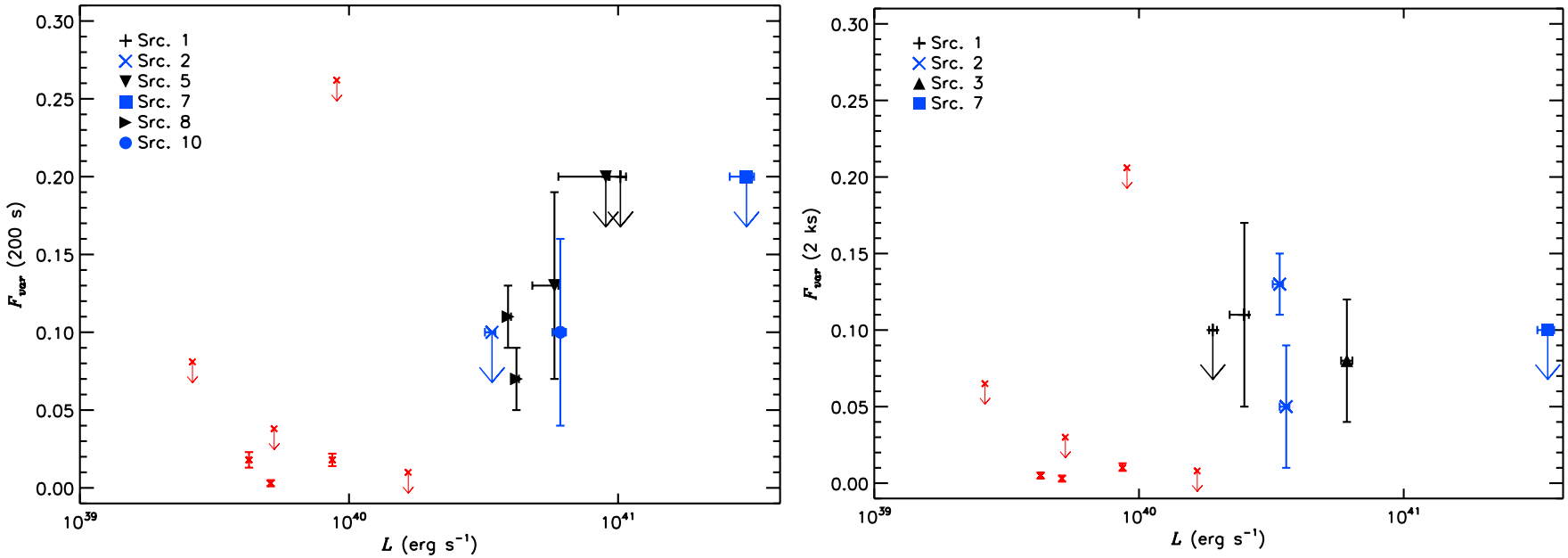


Spectra compared to other ULXs



Brightest ULX appear to be spectrally harder than general population (cf. also Berghea et al. 2008)

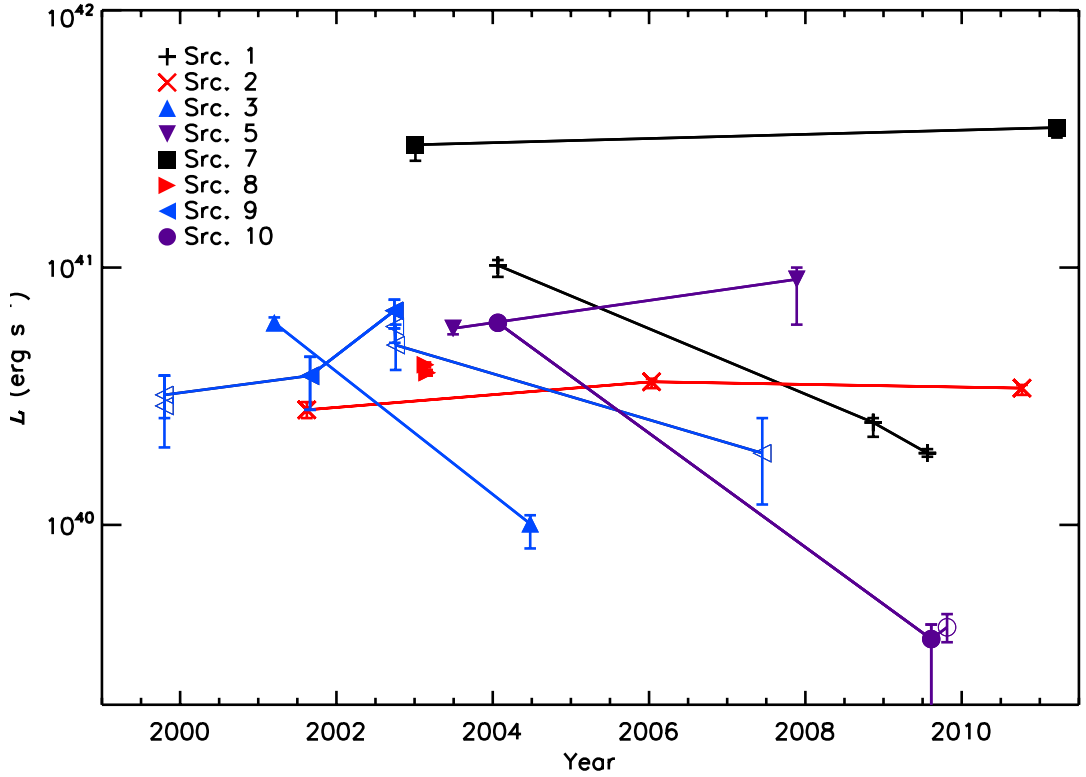
Variability compared to other ULXs



Fractional variability on 200 s and 2 ks timescales: brighter objects appear more variable

Longer term luminosity variability

Long term variability: data sparse, but some appear persistent, some decay in flux



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Do the brightest ULXs harbour IMBHs?

- X-ray data: brightest objects may be spectrally harder and more variable than ‘classic’ ULXs
- Locations: but found in similar habitats
- What are they? Alternatives:
  - IMBHs not ruled out!
  - Rare examples of hyper-accretion plus big stellar black hole (Zampieri & Roberts 2009)
  - Undiagnosed contaminants (QSOs, SNe, ...?)

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Conclusions

- Well-rehearsed spectral & temporal arguments for ULXs as super-Eddington accretors below ~ 2×10^{40} erg s^{-1}
  - Key: radiatively-driven wind
- But the brightest ULXs show signs of different behaviour – evidence for IMBHs?
- REQUIRES BETTER DATA
  - Multi-wavelength follow-up, deep X-ray obs.
  - Excellent targets for *ATHENA*