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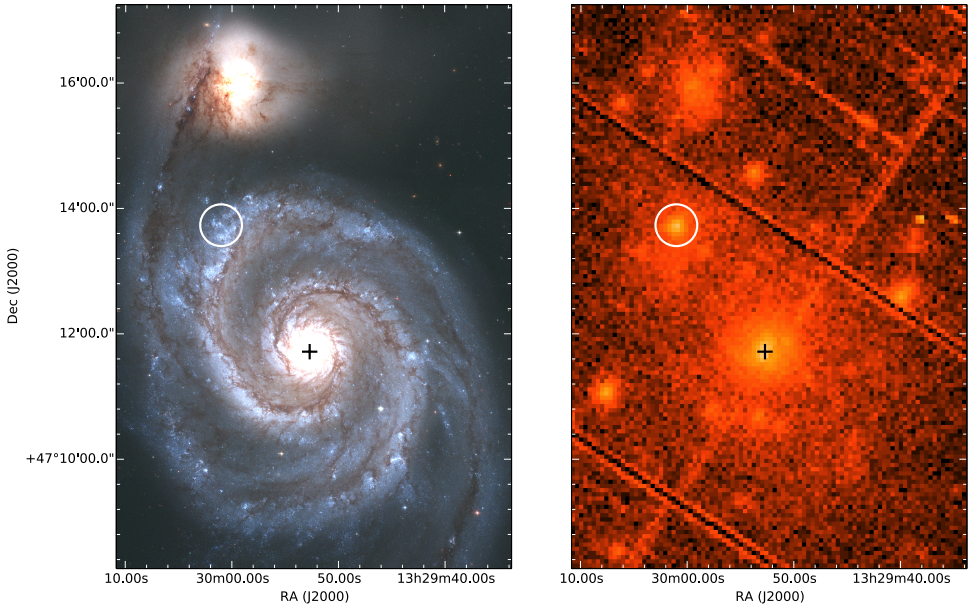
An IMBH candidate in M51?



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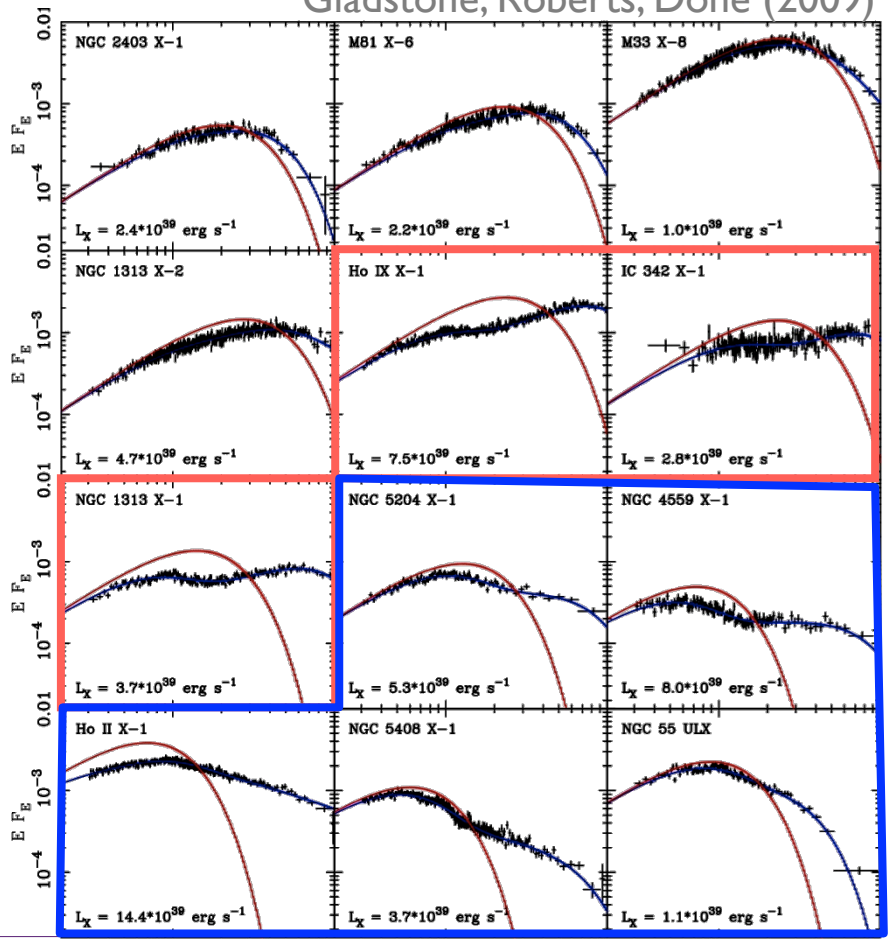
ULX X-ray Spectra

- Three spectral states different from sub-Eddington accretion:
  - Broadened disc
  - Hard ultraluminous
  - Soft ultraluminous
- Variability in soft ultraluminous state
  - Soft clumpy wind

Gladstone, Roberts, Done (2009)



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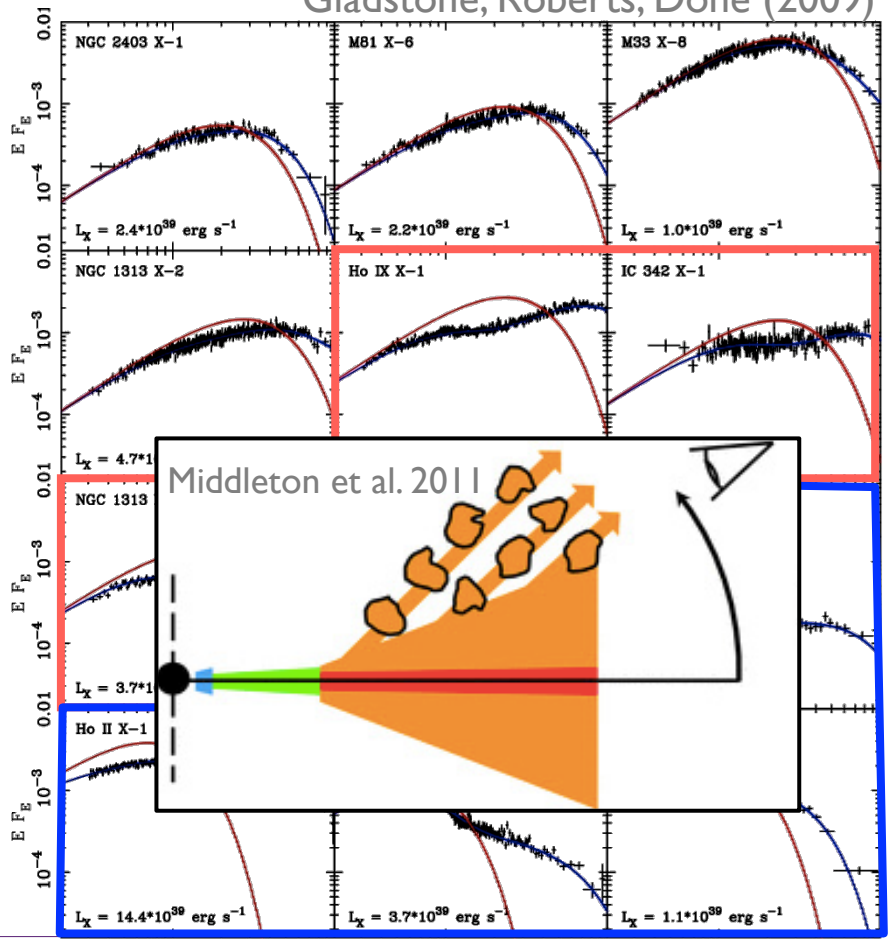

A new catalogue of ULXs

- We have been creating a new, clean catalogue of ULX candidates from 3XMM-DR4
  - 331 ULX candidates – 136 do not appear in other catalogues and 73 are new to 3XMM-DR4
- We have used this catalogue to search for interesting sources e.g. variable ULXs
  - 10 sources in the catalogue flagged as variable

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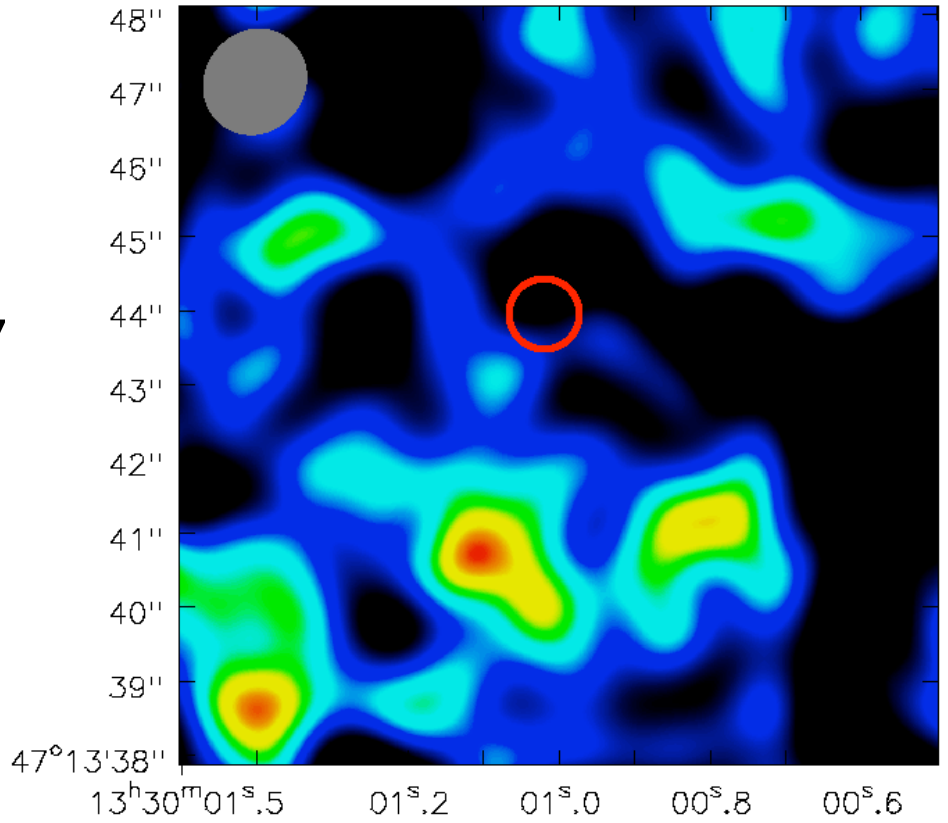
M51a ULX-7 – an interesting source!

- Is strongly variable with 30-40% rms in all observations, but has a hard spectrum
  - This does not match the behaviour seen in most other ULXs!
- Well-observed source:
  - 6 XMM-Newton observations, 12 Chandra observations, also detected in NuSTAR
- Found to be variable in previous studies of M51 ULXs e.g. Liu et al. (2002), Dewangan et al. (2005), Terashima et al. (2006) etc.

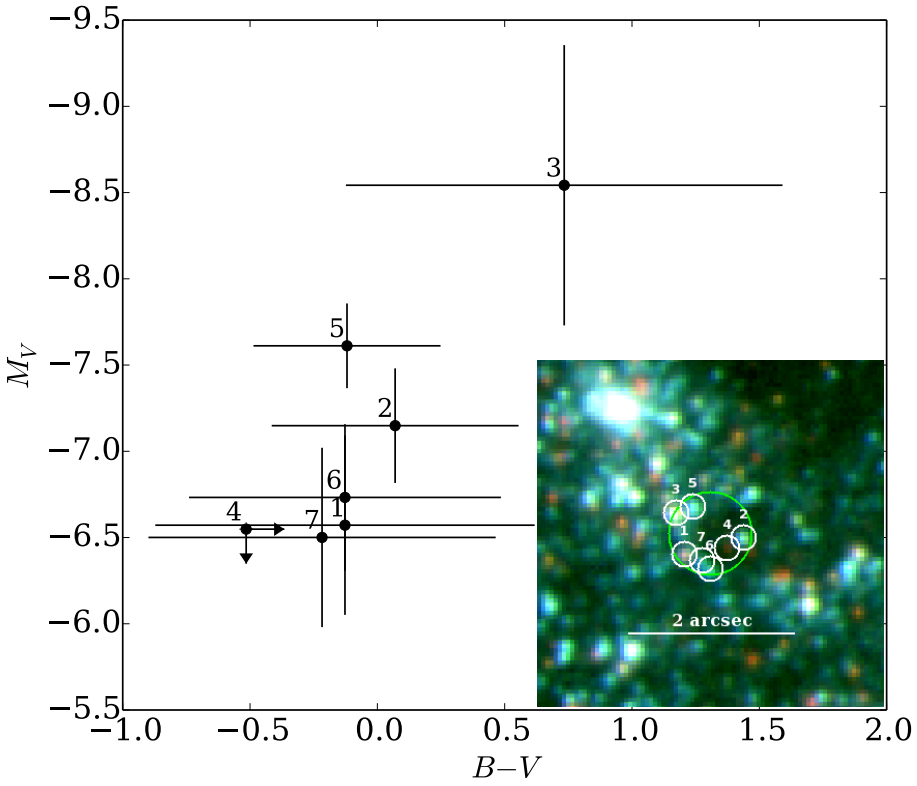
Observational results – radio

- No radio detection within 1” of ULX-7
- Upper limit on the 1.5 GHz flux density of 87 μJy/beam



Observational results – optical

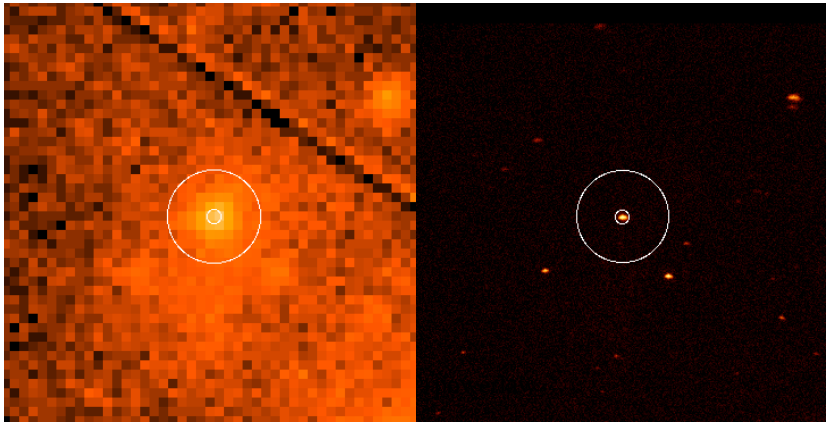
- Seven potential counterparts in HST data characterised using DAOPHOT
- Most counterparts consistent with being OB type supergiants
- $\log_{10}(F_{X,max}/F_{opt}) > 1$ for all counterparts

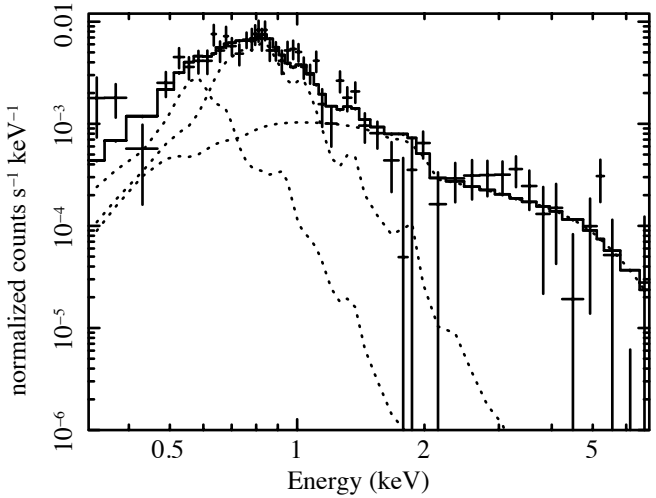


Observational results – X-ray spectra

- We account for extended diffuse emission using Chandra data
- Diffuse emission well-fitted with two MEKAL components

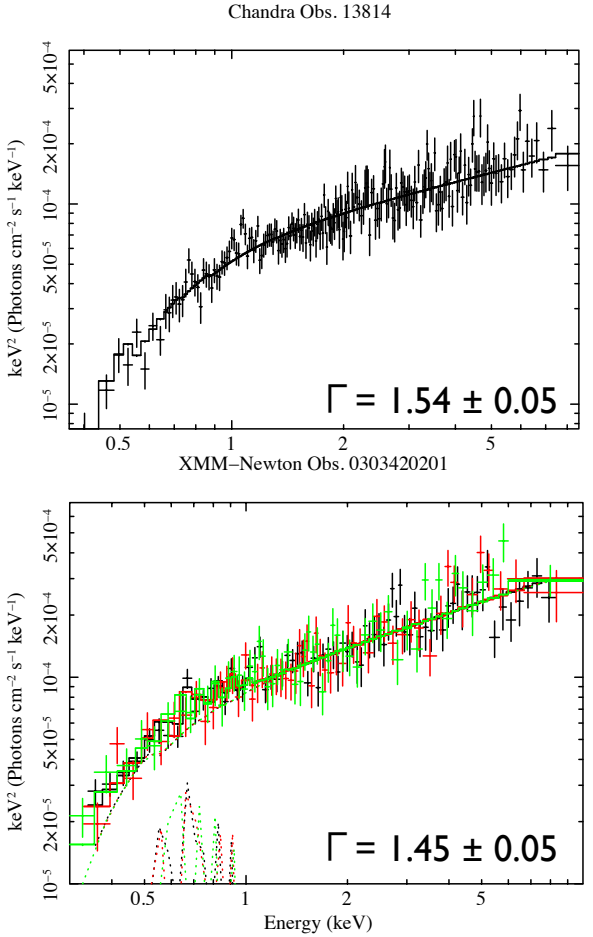
kT_1 (keV)	kT_2 (keV)	χ^2 / d.o.f.
0.26 ± 0.04	0.8 ± 0.2	279.9 / 258





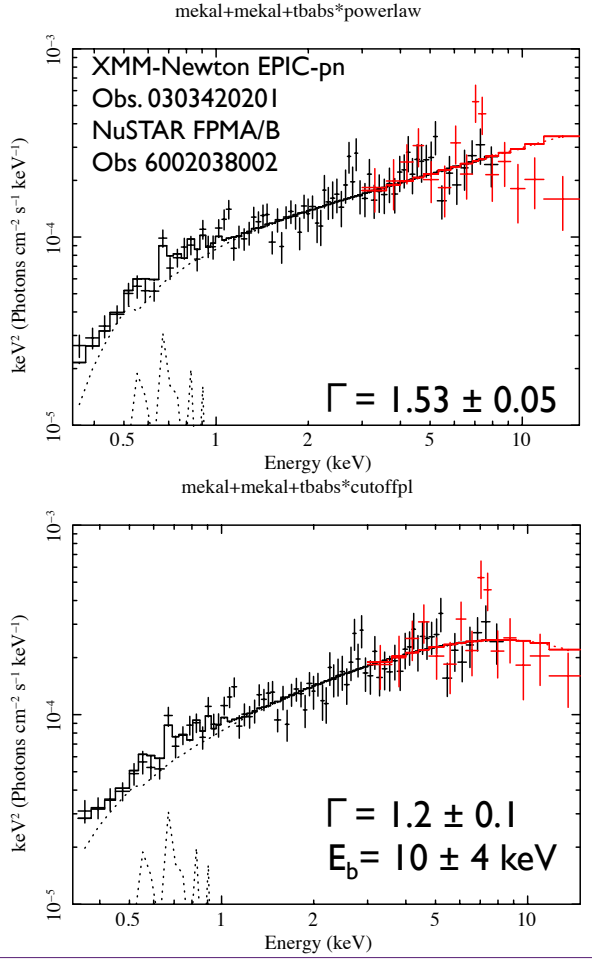
Observational results – X-ray spectra

- XMM-Newton and Chandra spectra consistently hard with $\Gamma \sim 1.5$
- No strong evidence for a disc once diffuse emission is accounted for



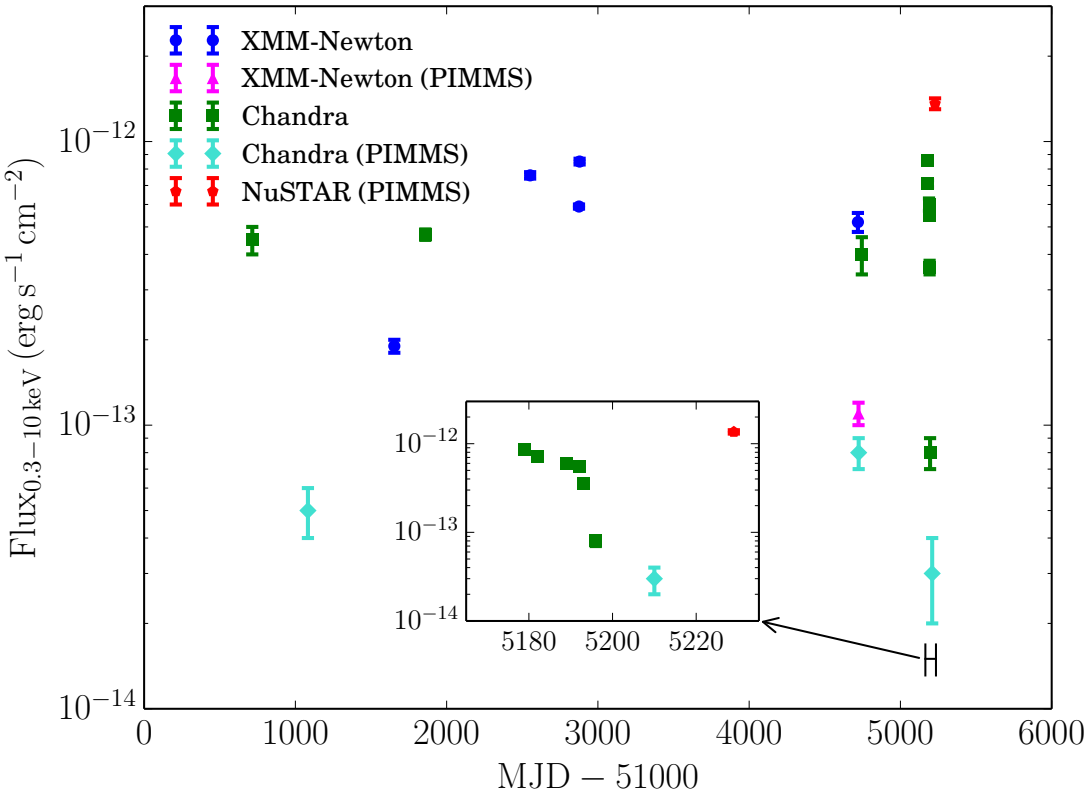
Observational results – X-ray spectra

- We fit NuSTAR data alongside XMM-Newton spectrum nearest in flux
- Hints at a turnover BUT:
  - Observations not simultaneous!
  - Data is noisy and contaminated by other hard sources
  - Not significant when fitted with any other XMM-Newton observations



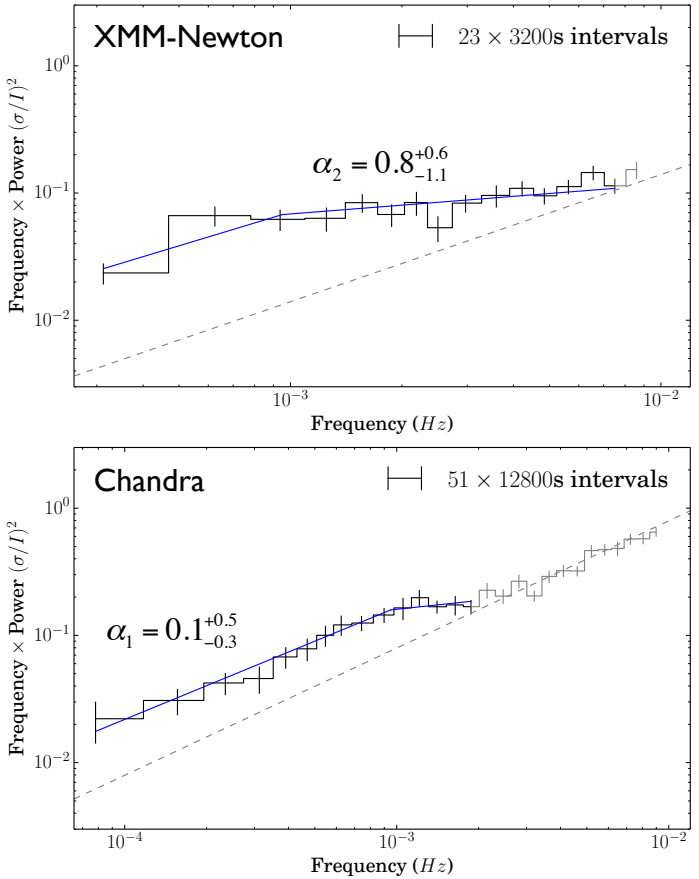
Observational results – X-ray timing

- Large dynamic range over 12 years
- No significant change in spectral shape over time



Observational results – X-ray timing

- 30-40% rms for most observations, consistent for all energies
- PSD break at 10^{-3} Hz, from $\alpha \sim 0$ to $\alpha \sim 1$:
  - Analogous to low frequency break of the low/hard state



What is it?

- ‘Normal’ stellar mass ULX?
  - Spectral/variability behaviour different
- Background AGN?
  - Optical counterparts consistent with OB stars
  - High X-ray/optical flux ratio
  - High frequency variability
- Neutron star ULX?
  - No coherent pulsations found
  - Doesn’t look like a Z source e.g. LMC X-2

What is it?

- IMBH in a low/hard state?
  - Consistent hard X-ray spectrum ($\Gamma \sim 1.5$)
  - No radio detection, upper limit of 87 μJy/beam
    - Mass upper limit of $M_\bullet < 1.95 \times 10^5\ M_\odot$
  - Power spectrum features a low-frequency break
    - Mass upper limit of $M_\bullet < 9.12 \times 10^4\ M_\odot$
  - Counterpart colours consistent with OB stars
  - NuSTAR results ambiguous as to whether turnover exists at high energies

M51 ULX-7 – Summary

- We have found an unusual ULX with a hard X-ray spectrum and high short-term variability
- Does not behave like a 'normal' ULX, and is not a background AGN
- Neutron star not ruled out
- Also consistent with being an IMBH
- Needed: simultaneous deep observations with both XMM-Newton and NuSTAR