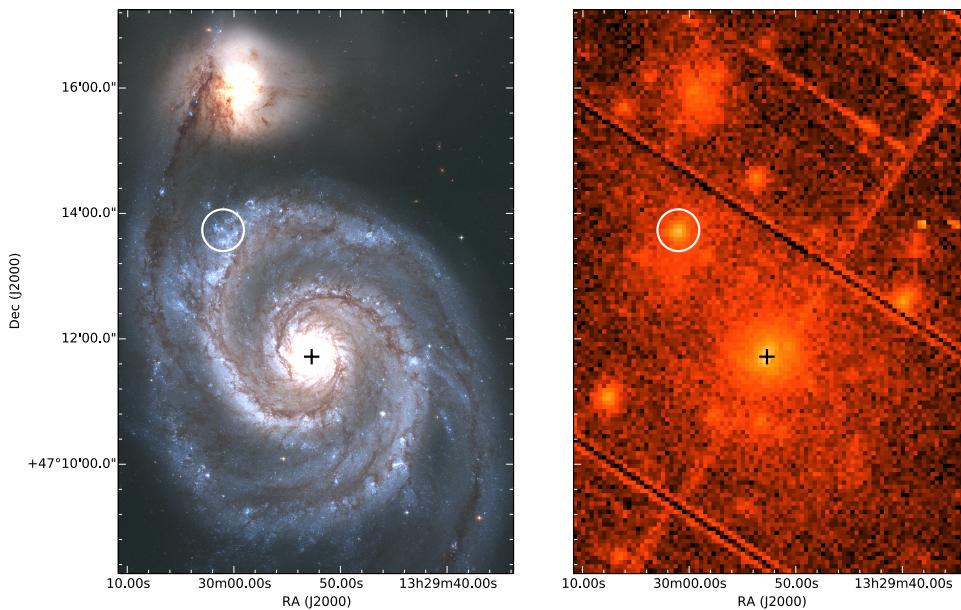


# An IMBH candidate in M51?

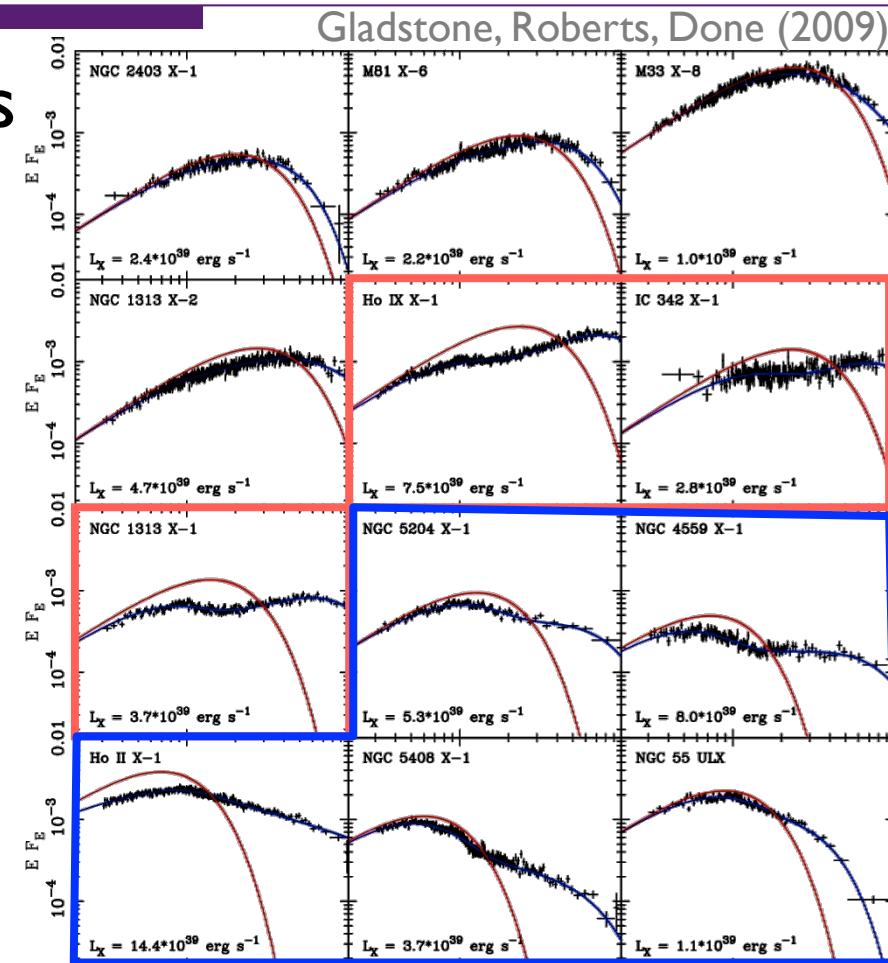


**Hannah M Earnshaw**  
Tim Roberts (Durham)

Chris Done (Durham)  
Fiona Harrison (Caltech)  
Lucy Heil (Amsterdam)  
George Lansbury (Durham)  
Mar Mezcua (CfA)  
Matthew Middleton (Cambridge)  
Andrew Sutton (MSFC)  
Dom Walton (Caltech)

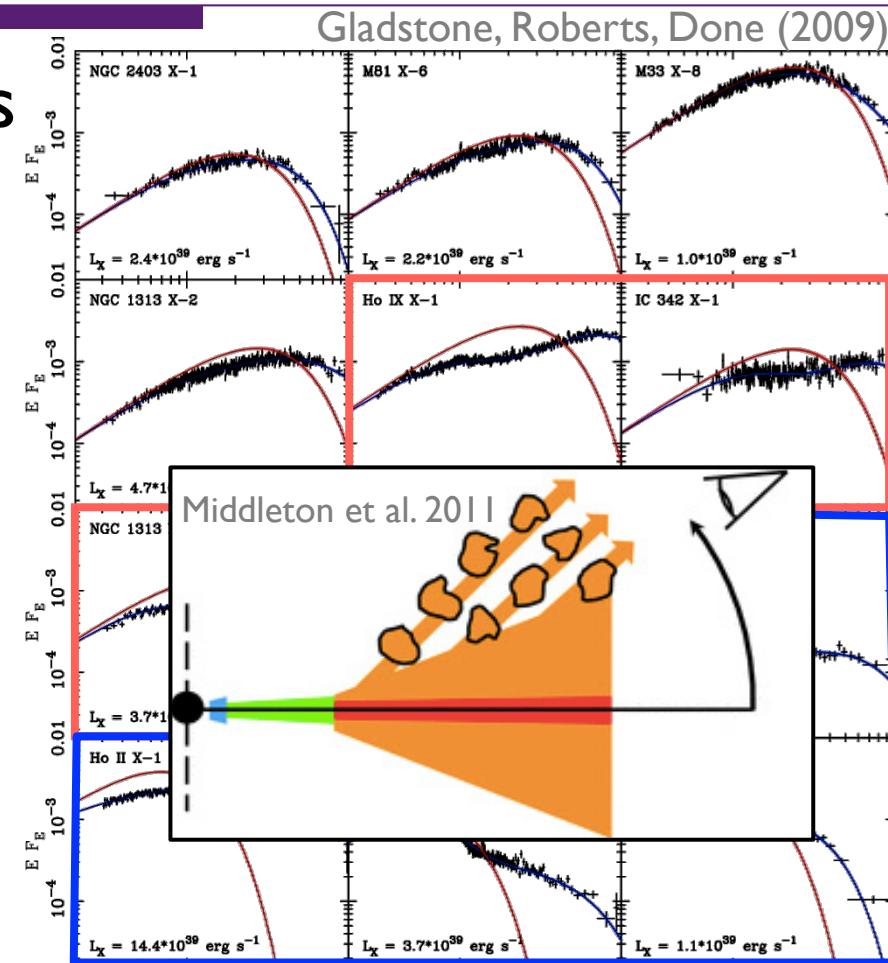
# ULX X-ray Spectra

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



# ULX X-ray Spectra

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# A new catalogue of ULXs

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- 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

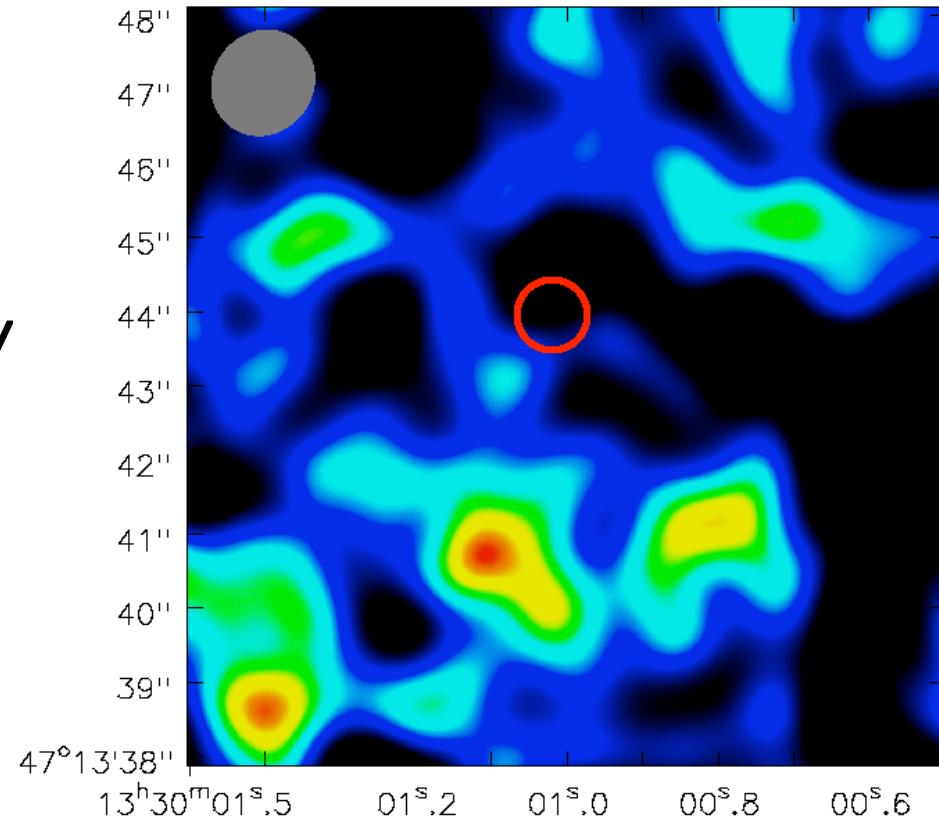
# M5 Ia ULX-7 – an interesting source!

---

- 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 M5 I ULXs e.g. Liu et al. (2002), Dewangan et al. (2005), Terashima et al. (2006) etc.
-

# Observational results – radio

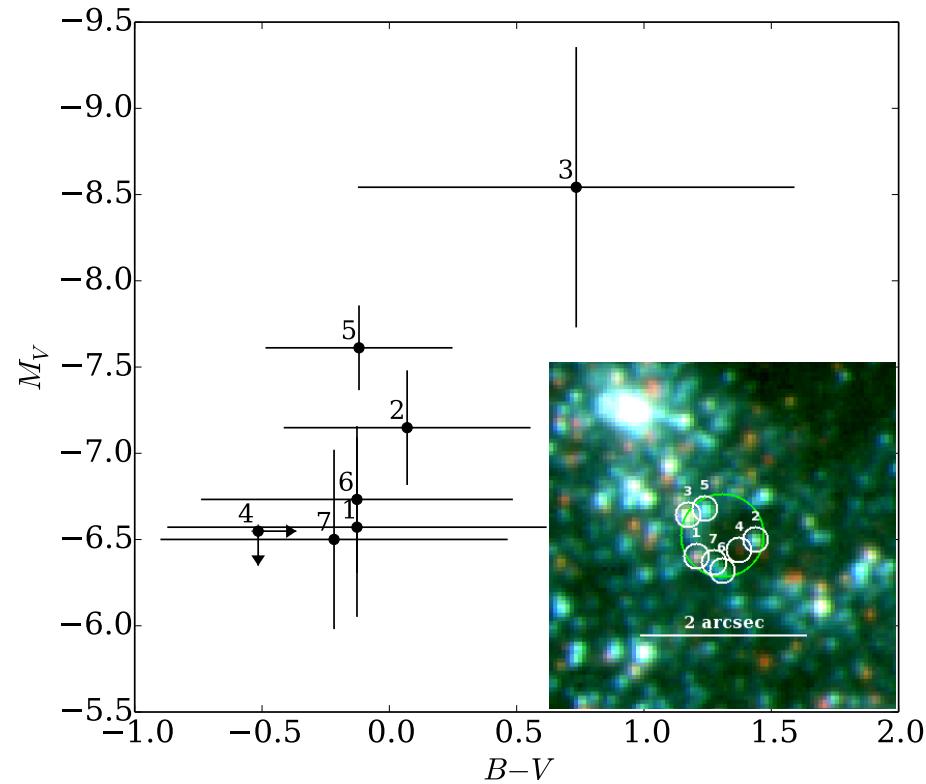
- No radio detection within 1" of ULX-7
- Upper limit on the 1.5 GHz flux density of 87  $\mu$ Jy/beam



# Observational results – optical

---

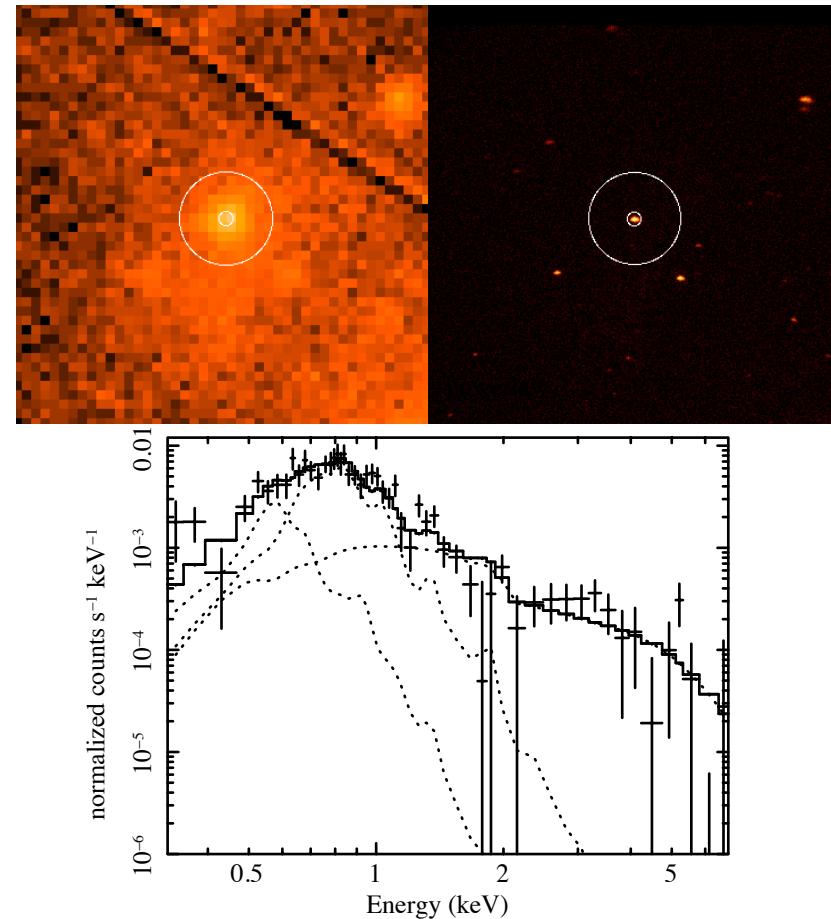
- Seven potential counterparts in HST data characterised using DAOPHOT
- Most counterparts consistent with being OB type supergiants
- $\log_{10}(F_{X,\max}/F_{\text{opt}}) > 1$  for all counterparts



# Observational results – X-ray spectra

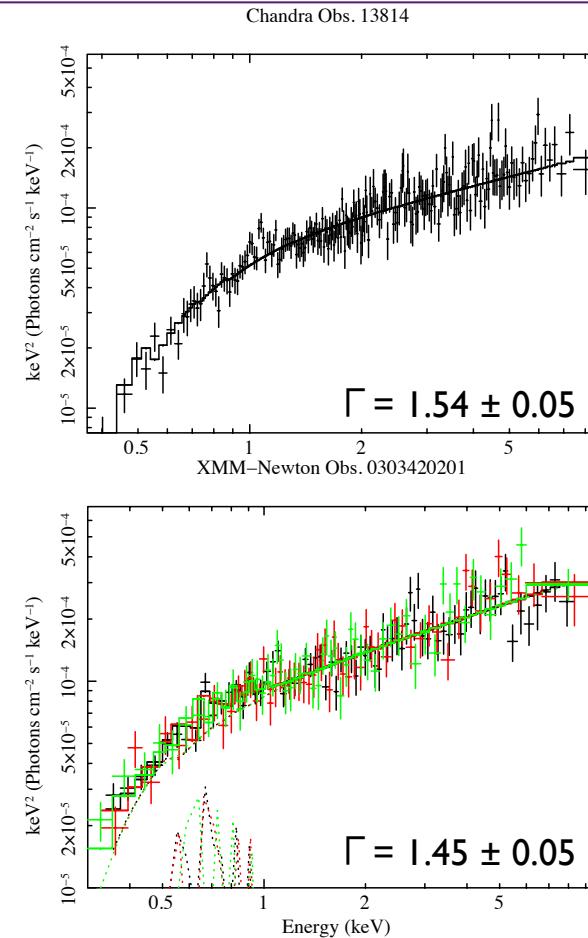
- We account for extended diffuse emission using Chandra data
- Diffuse emission well-fitted with two MEKAL components

$kT_1$ (keV)	$kT_2$ (keV)	$\chi^2 / \text{d.o.f.}$
$0.26 \pm 0.04$	$0.8 \pm 0.2$	$279.9 / 258$



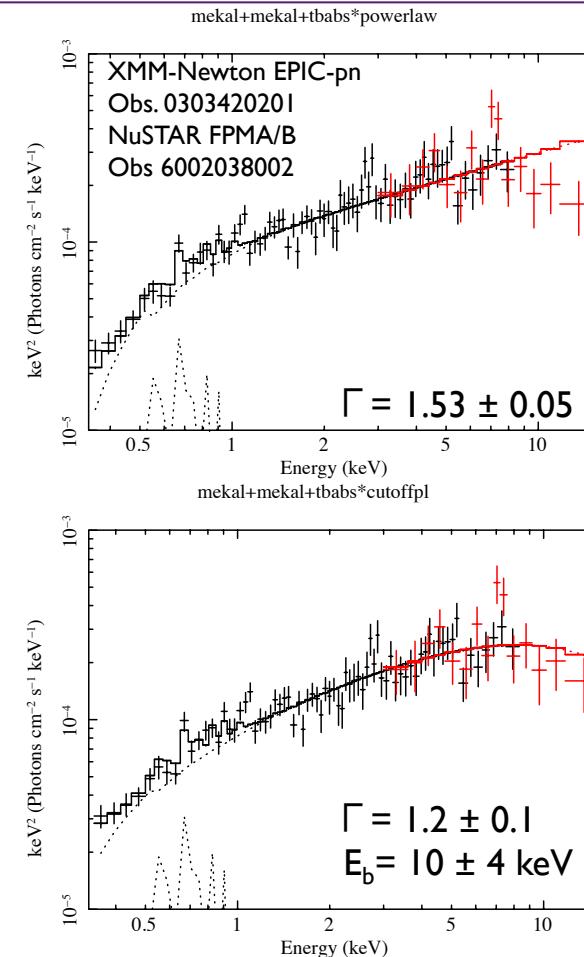
# Observational results – X-ray spectra

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



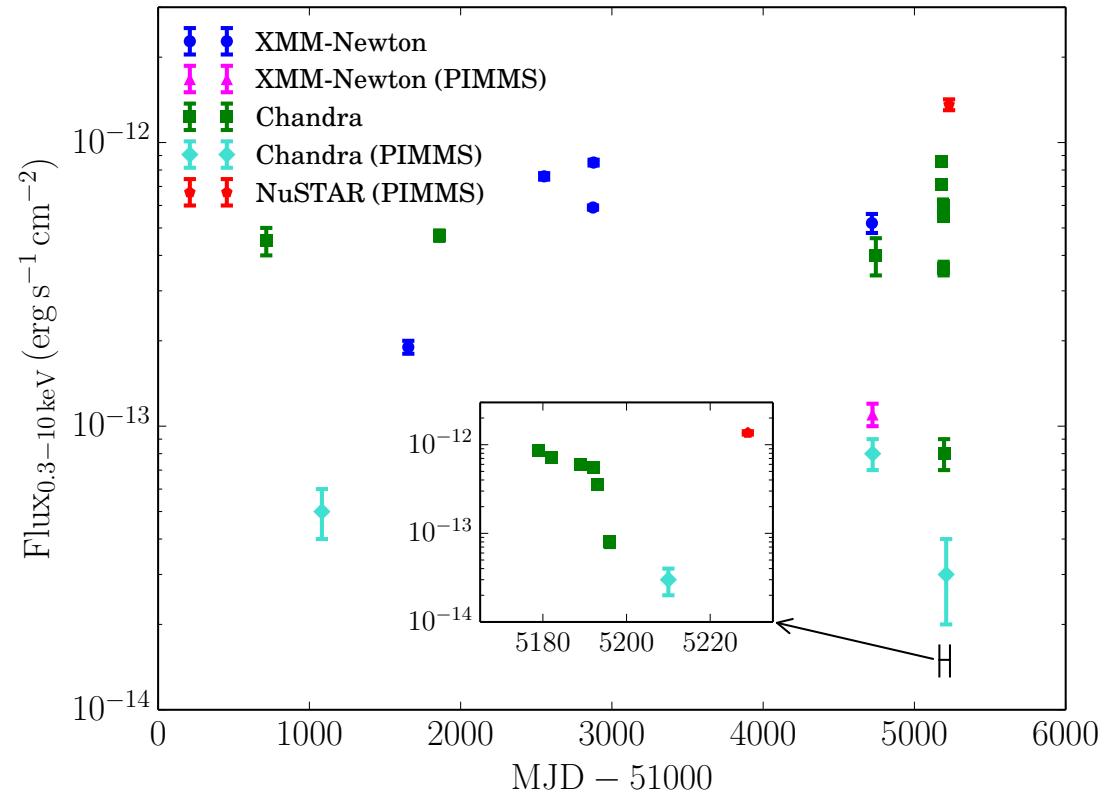
# Observational results – X-ray spectra

- 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

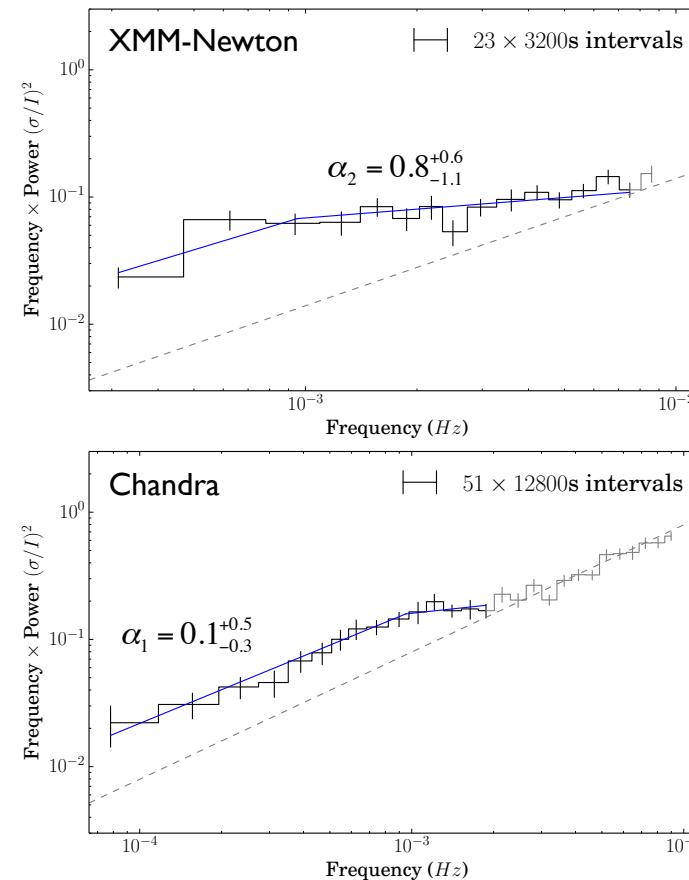
- Large dynamic range over 12 years
- No significant change in spectral shape over time



# Observational results – X-ray timing

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- 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?

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- ‘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  $87 \mu\text{Jy}/\text{beam}$ 
    - Mass upper limit of  $M_* < 1.95 \times 10^5 M_\odot$
  - Power spectrum features a low-frequency break
    - Mass upper limit of  $M_* < 9.12 \times 10^4 M_\odot$
  - Counterpart colours consistent with OB stars
  - NuSTAR results ambiguous as to whether turnover exists at high energies

# M51 ULX-7 – Summary

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- 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