Piecing Together the X-ray Background: The Bolometric Output of AGN

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Active Galactic Nuclei: Geometry of Emitting Regions

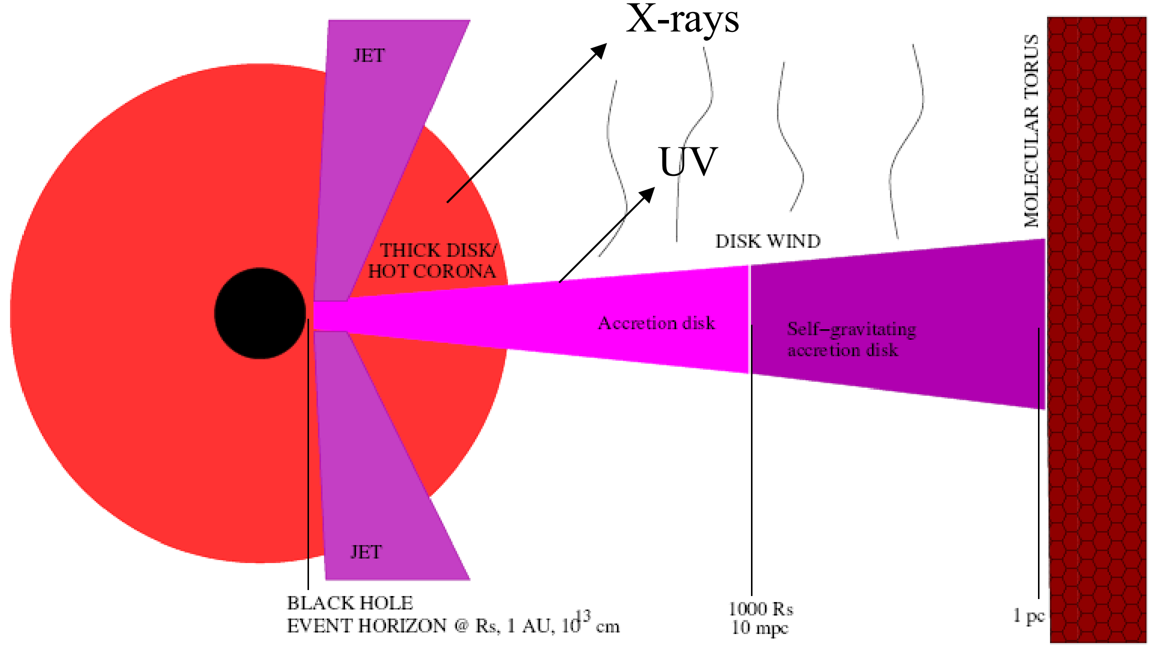
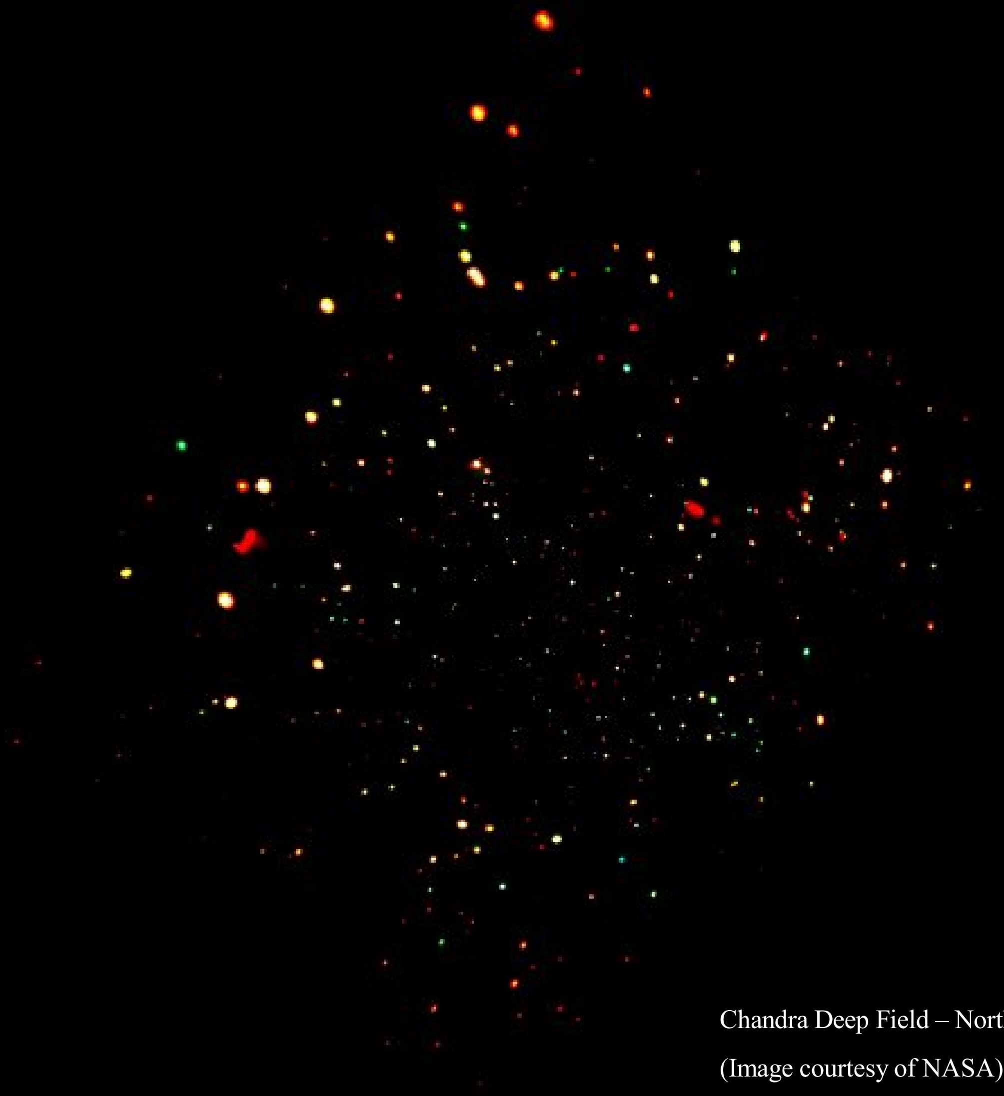


Figure 1.7: *Sketch of the inner parsec of an active galactic nucleus.*

Martin Krause (2007)

Active Galactic Nuclei: Combined Emission from AGN in the X-ray Background



Chandra Deep Field – North

(Image courtesy of NASA)

Accretion Makes Supermassive Black Holes: The Soltan Argument

Accretion makes massive black holes

$$\varepsilon(1+z) = 0.1\rho_{\bullet}c^2$$

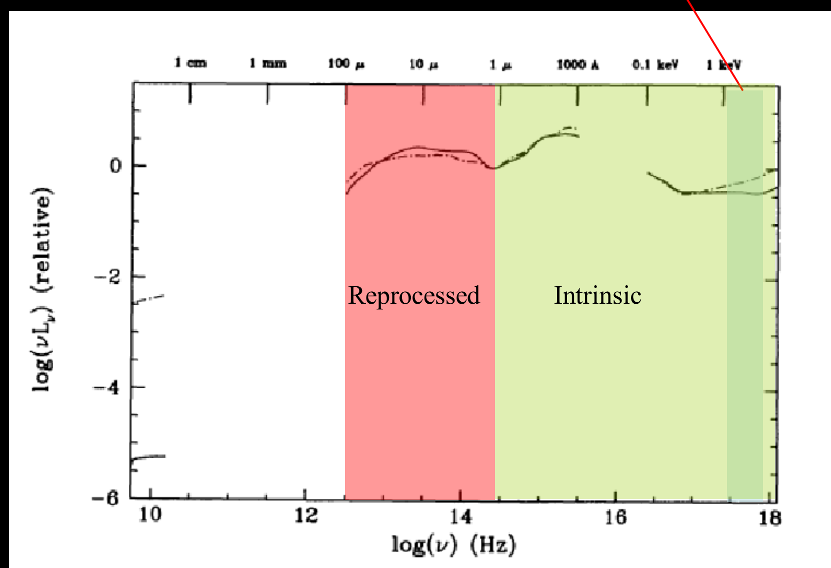
Soltan 82

Mean redshift — *Radiative efficiency*

$$\frac{4\pi I_{Bol}}{c} = \varepsilon$$

$$I_{Bol} = \kappa I_{XRB}$$

$\kappa = L_{opt+UV+X\text{-}ray} / L_{X\text{-}ray}$



The Literature:

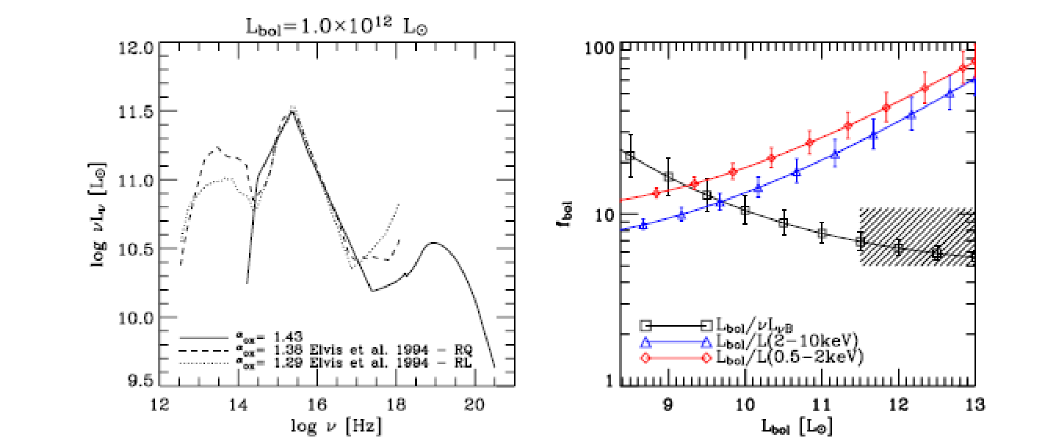
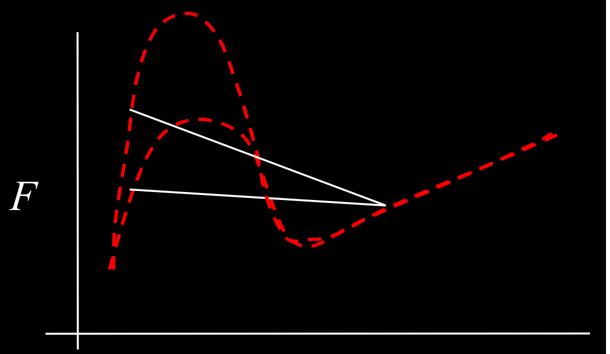


Figure 3. (a) Template spectrum for a $L = 10^{12}$ L⊙ AGN obtained as described in the text (solid line). The dashed and dotted lines represent the radio-quiet and radio-loud templates by Elvis et al. (1994). (b) Bolometric corrections derived from the spectral templates built as described in the text. The error bars represent the 16th and 84th percentiles of the 1000 Monte Carlo realizations described in the text. The hatched area represents the *B*-band bolometric correction (with $\pm 1\sigma$ scatter) by Elvis et al. (1994).

Marconi et al. (2004)



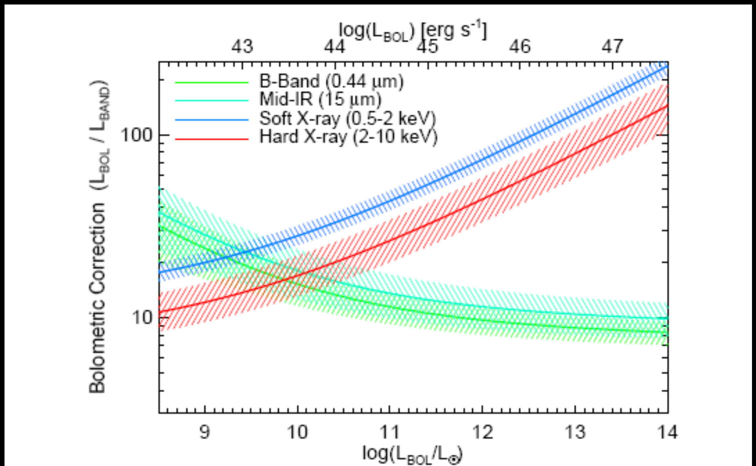


FIG. 1.— Bolometric corrections for *B*-band, mid-IR, soft and hard X-ray bands, determined in § 2.1 from a number of observations as a function of luminosity and given by the fitting formulae in Equation (2). The lognormal dispersion in the distribution of bolometric corrections at fixed *L*, given by Equation (3) is shown as the shaded range for each band.

Hopkins et al. (2006)

$_{OX}$ – L(2500Å) relation:

L(2500Å) up, $_{OX}$ down

Investigating the 'cosmic scatter' in κ (I):

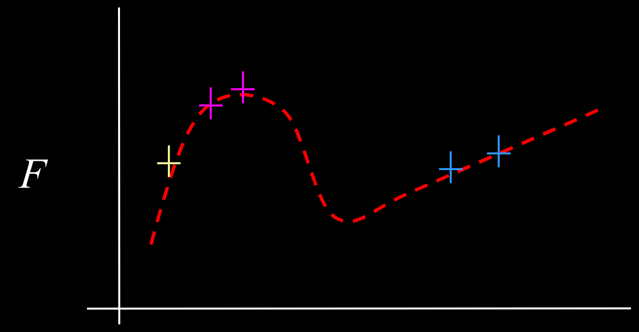
Constructed SEDs for 54 AGN. Sources:

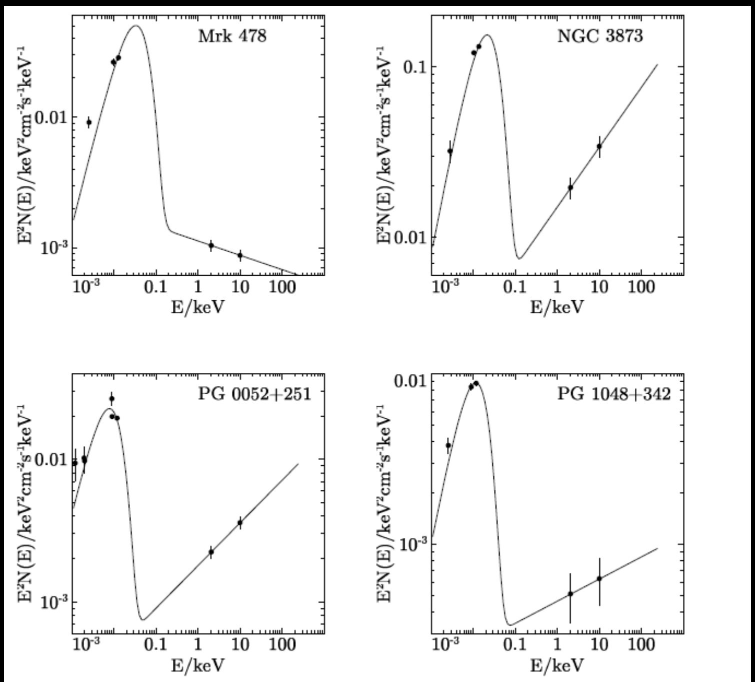
Optical: HST+…

UV: FUSE

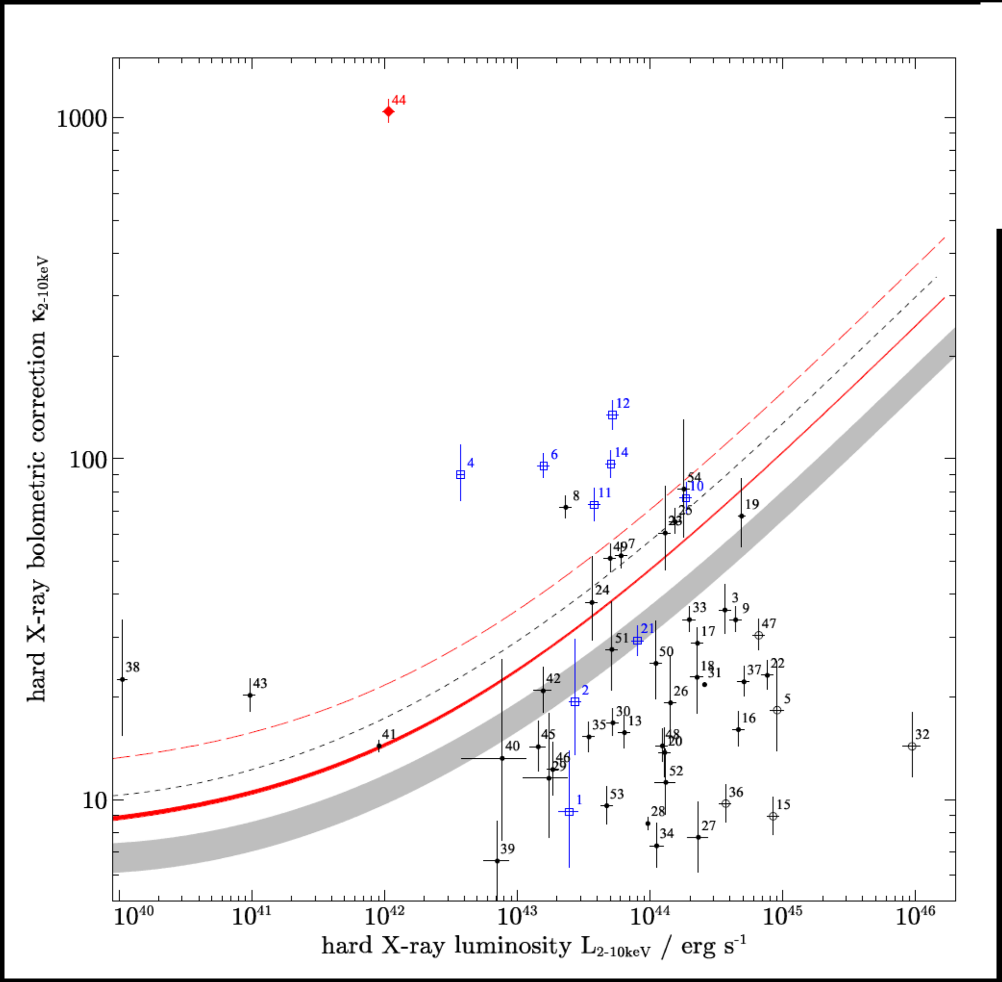
X-ray: ASCA, XMM +…

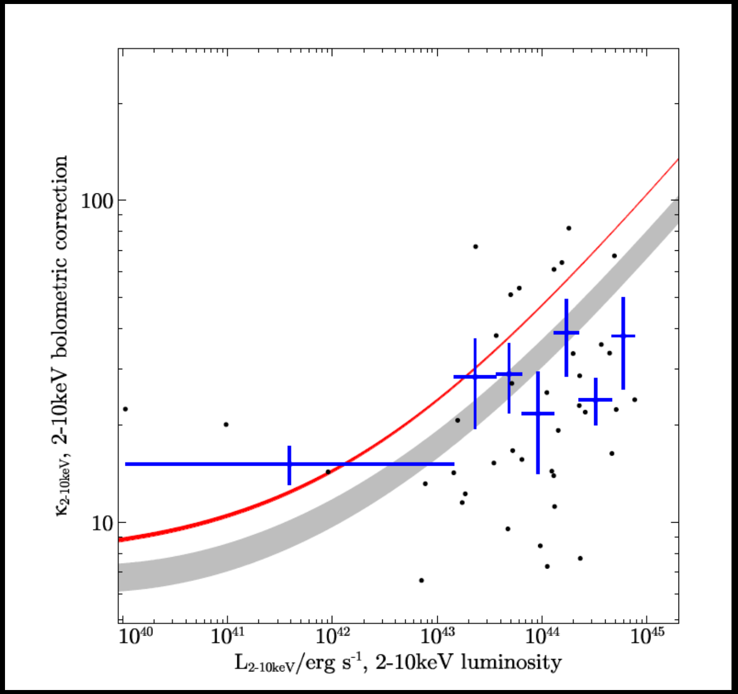
Model: SMBH mass estimates





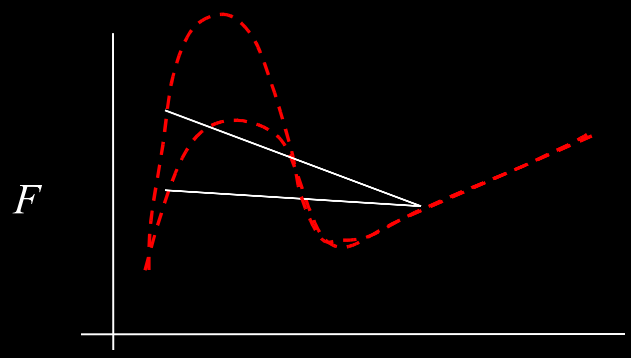
Investigating the 'cosmic scatter' in κ (II):

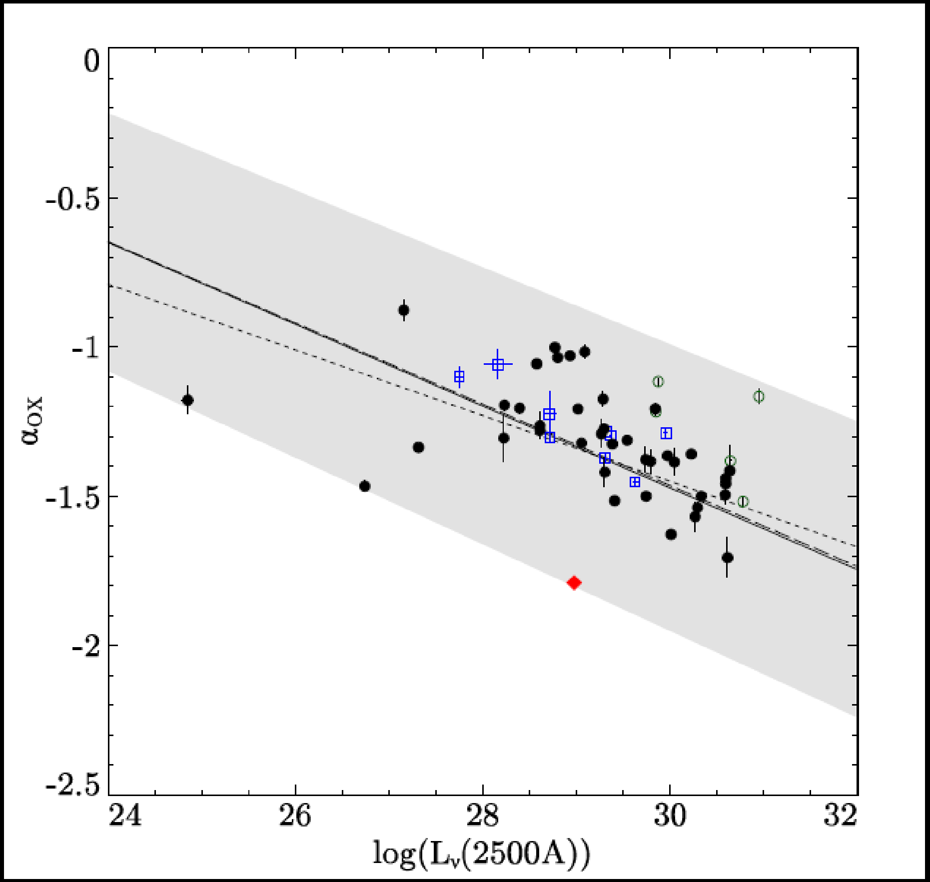




Checking SED reconstruction:

Solid line: empirical relation between X-ray to UV spectral index ($_{OX}$) and UV luminosity from Steffen et al. (2006). Points: our sample (NLS1s blue, Radio Loud empty circles, diamonds X-ray weak).

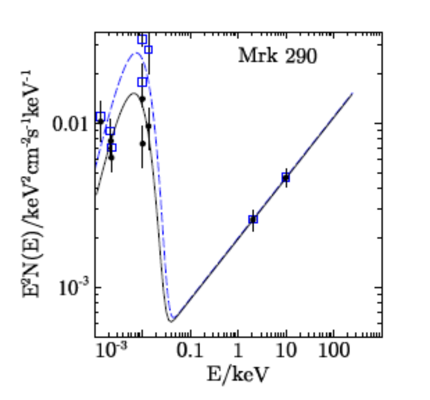




Systematics investigated: Intrinsic Reddening

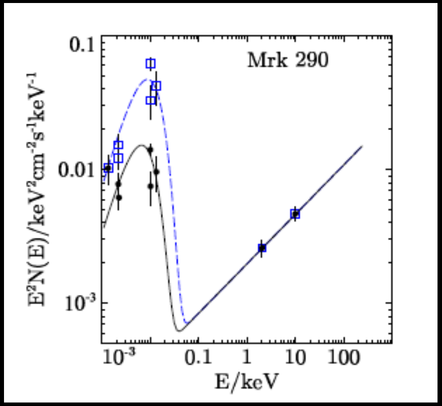
Small Magellanic Cloud-type reddening

(Pei 1992)

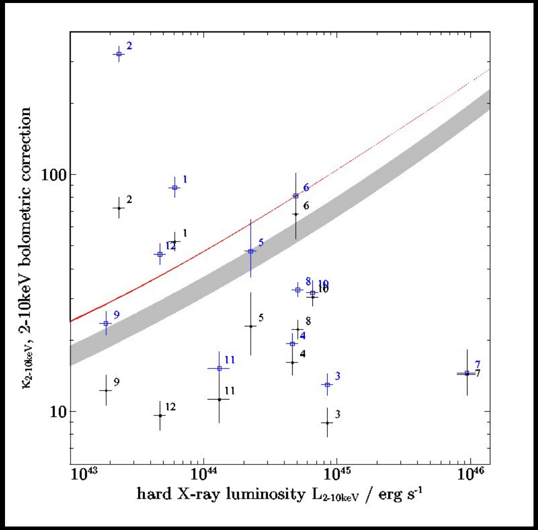


Change in κ: factor of 2 assuming a high reddening of E(B-V) = 0.055

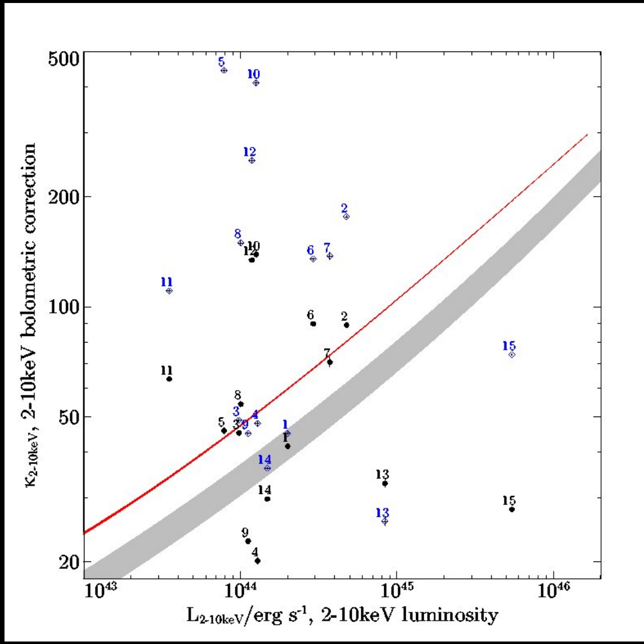
Gaskell and Benker (2005 – in prep.)



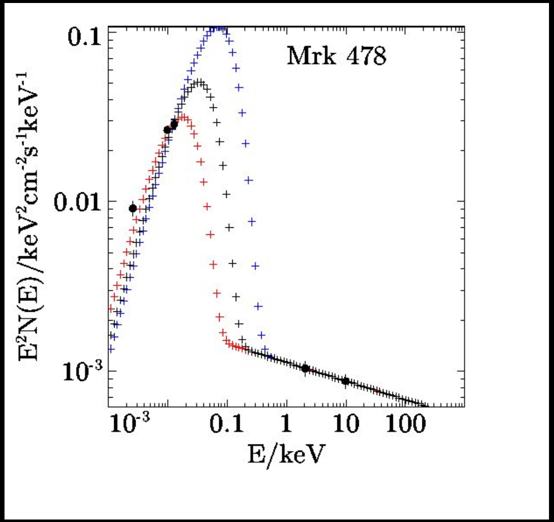
possible luminosity dependence of reddening correction



Systematics investigated: SED simultaneity, mass estimates

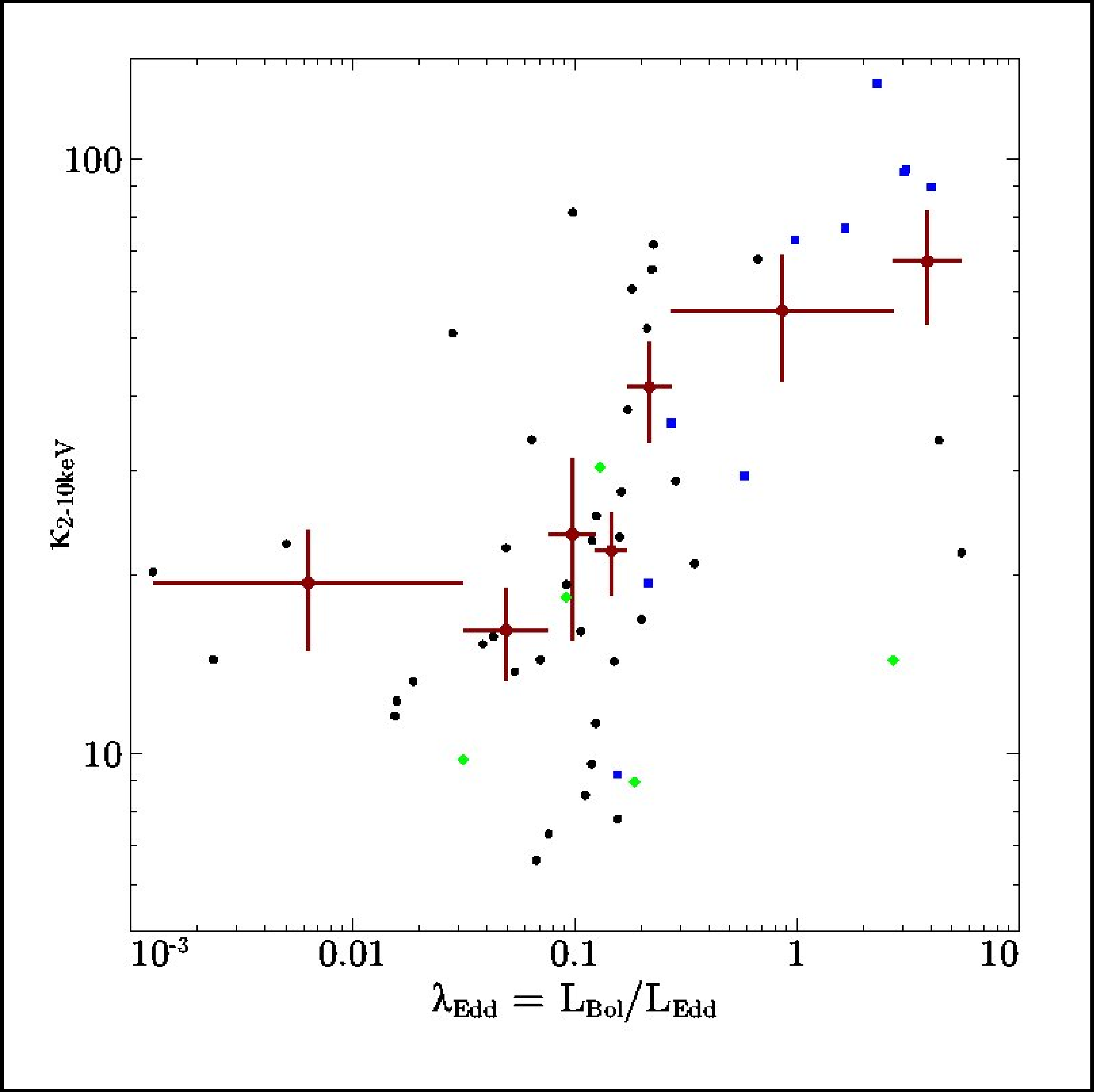


Systematically higher bolometric corrections from SEDs from XMM + XMM optical monitor (Brocksopp 2005).



Uncertainties in κ due to mass uncertainties: at ~ 14% level

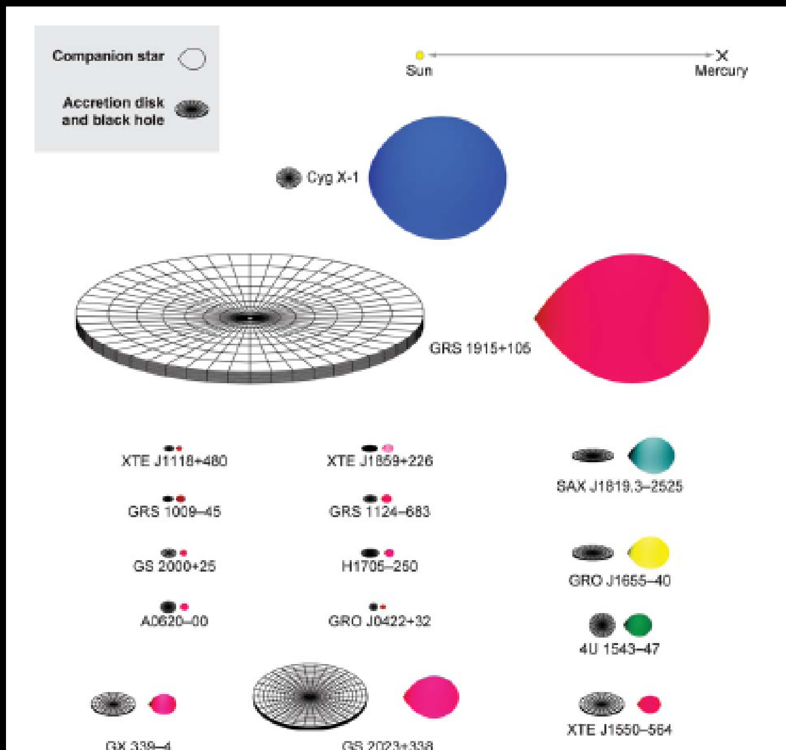
Bolometric Corrections against Eddington Ratio for AGN

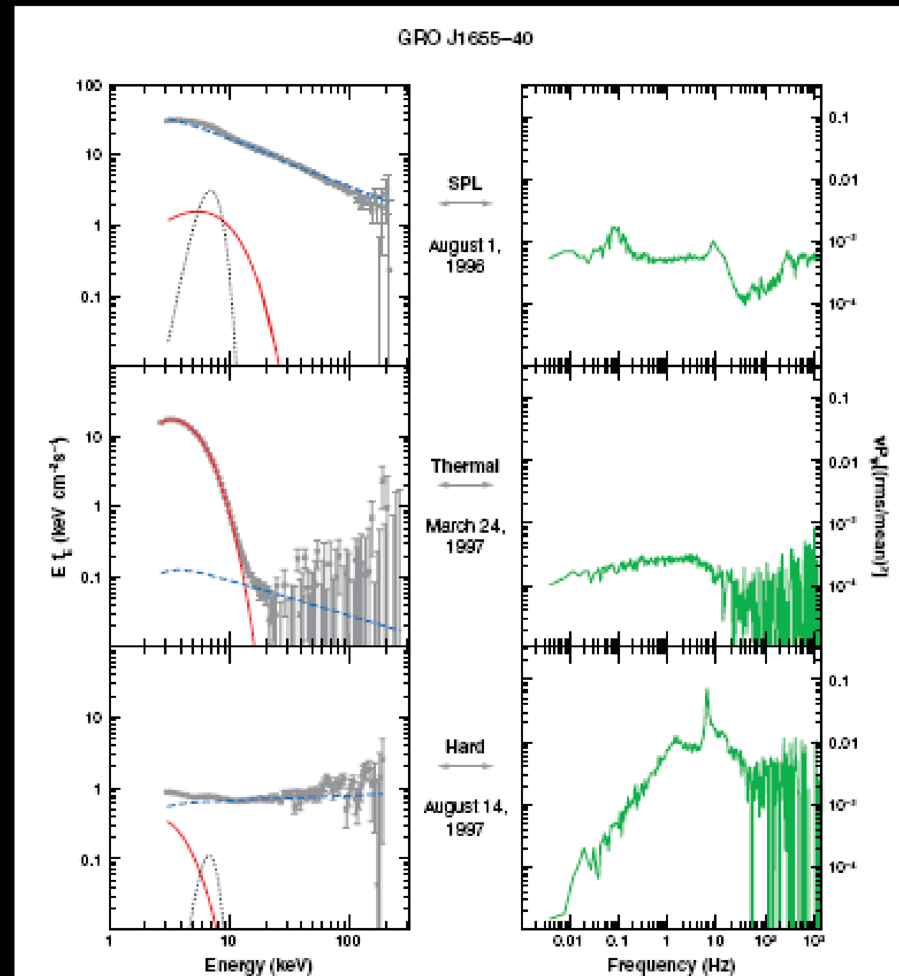


Blue points – NLS1s

Green points – Radio Loud (3C, 4C catalogues etc.)

Coming closer to home: Galactic Black Holes (GBHs)



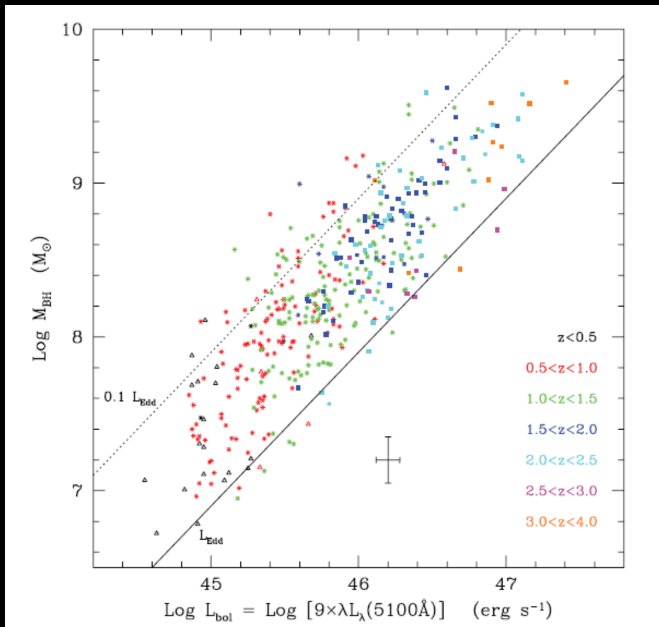


Remillard & McClintock (2006)

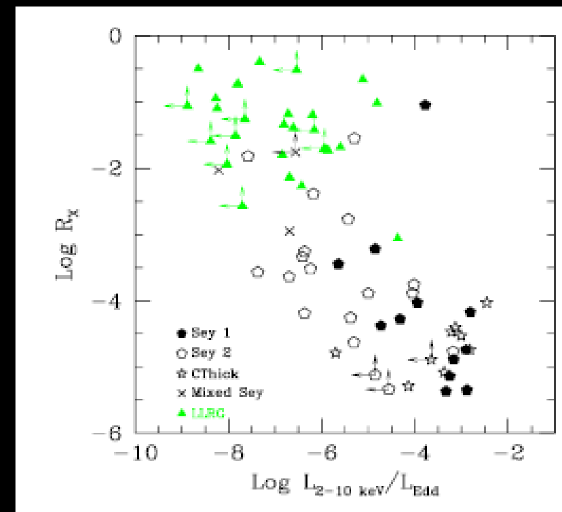
- **Eddington ratio** appears to clearly divide accretion states

The Eddington Ratio in AGN; parallels with GBH accretion

There have been numerous studies investigating the variation of various properties of AGN with Eddington ratio, $= L_{bol}/L_{Edd}$.



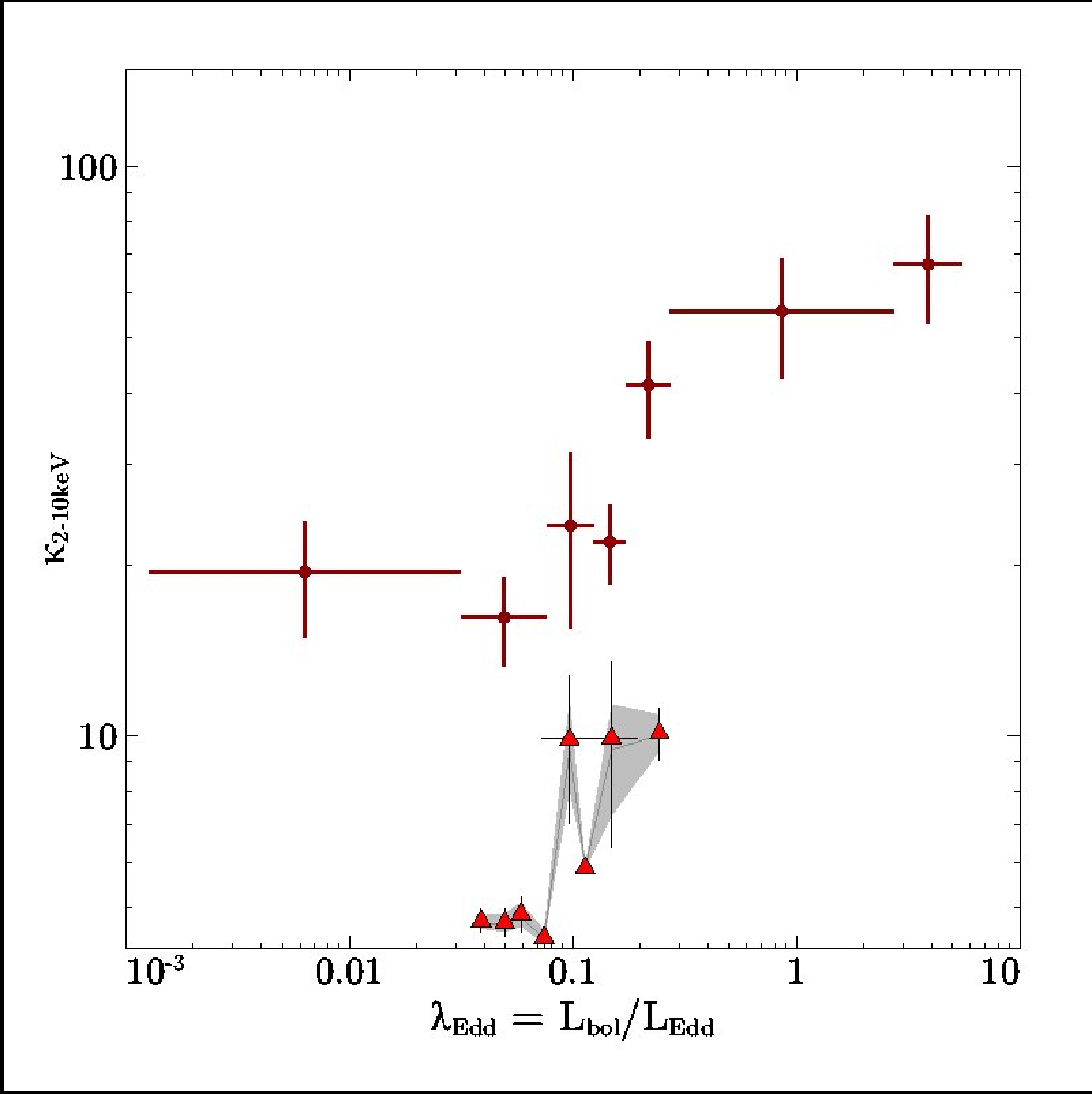
Kollmeier et al. (2006)

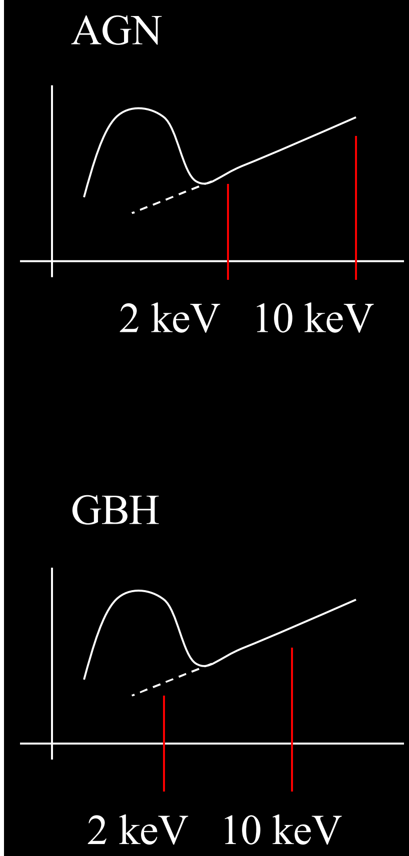


Panessa et al. (2007)

McHardy et al. (2006) discuss the concept of AGN as “scaled-up” GBHs, with specific reference to the “break frequency” in their Power Spectral Density (PSD) functions; also see work by Rob Fender et al.

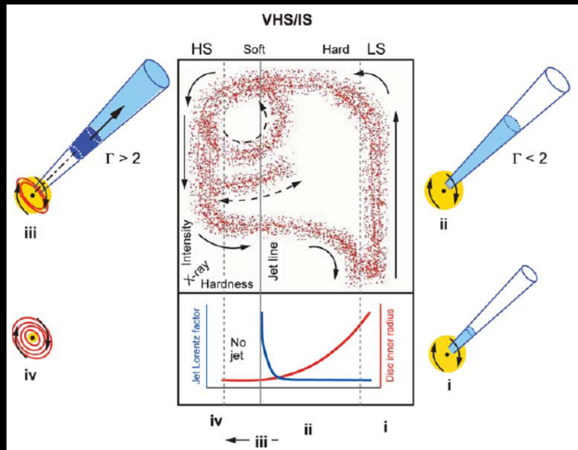
Bolometric Corrections against Eddington Ratio for AGN: Comparison with GX 339-4



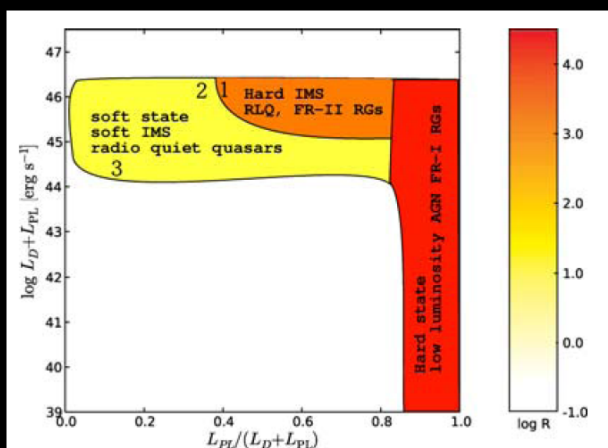


Hardness-Intensity Diagrams in AGN:

X-ray binaries



AGN



$L_{PL} = 3\ L_{0.5\text{-}10keV}$

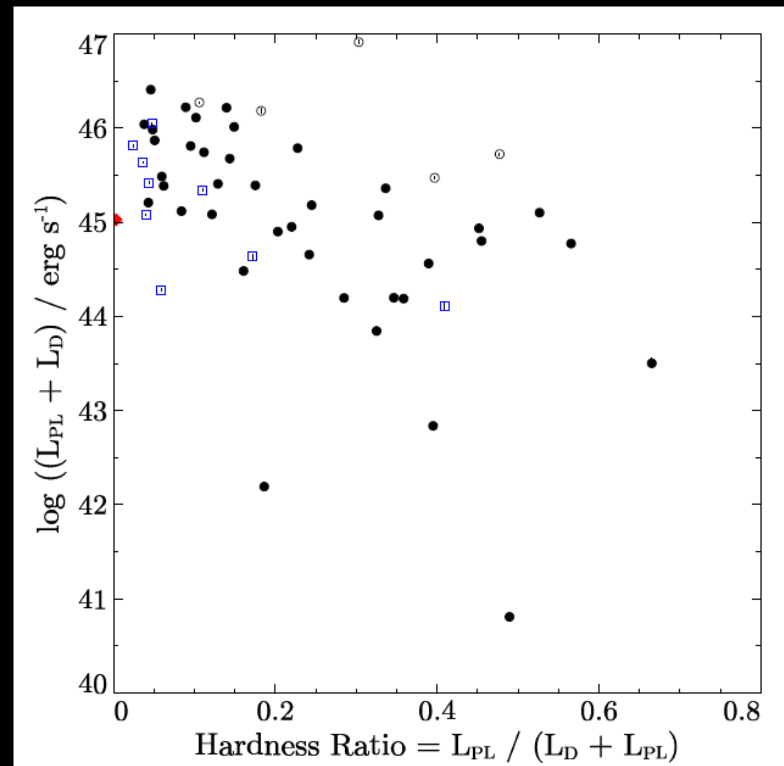
L_D approximated from the B-band

Koerding, Jester and Fender (2006)

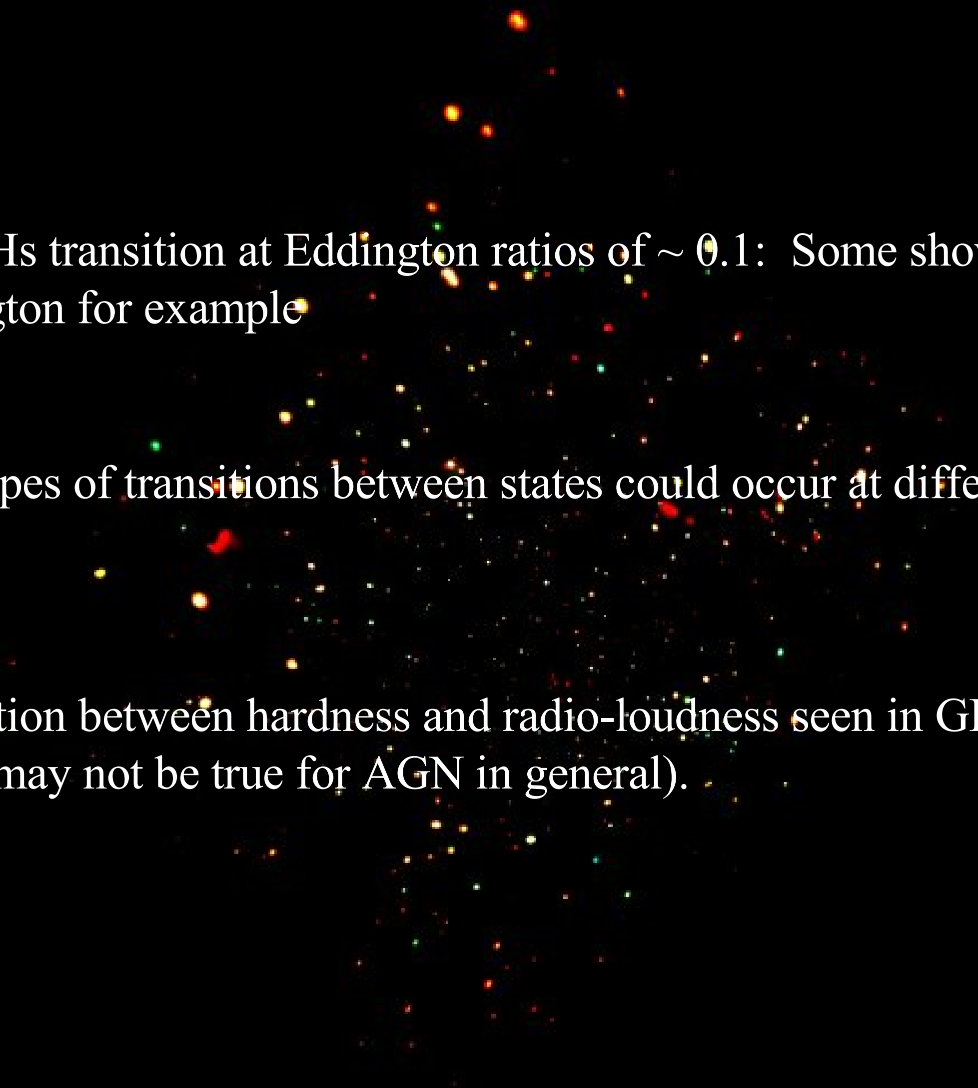
Our sample:

$L_{PL} = 3\ L_{2\text{-}10keV}$

$L_D = L_{0.001\text{-}0.1keV}$



Complications:

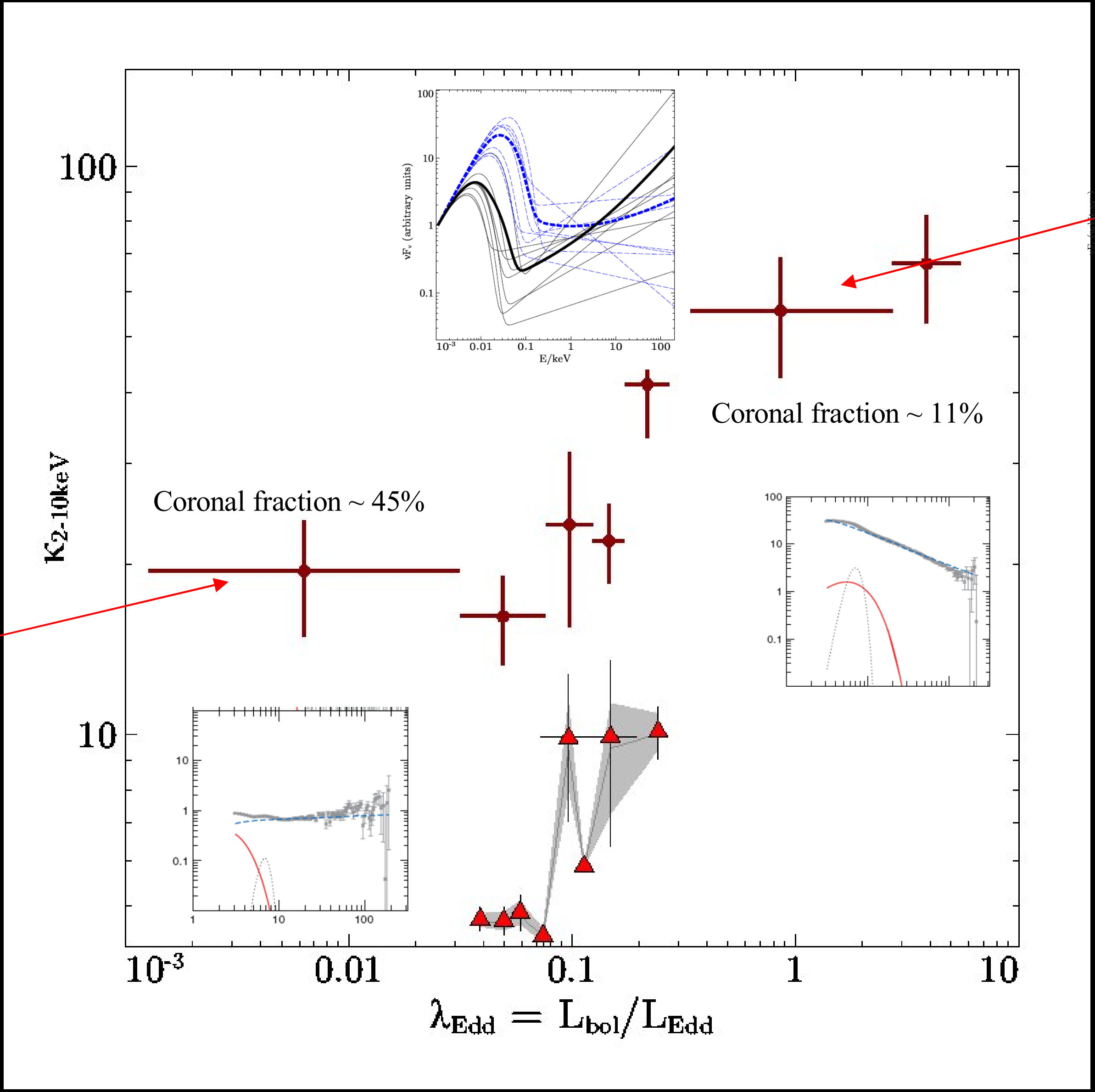


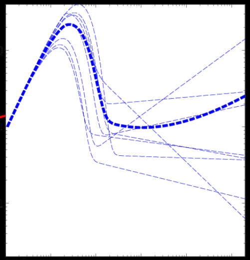
- Not all GBHs transition at Eddington ratios of ~ 0.1: Some show transitions at around ~0.02 Eddington for example

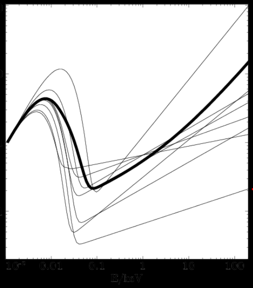
- Different types of transitions between states could occur at different Eddington ratios (hysteresis)

- The correlation between hardness and radio-loudness seen in GBHs not seen in this sample (and may not be true for AGN in general).

Changes in the AGN SED shape with Eddington ratio







Summary and Conclusions

- κ for AGN may ***not*** have a strong dependence on luminosity,
- May be more naturally divided by a threshold Eddington ratio
- **Below L_{bol}/L_{Edd} ~ 0.1: κ ~ 20. Above L_{bol}/L_{Edd} ~ 0.2: κ ~ 50**
- May provide clues on parallels between AGN accretion and smaller scale GBH accretion and accretion states.

Summary and Conclusions (continued…)

• Complications – some parallels hold (e.g. shapes of SEDs) and some don't (e.g. Radio Loudness – Eddington Ratio correlation)

• Intrinsic reddening in AGN still very difficult to account for; could increase bolometric corrections by up to a factor of ~2

• Future work: use simultaneous SEDs (XMM + XMM optical monitor), refine SMBH mass density calculation from XRB using Eddington dependence of κ

THE END