Bolometric Corrections for AGN and Studies of the X-ray Background

Ranjan Vasudevan

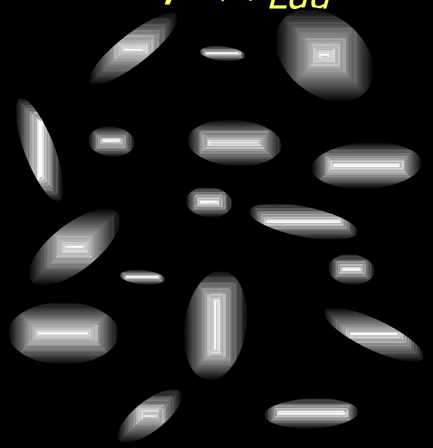
Supervisor: A. C. Fabian

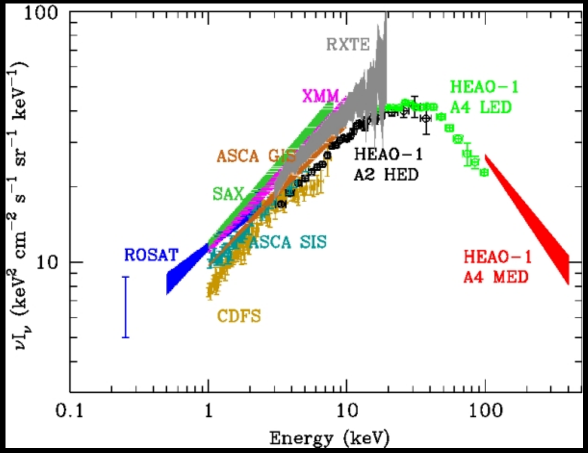
The Big Picture (1)

- The hard X-ray background (XRB) spectrum is understood to be the total emission due to accretion from AGN;

- Established convincingly by observations (e.g. Hasinger 2004);

- Can use XRB to infer SMBH mass density $\rho_{BH,}$ Eddington ratio of AGN, λ_{Edd} and mass-to-light conversion efficiency, η



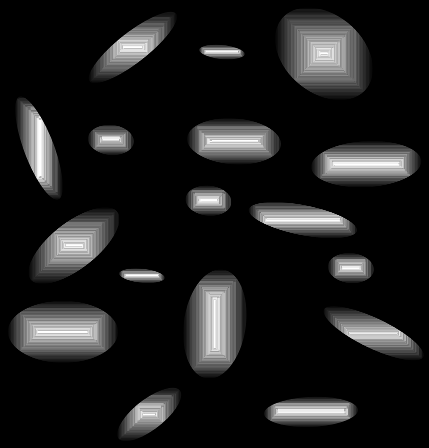


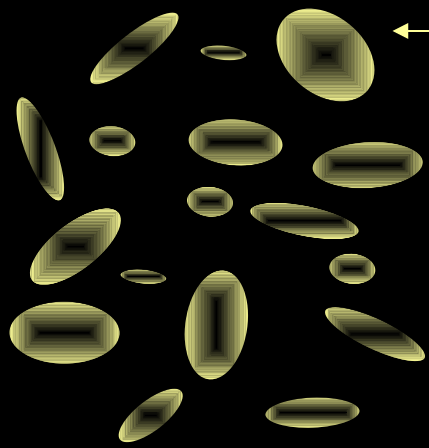
Emission from AGN gives rise to… XRB spectrum

But many details are uncertain…

The Big Picture (2)

- It is also useful to compare past AGN activity with what the distribution of SMBHs in the local universe to see if "present day" conditions follow on simply from past conditions.
- For this exercise we require AGN and local galaxy luminosity functions.





Give rise to this? (Present day SMBHs in galaxies)

Does this (past AGN activity)…

The Specifics (3)

- For these studies we are clearly interested in the total luminosity due to accretion emitted by a object. We require one crucial input before attempting these studies…

The bolometric correction

Accretion makes massive black holes

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

Soltan 82

Mean redshift

Radiative efficiency

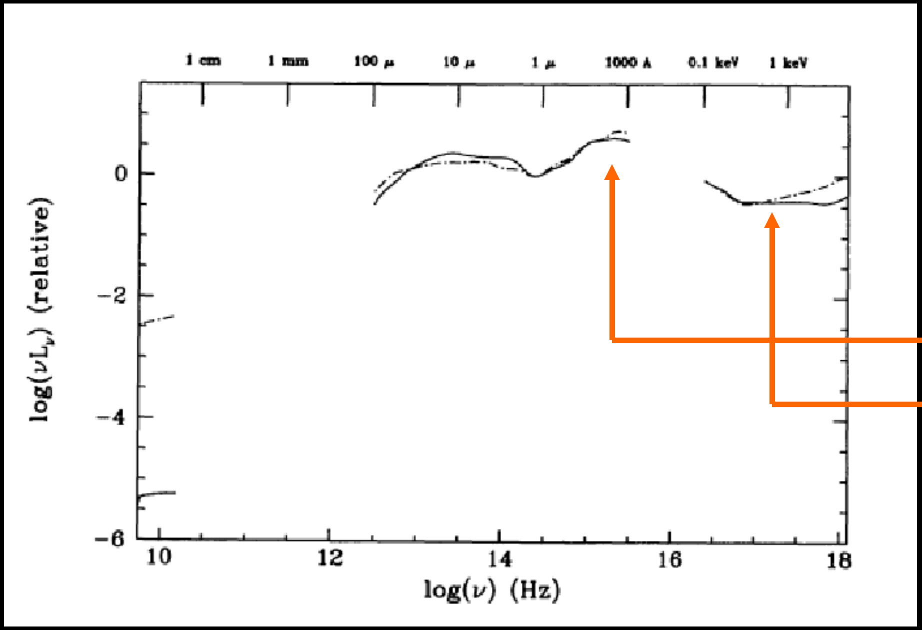
$$\frac{4\pi I_{Bol}}{c} = \varepsilon$$

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

This correction is needed so that we can scale up the XRB light to get the true luminosity due to accretion. It can also be used to scale up the luminosities seen in luminosity functions.

Previous work (1)

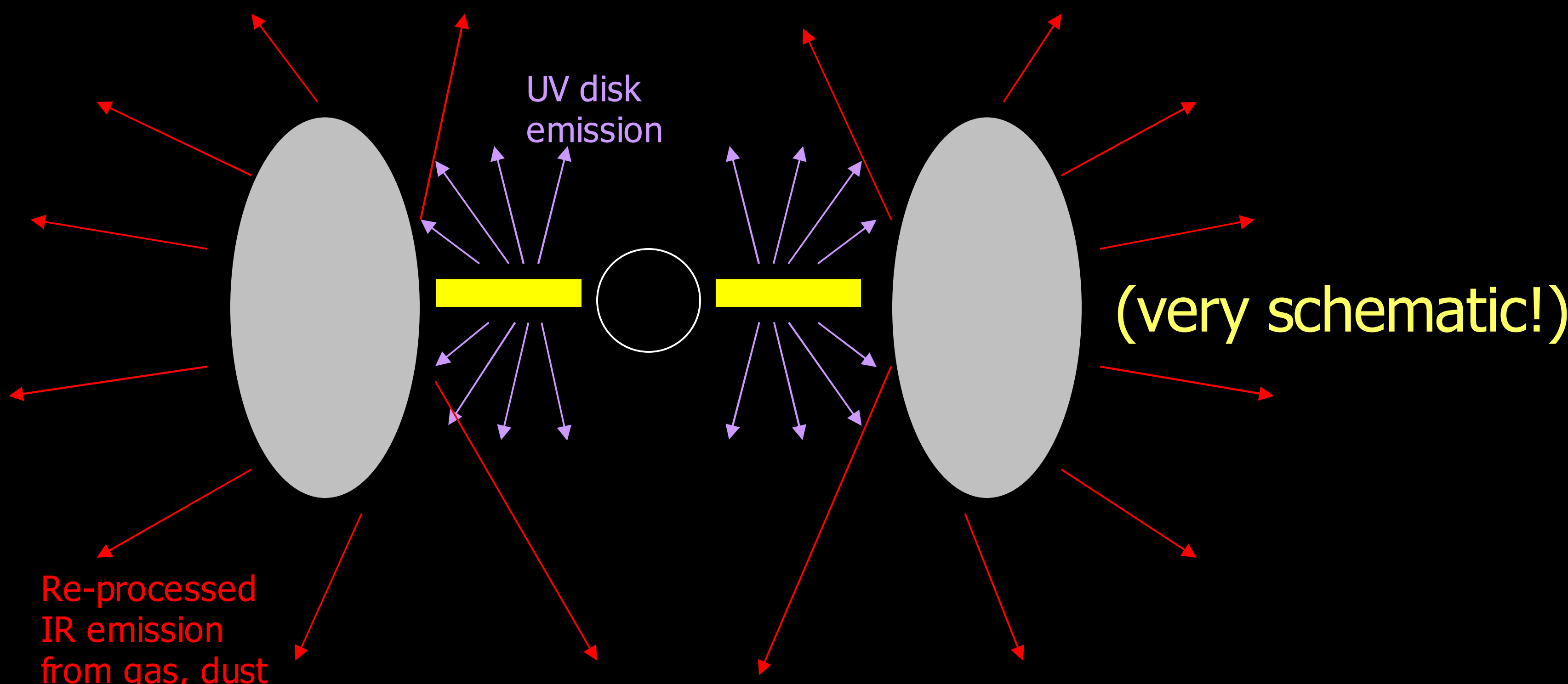
- The quasar SED presented by Elvis et al (1994) has been adopted by many as the "canonical" quasar SED by many in the field - a mean quasar SED calculated from observations of 47 quasars.



- Dashed line: radio loud, solid line: radio quiet
- We can see some of the main spectral features common to AGN: UV/optical "big blue bump", power law in hard X-ray
- Disadvantage:
  the dispersion in this mean SED is large due to the diverse spectral shapes of the individual quasars

Previous work (2)

- Elvis et al have determined bolometric corrections from this SED, but their bolometric luminosities include IR emission, which is known to be reprocessed from the UV (Antonucci 1993) so their bolometric corrections "count radiation twice"



Previous work (3)

- Marconi et al (2004) identify this problem, and suggest calculating bolometric corrections without the IR emission
- They construct a template spectrum for AGN from a set of power laws and enforce the relationship between the spectral index connecting X-ray and optical, α_{OX}, and luminosity (Vignali, Brandt and Schneider 2003)

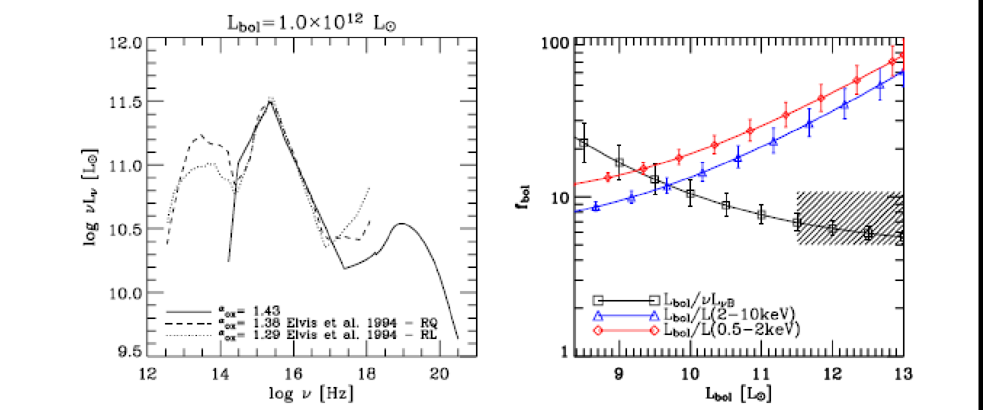


Figure 3. (a) Template spectrum for a $L = 10^{12}\ L_\odot$ AGN obtained as described in the text (solid line). The dashed and dotted lines represent the radio-quiet and radio-loud templates by Elvis et al. (1994). (b) Bolometric corrections derived from the spectral templates built as described in 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 $\pm$ 1σ scatter) by Elvis et al. (1994).

- Disadvantage:

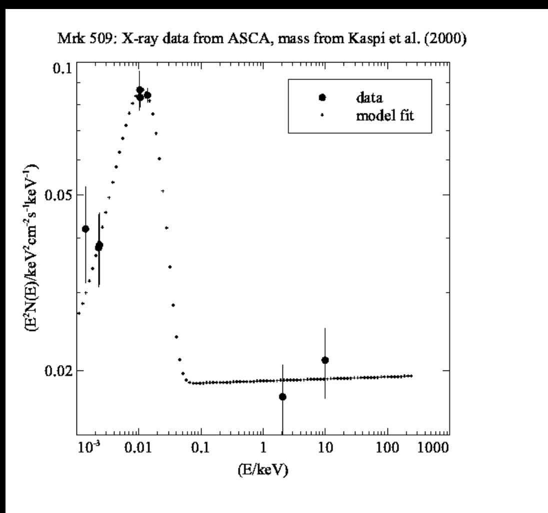
  No window onto the actual variation of bolometric corrections in the real AGN population.

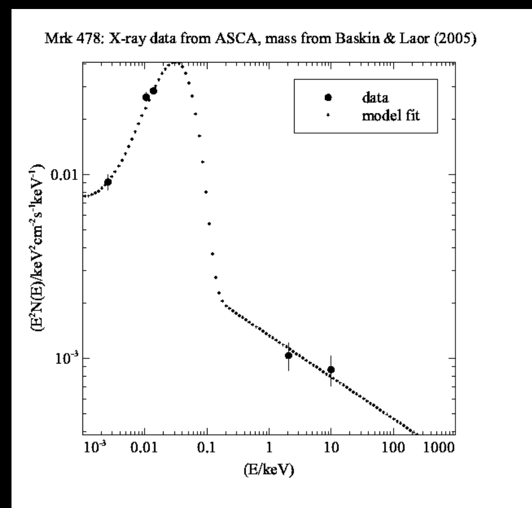
Investigating the Distribution of Bolometric Corrections (1)

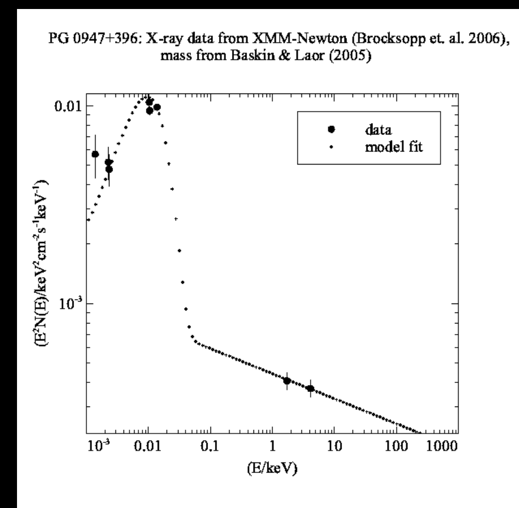
- We have attempted to construct SEDs for a sample of "local" ($z<0.7$) AGN to calculate their bolometric corrections
- Our sample is drawn from the 85 AGN observed by FUSE as presented in Scott et al 2004, which allows the inclusion of UV points where the blue bump dominates. Optical points were gathered from HST, KPNO (Shang et al 2005, Baskin & Laor 2005) with X-ray data points obtained from the Tartarus Database of ASCA observations (Nandra et al, Imperial College) and a host publications providing XMM and ROSAT observations.

Investigating the Distribution of Bolometric Corrections (2)

- We then fit disk and power law models to the points (diskpn + powerlaw in XSPEC or suitable variant) and determine bolometric corrections from the fit.

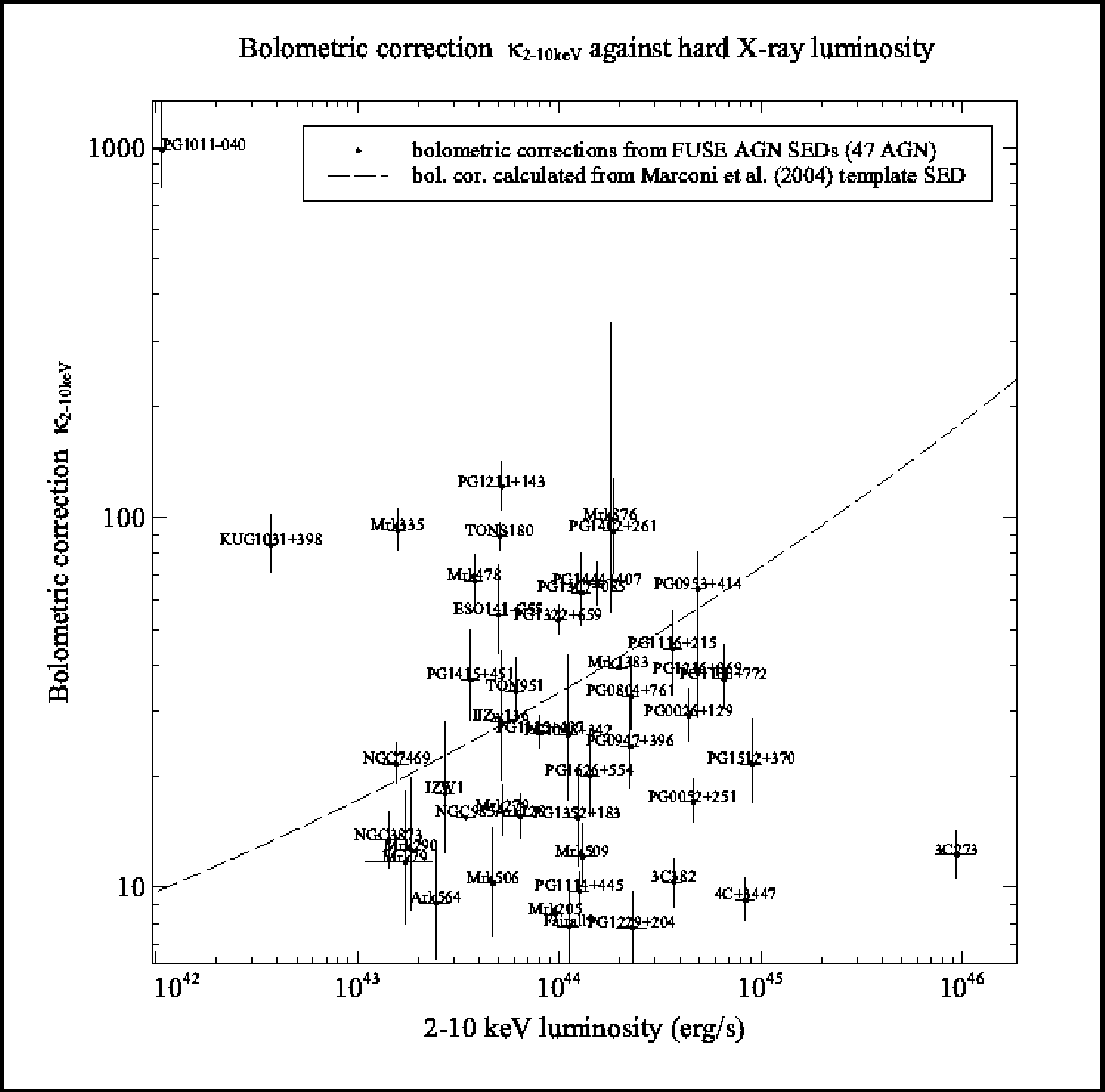






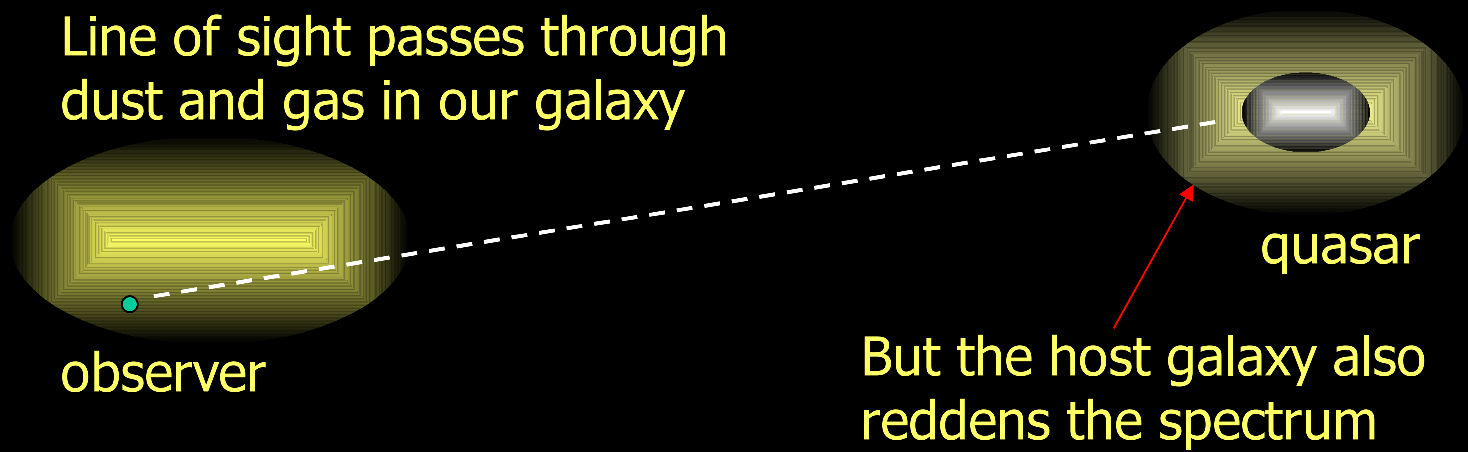
- In order to constrain the physics underlying the disk emission, we have used SMBH mass estimates to fix the normalisation of the disk component, from Kaspi et al (2000), McLure & Dunlop (2001), Baskin & Laor (2005) and others.

Results so far (1)



Systematics: Intrinsic Reddening of the Host Galaxy (1)

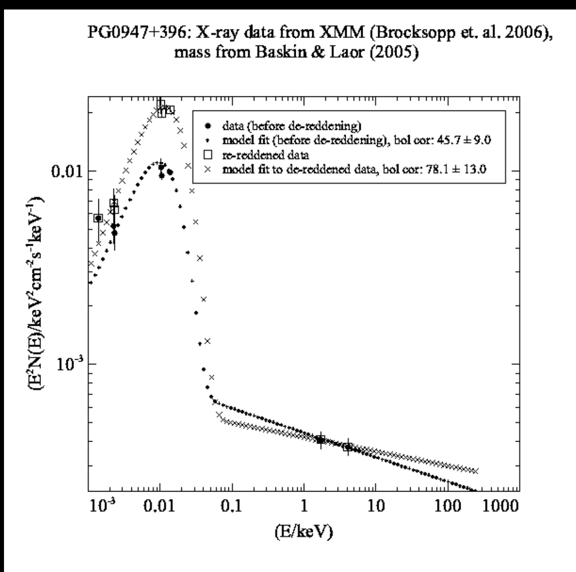
- The effect of galactic reddening on extragalactic objects have been studied in relative detail

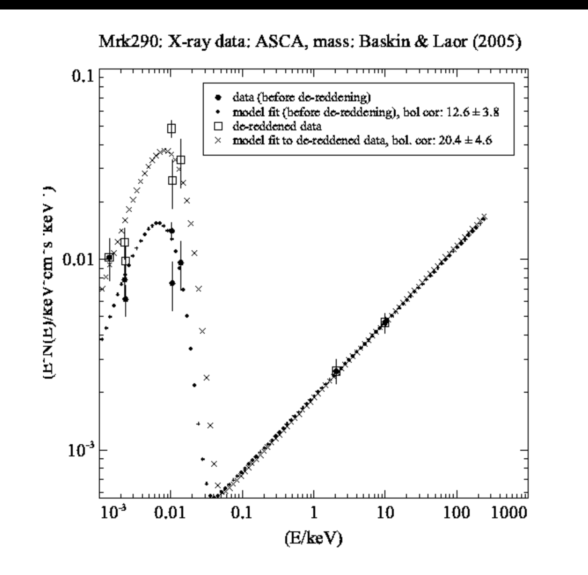


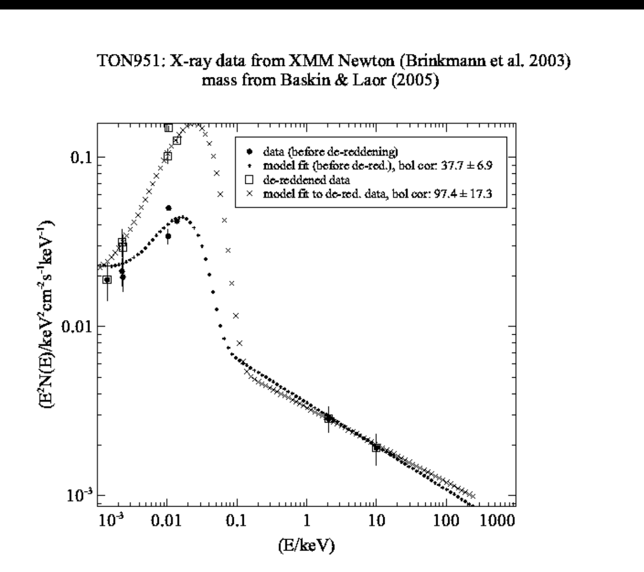
- Gaskell & Benker (2005) present a detailed analysis of this phenomenon and provide an extinction curve along with values of the reddening E(B-V) for some of our sample, allowing us to take this into account.

Systematics: Intrinsic Reddening of the Host Galaxy (2)

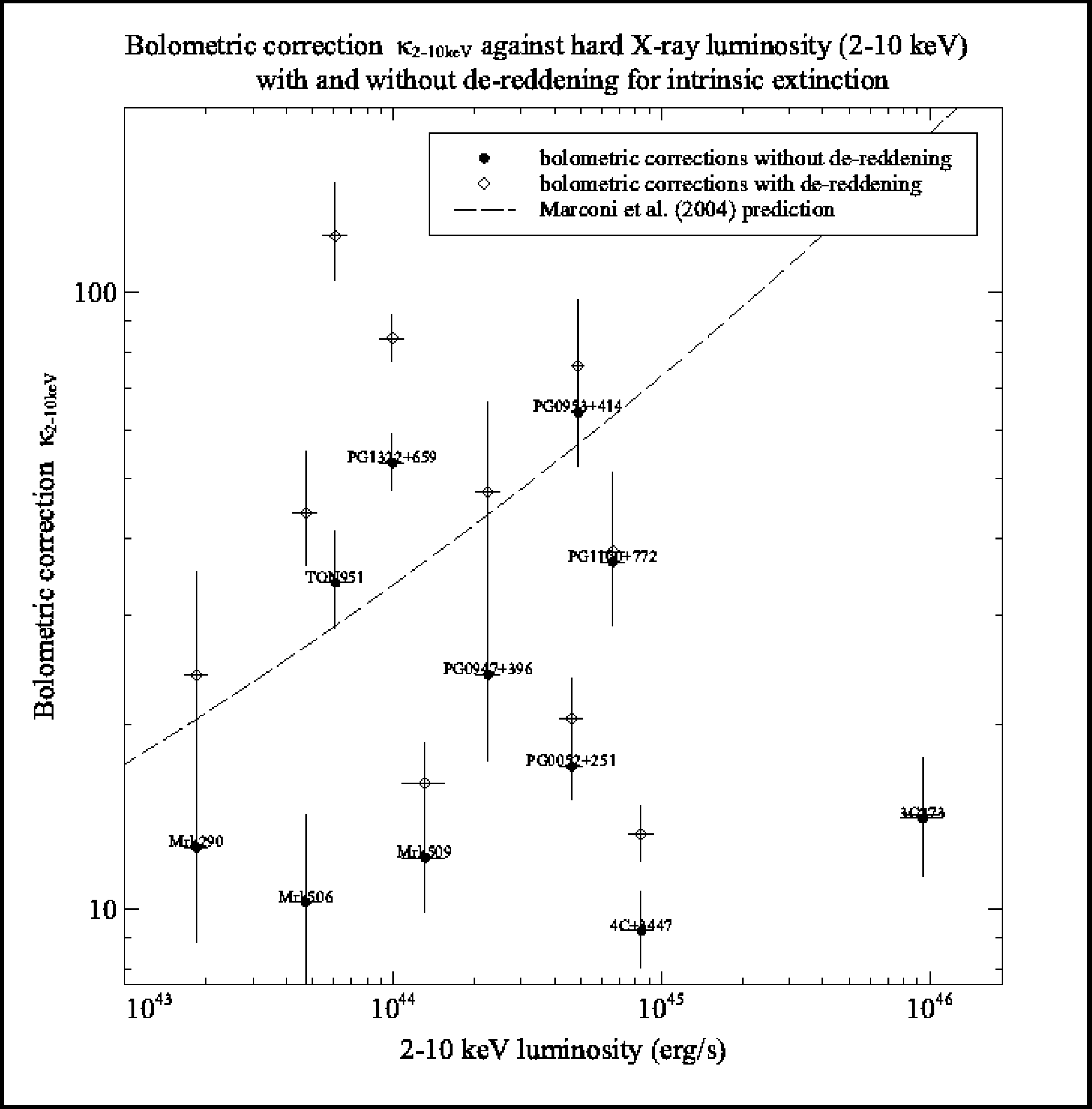
- Applying intrinsic reddening corrections, we can see clear differences between the reddened and de-reddened spectra in some cases, and correspondingly significant differences in their bolometric corrections



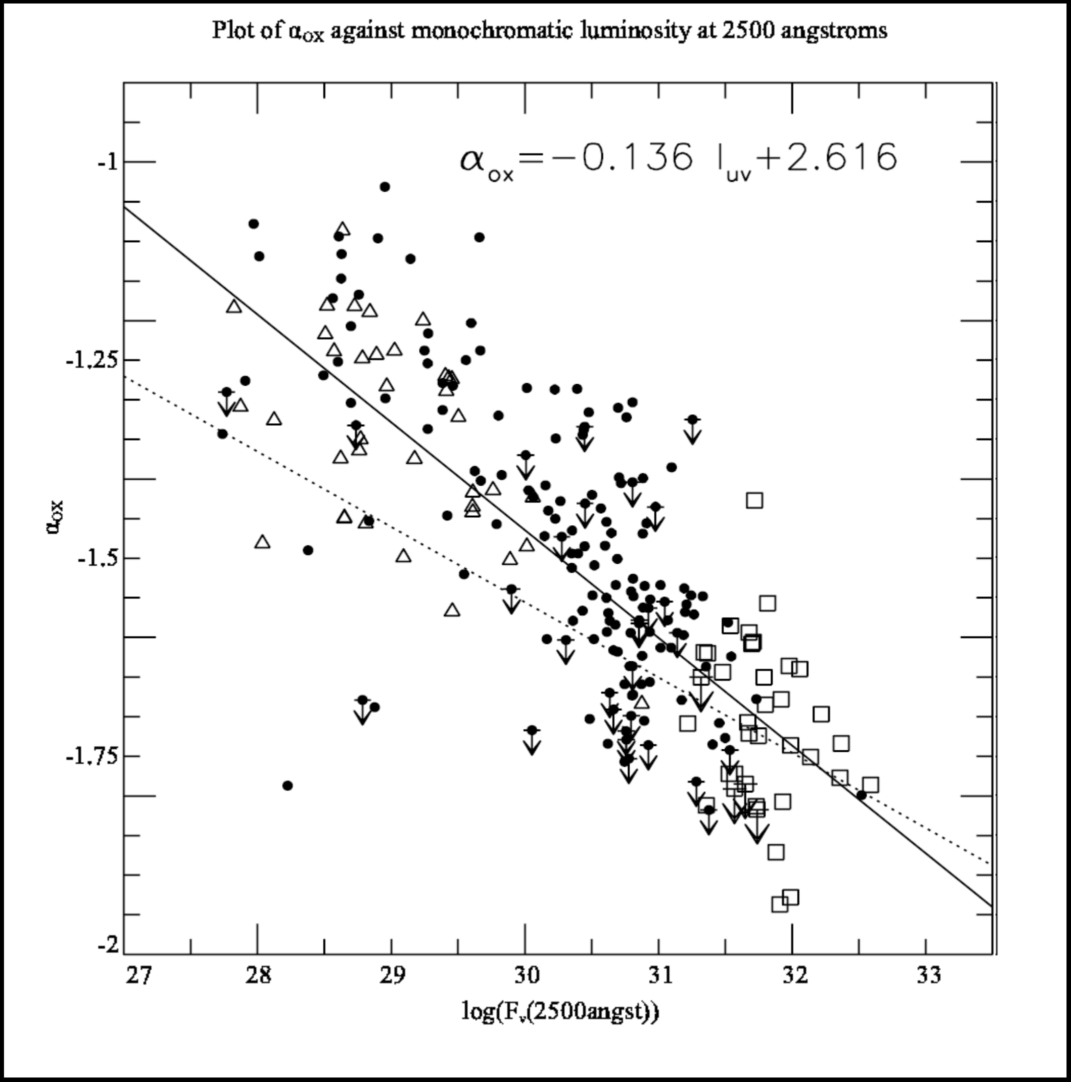




Results so far (3): The effect of intrinsic reddening

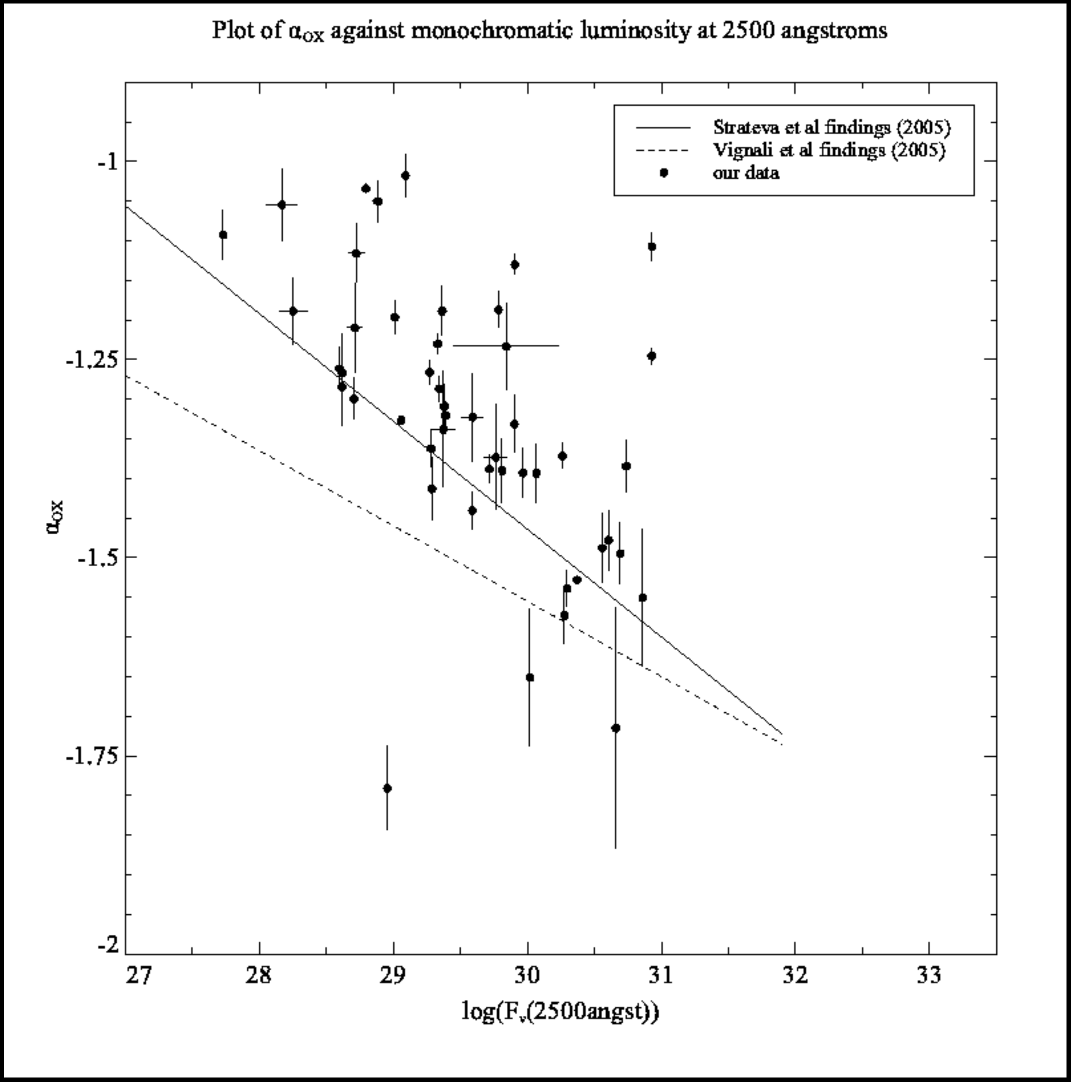


Checking results (1): α_{ox} vs 2500Å monochromatic luminosity

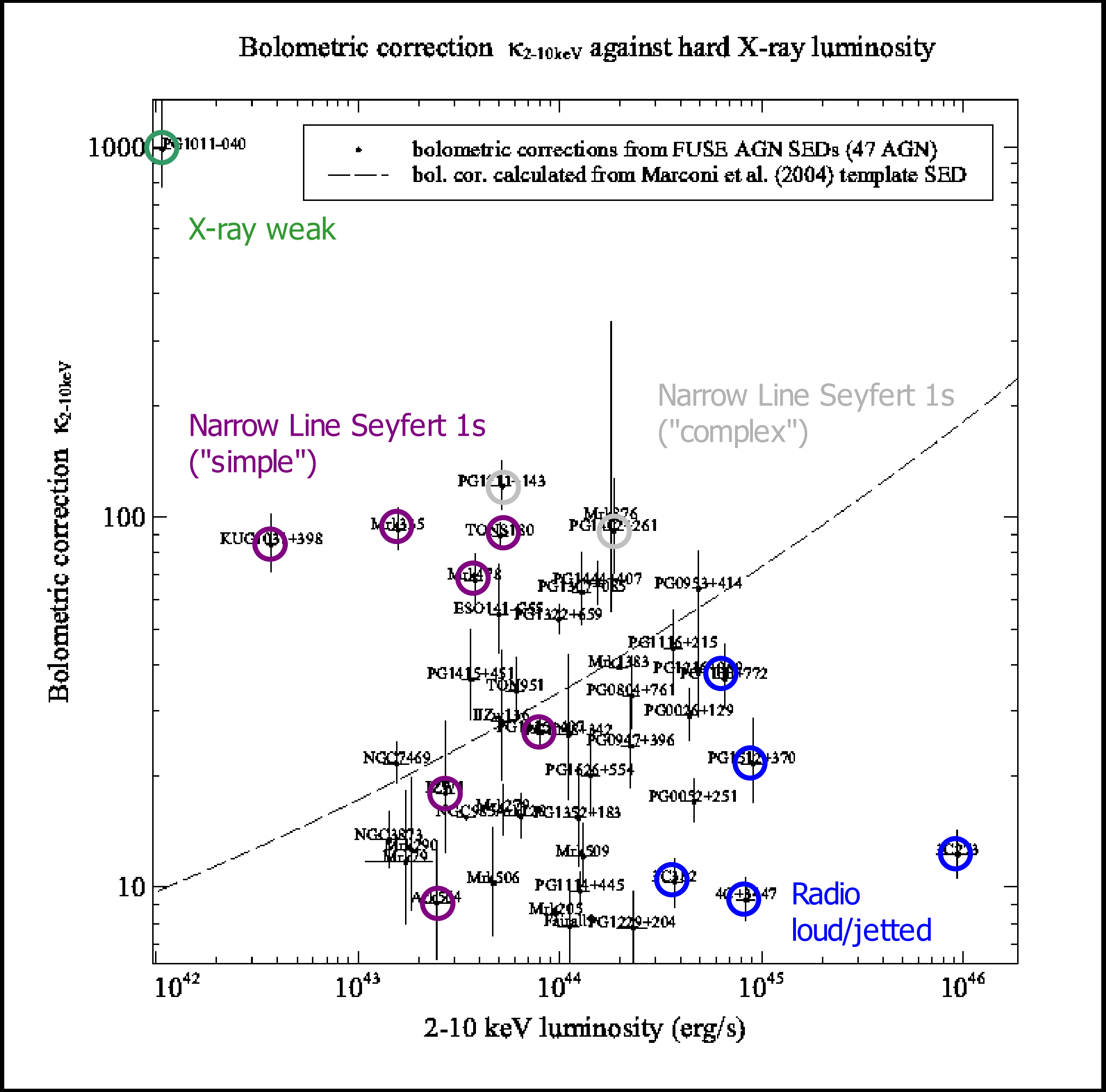


Strateva et al. (2005) Fig 11

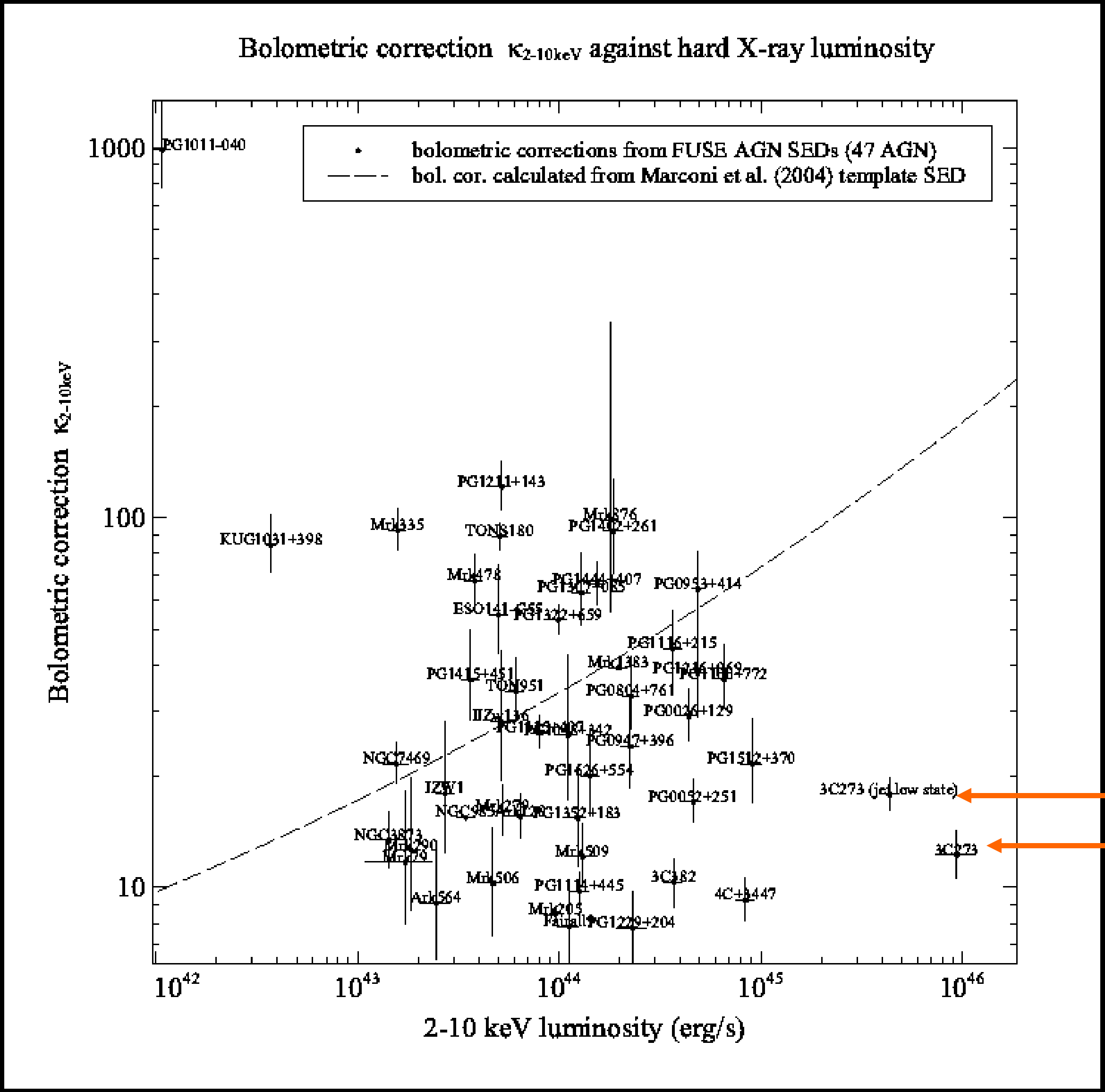
Checking results (2): α_{OX} vs 2500Å monochromatic luminosity



Some interesting objects (1)



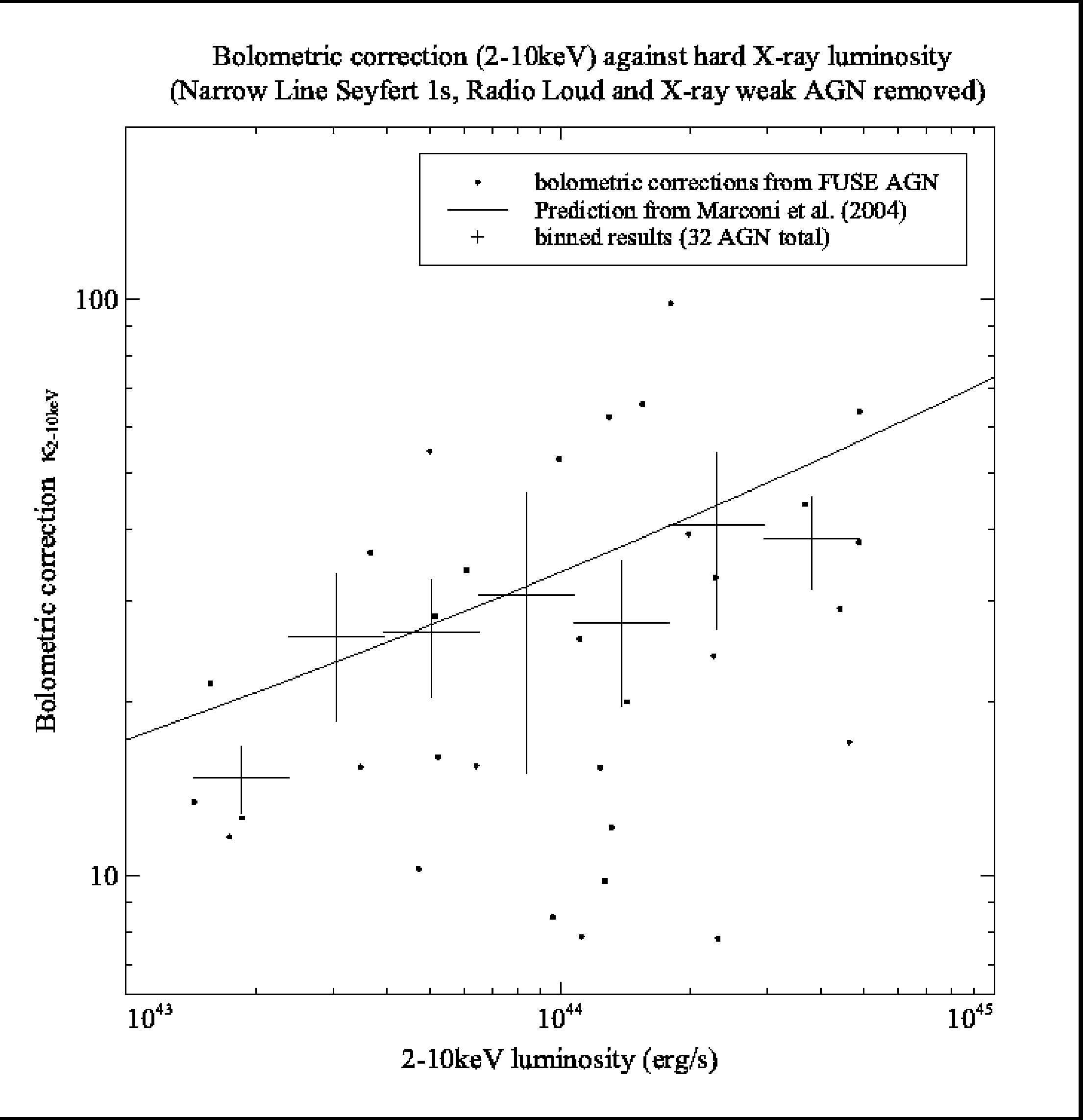
Some interesting objects (2): radio loud AGN



Bolometric correction calculated using an XMM observation taken at a minimum of jet emission (Türler et al 2006)

Case study:3C273. Hard X-ray spectrum contains significant contribution from jet (e.g. Dremer et al 1997)

Revised Results so far



Summary and Further Work

- Bolometric corrections for AGN seem to show a large spread in the real AGN population, when taking into account the effects of UV reprocessing in the IR;
- The causes for this spread could be diverse - AGN variability; the intrinsic spread in AGN SEDs discussed by Elvis et al (1994), the effect of jet emission
- A weak variation of bolometric correction with luminosity may be present, but more low luminosity AGN from the FUSE sample are needed to verify this;
- Intrinsic reddening due to the host galaxy may be very significant for AGN, further studies are needed.

Implications

It may be necessary to take into account the different bolometric corrections relevant for different types of sources in a more detailed manner. XRB modelling beckons…