

'Harder when Brighter' Behaviour in Low-Luminosity AGN



Sam Connolly

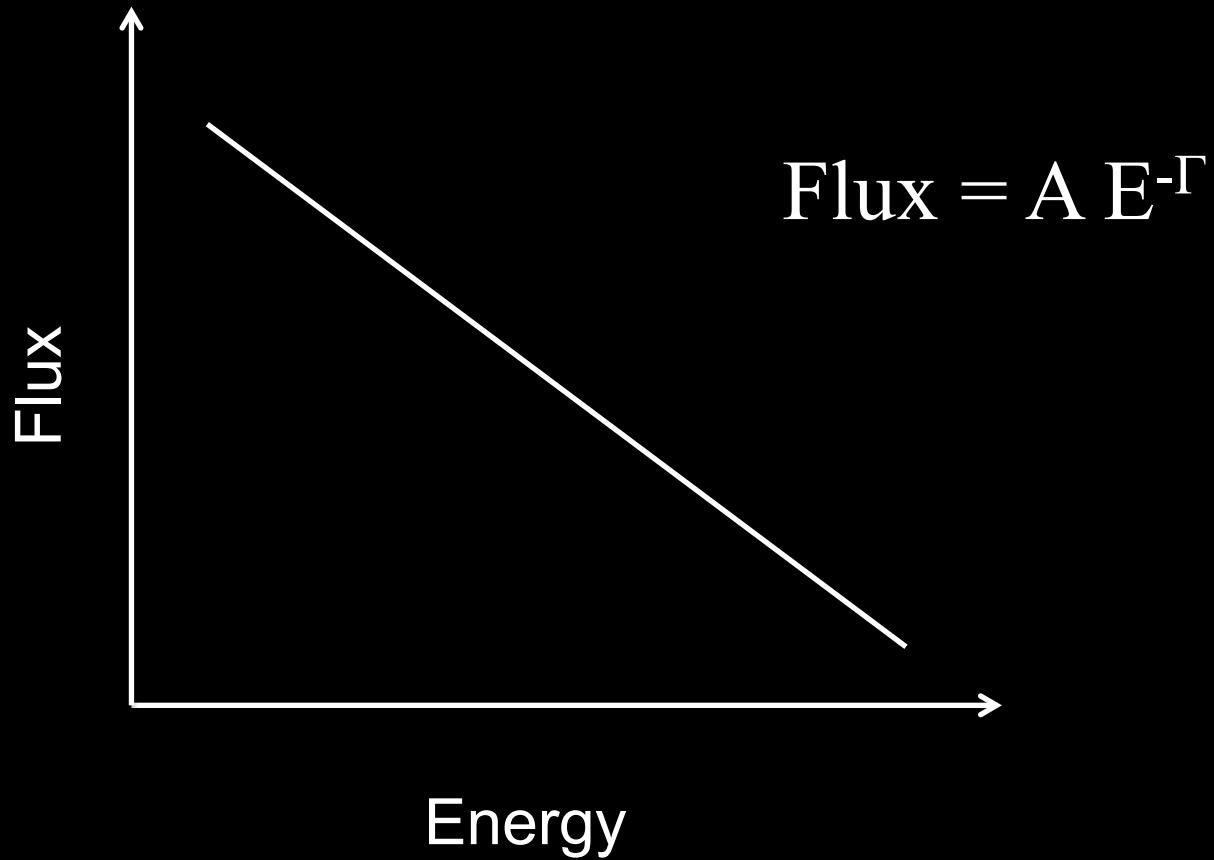
Ian McHardy, Chris Skipper, Dimitrios Emmanoulopoulos

University of Southampton

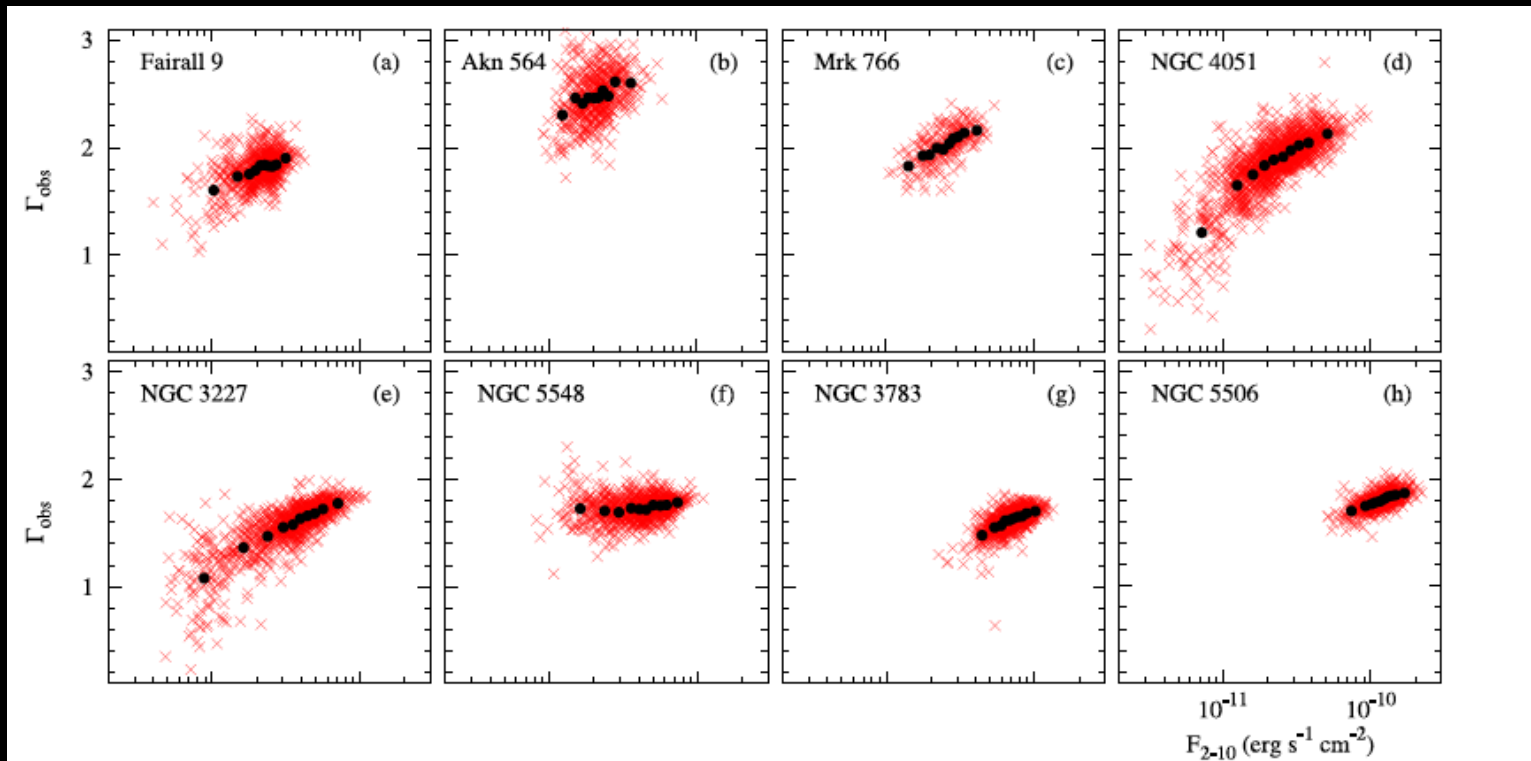
The Extremes of Black Hole Accretion

ESAC.2015

AGN X-ray Spectra



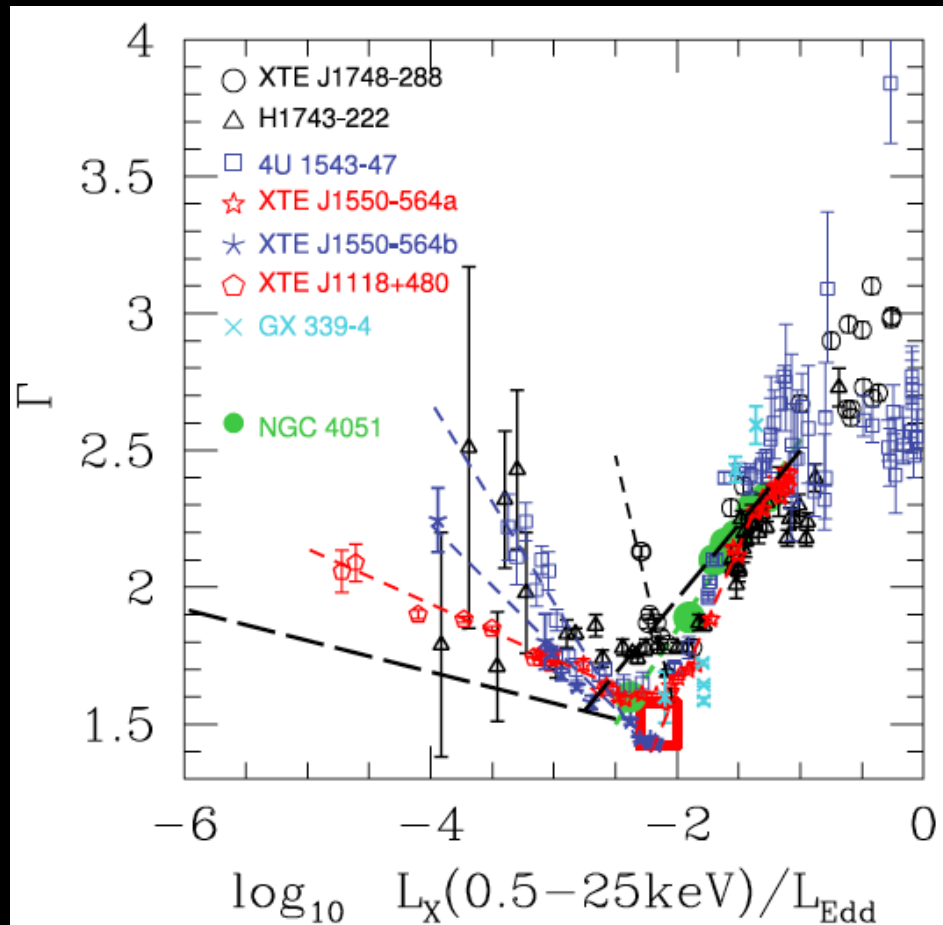
'Softer when Brighter' AGN



Sobolewska & Papadakis 2009

- Correlation between photon index and accretion rate
- Higher accretion rate leads to greater supply of soft photons, decreasing the Compton parameter.

Black Hole X-ray Binaries

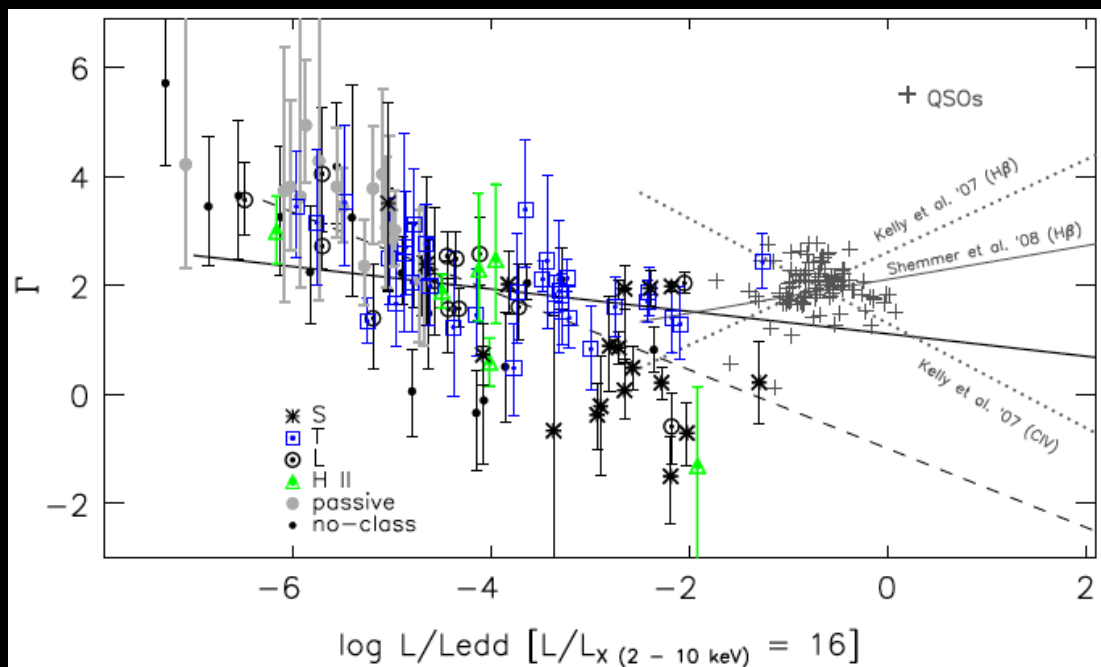
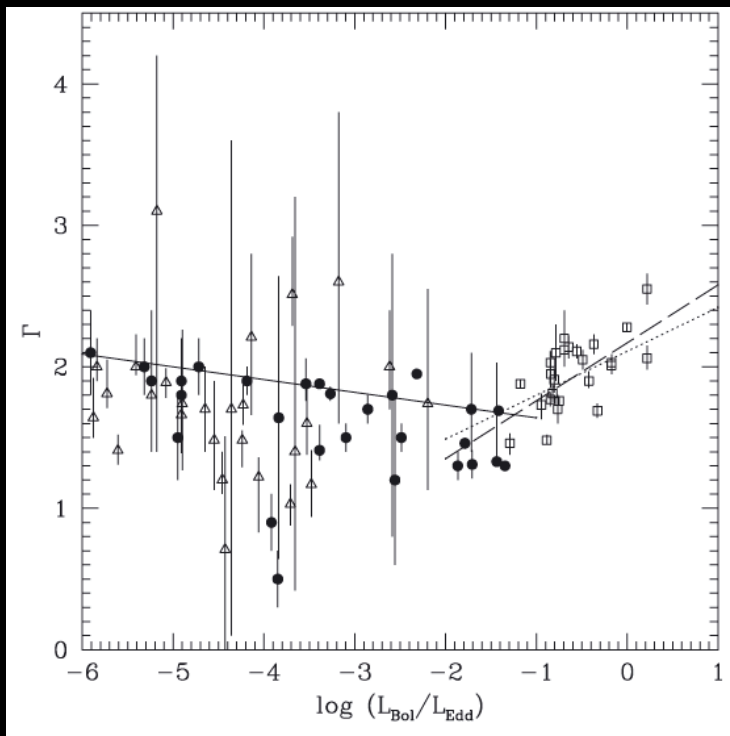


Wu & Gu 2008

- 'Softer when brighter' at high Eddington ratio
- 'Harder when brighter' at low Eddington ratio

'Harder when Brighter' Behaviour in Samples of AGN

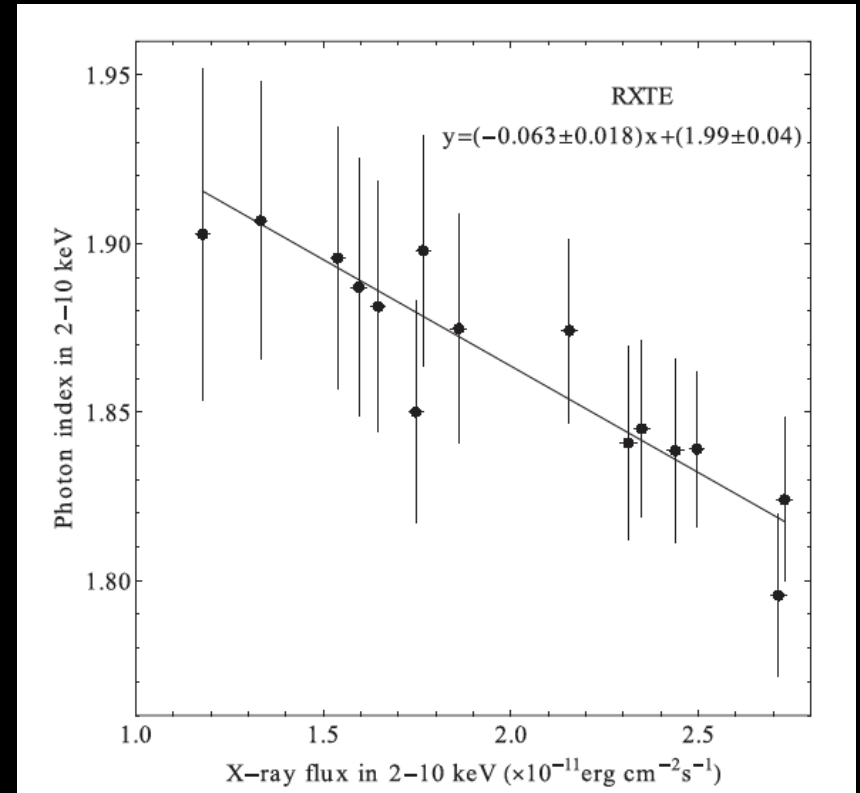
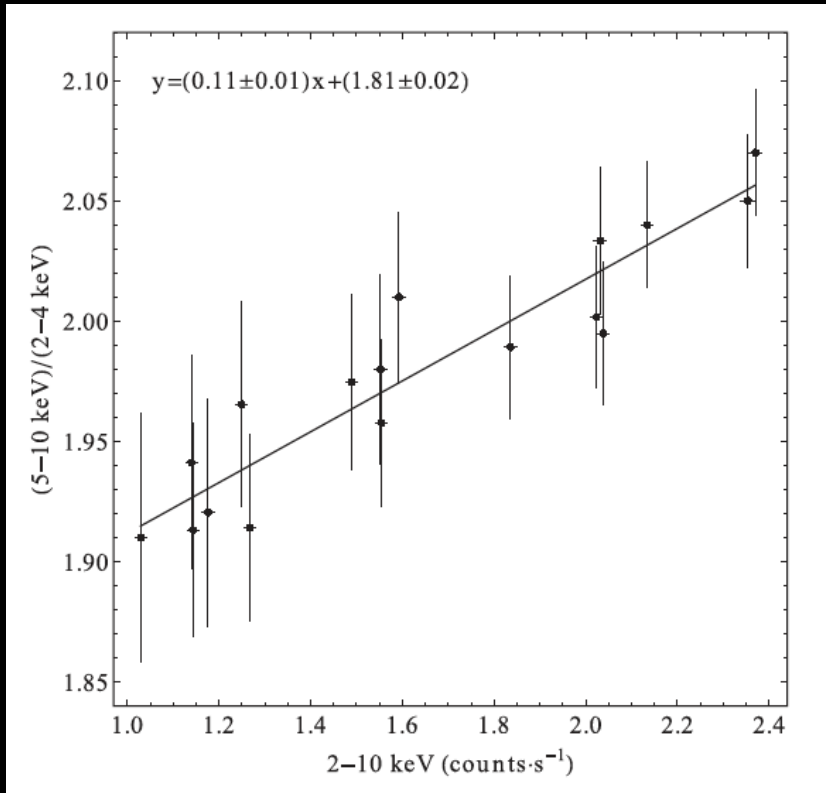
Gu & Cao 2009



Constantin et al. 2009
(+ Shemmer et al. 2006)

NGC 7213

Harder when brighter behaviour in a single AGN

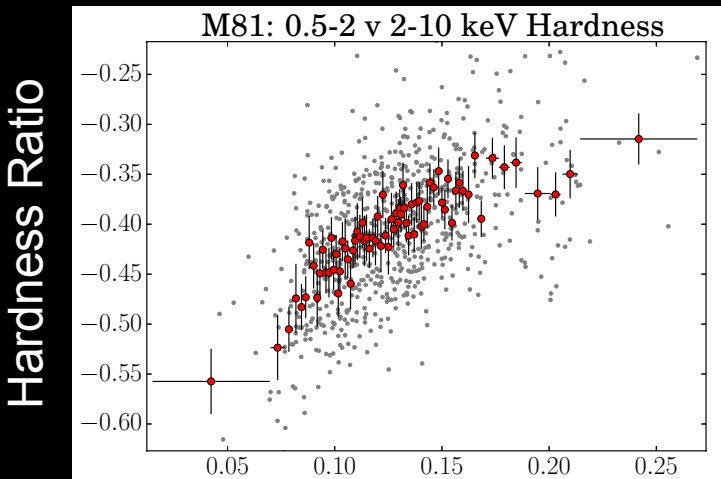


- Only previous example of this behaviour in a single AGN

Emmanoulopoulos et al. 2012

Hardness Ratios

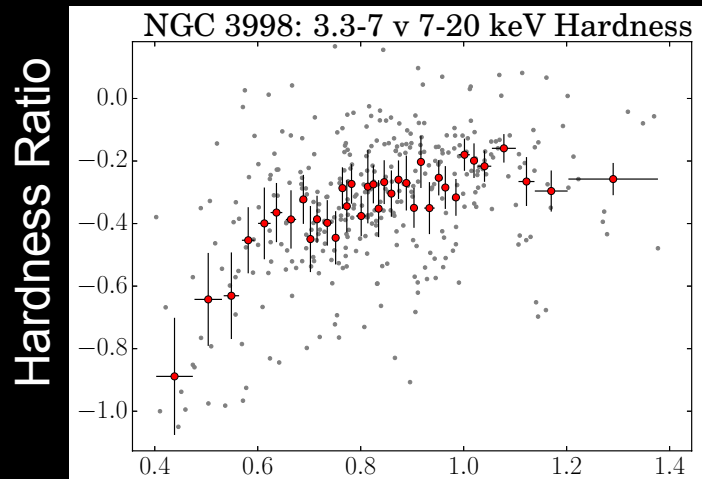
$6.7 \times 10^7 M_{\text{solar}}$ $3.4 \times 10^{-5} \dot{m}_{\text{Edd}}$



Hardness Ratio

Count Rate

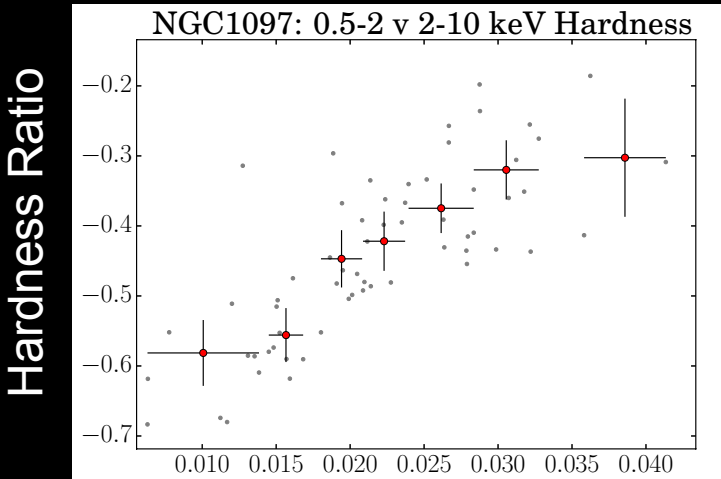
$7.9 \times 10^8 M_{\text{solar}}$ $2.0 \times 10^{-3} \dot{m}_{\text{Edd}}$



Hardness Ratio

Count Rate

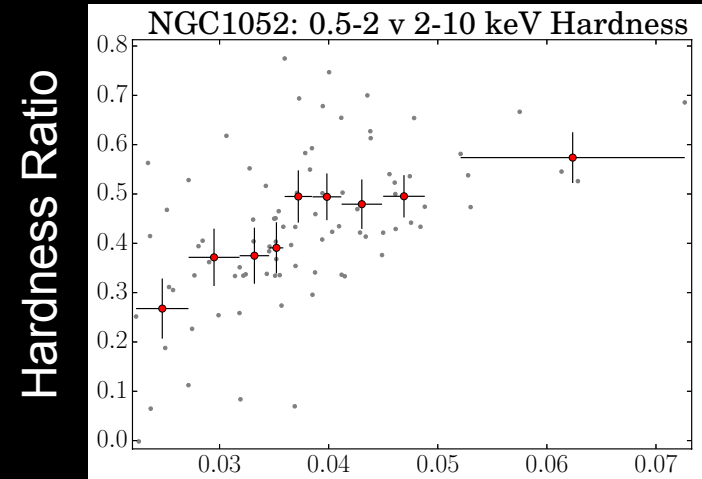
$1.25 \times 10^8 M_{\text{solar}}$ $5.7 \times 10^{-5} \dot{m}_{\text{Edd}}$



Hardness Ratio

Count Rate

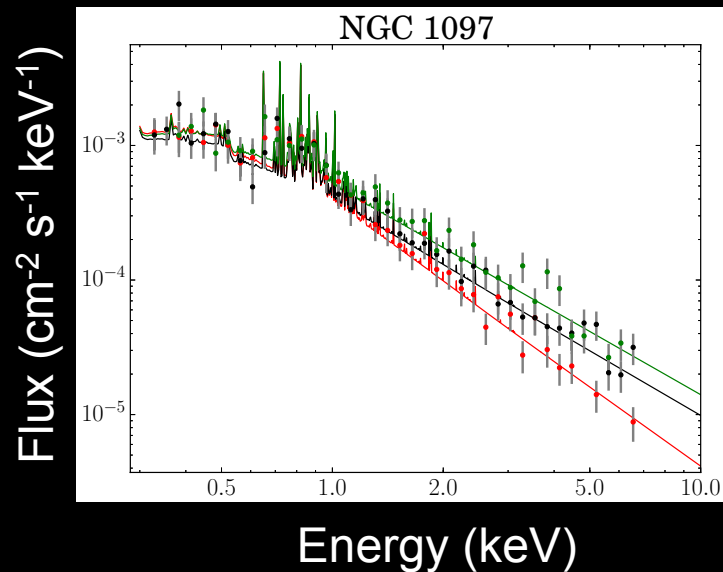
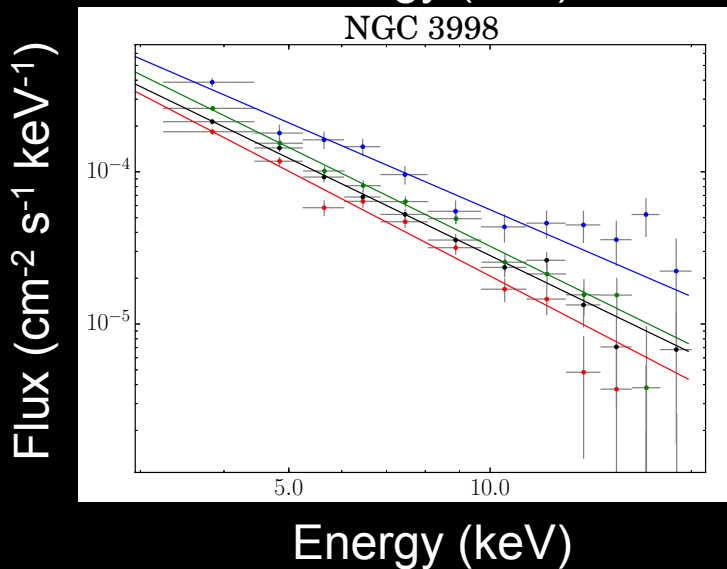
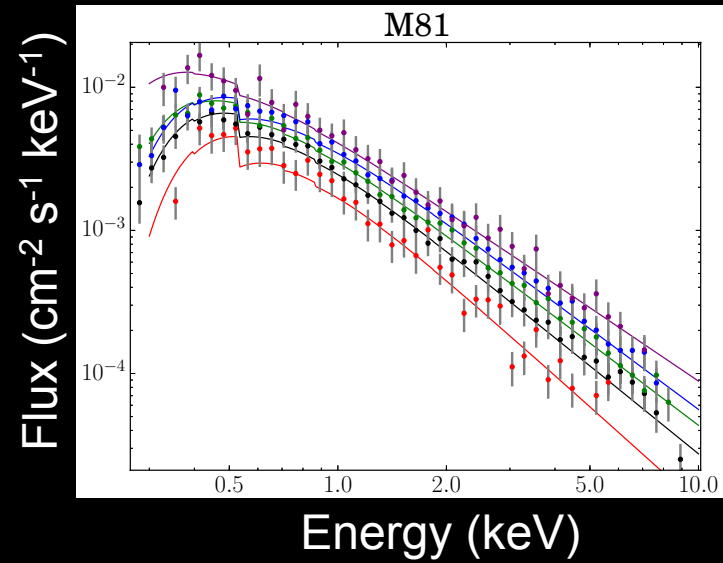
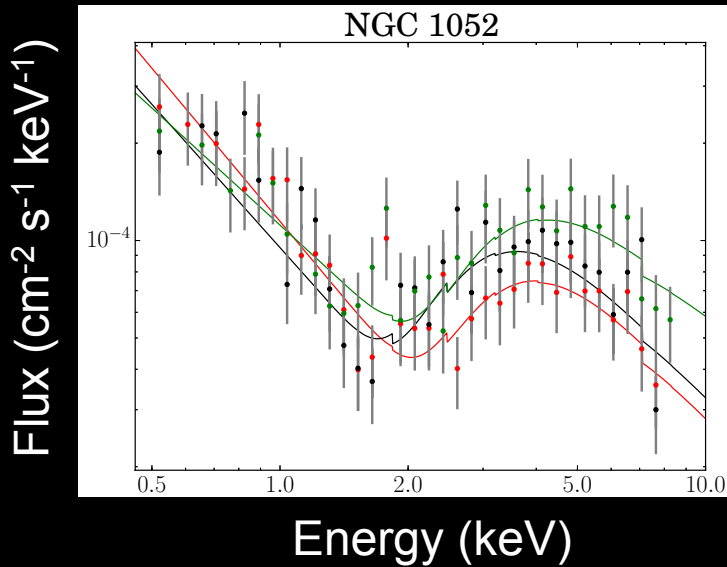
$1.99 \times 10^8 M_{\text{solar}}$ $7.2 \times 10^{-3} \dot{m}_{\text{Edd}}$



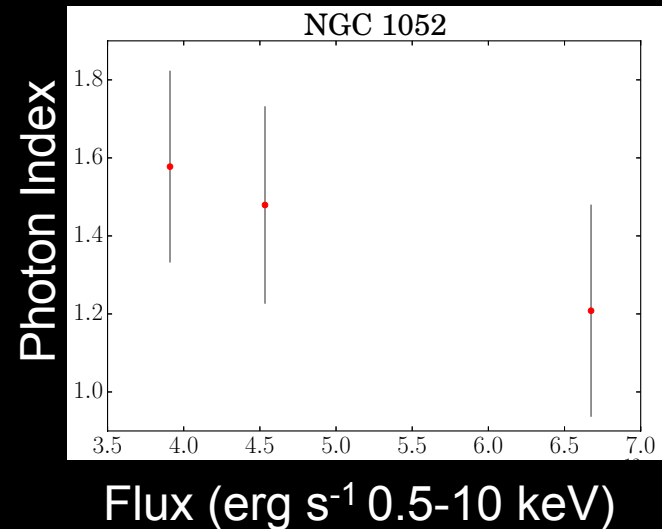
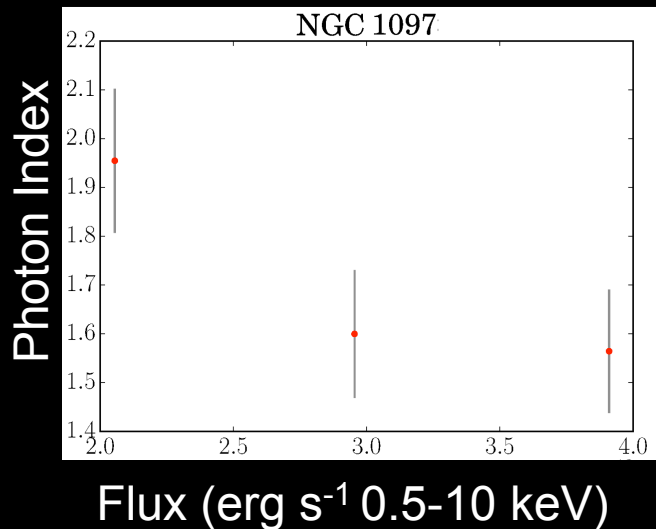
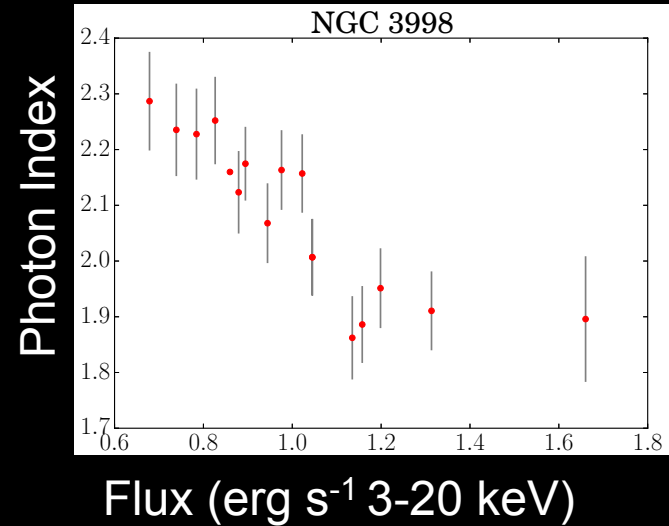
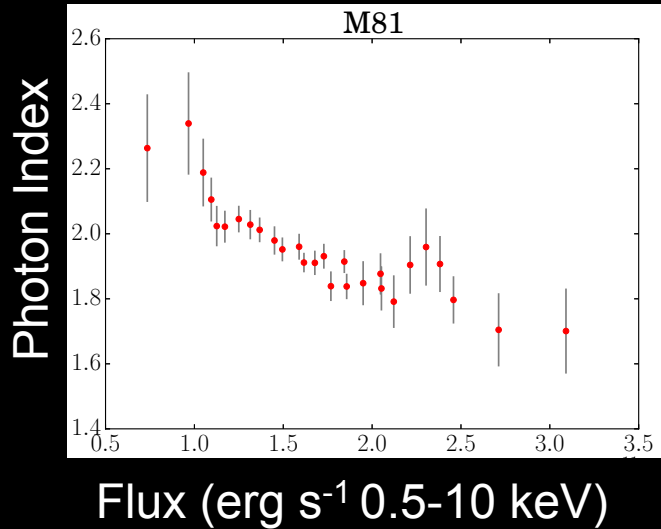
Hardness Ratio

Count Rate

X-ray Spectra

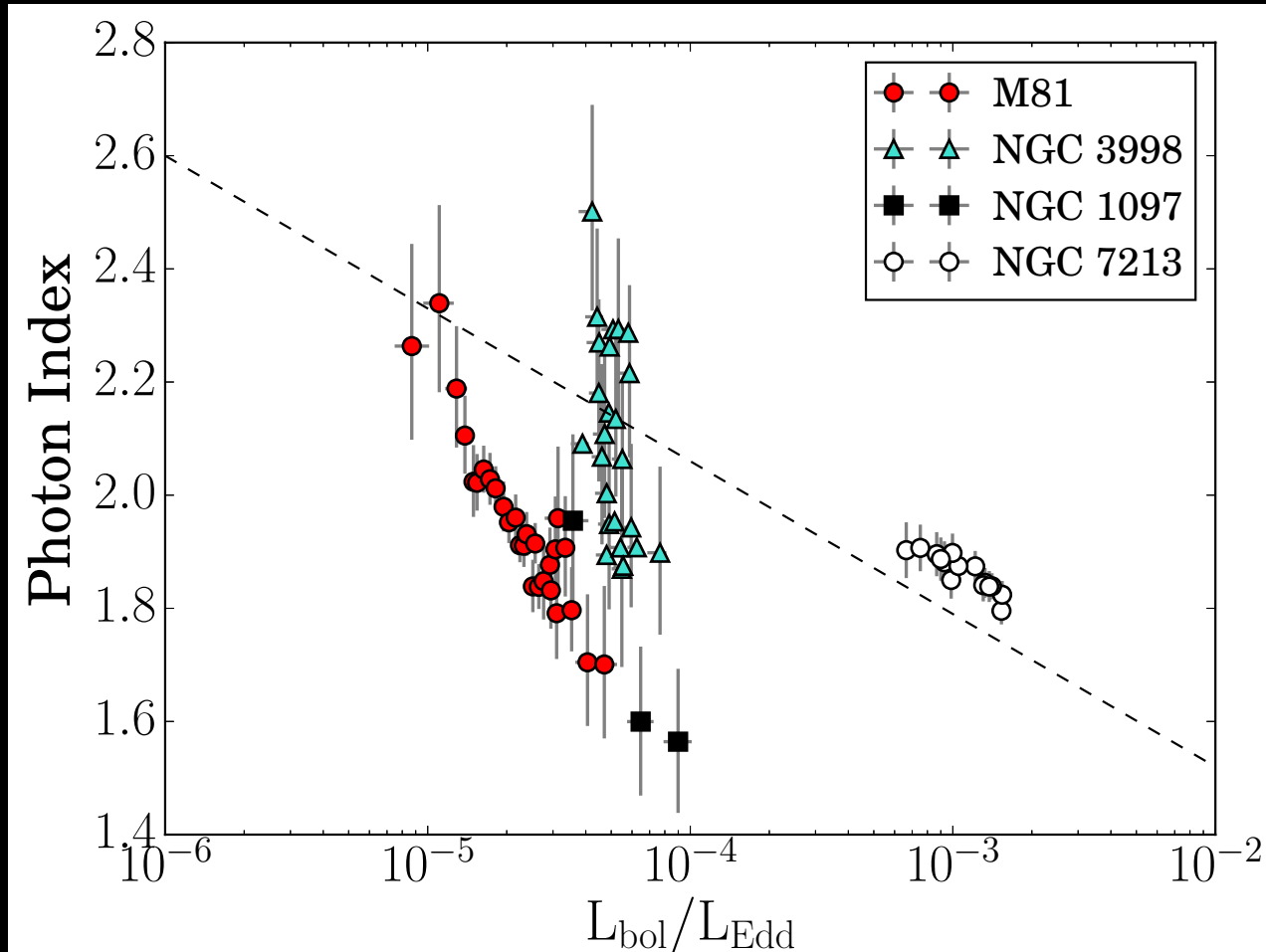


Photon Index-Luminosity Anticorrelation



Connolly et al. 2015 (submitted)

Comparison to accretion rate



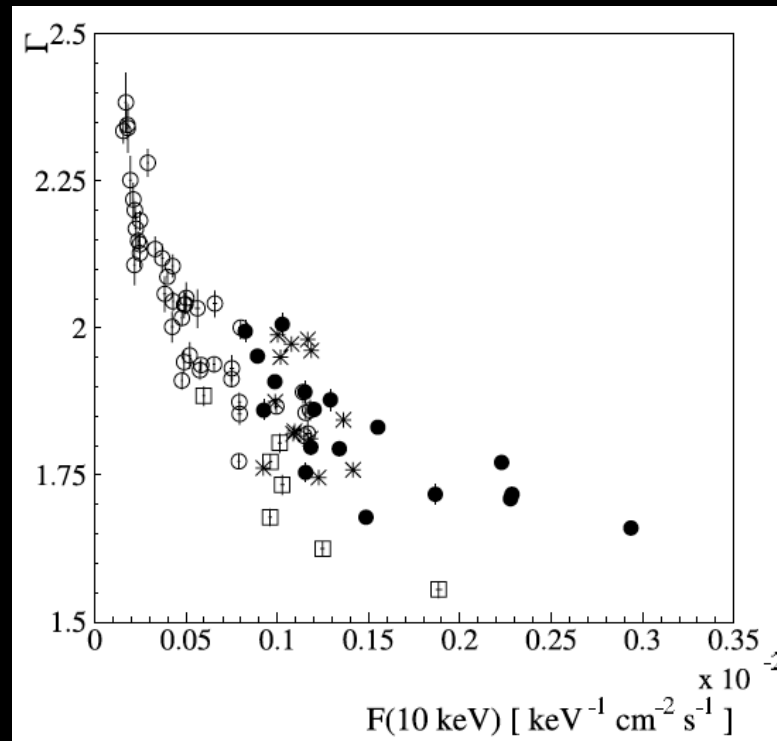
- Data compared to the fit of Constantin et al. 2009 to a sample of LLAGN

Connolly et al. 2015 (submitted)

Advection Dominated Accretion Flow

- ADAF models predict harder when brighter behaviour (e.g. Esin et al. 1997)
- Increase in accretion rate injects energy into electron population
- This leads to more high-energy synchrotron seed photons and a harder Compton-scattered X-ray spectrum

Jets: Harder when Brighter Behaviour in Blazars



1ES 1959+650, Krawczynski et al. 2004

- Synchrotron Self-Compton leads to an anticorrelation between accretion rate and photon index
- LLAGN much weaker, unlikely to be main cause of spectral behaviour

Conclusions

- Four new LLAGN found to be 'harder when brighter'
- At least three show a Γ -luminosity anticorrelation
- Could be caused by ADAF and/or Jets
- Supports the theory that LLAGN are analogous to the low-hard state in BHXRBs