The BAT AGN Survey - Progress Report

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- The Swift BAT (Burst and Transient Telescope) has been observing the sky in the 15-200 keV band for ~56 months
- follow-up x-ray and optical and IR observations- a progress report -only first 9 months data **'fully'** analyzed
- **The 'first' unbiased survey of AGN in the local universe- no selection effects due to obscuration, galaxy properties or optical or radio properties.**
- **High quality data - majority of the objects are close and bright**

BAT data

•Large sample (>500 AGN (Cusumano et al 2009))

•Light curves

• Good angular accuracy

•Spectra (15-200 keV)

>2Ms of exposure over the whole sky

>16 referred papers ~400 citations

Data allows measurement of

•host galaxy properties

• relation of spectral properties to intrinsic luminosity

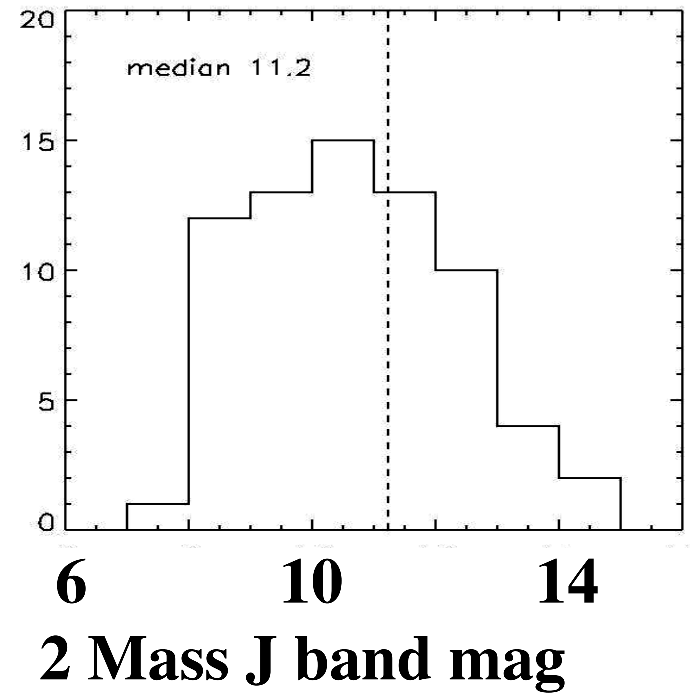
•Direct comparison with z~1 Chandra and XMM surveys

* **please see posters by M. Koss and W. Baumgartner**

Statistics of 22 Month Survey

No source type	26
Galactic	4
Extragalactic	20
Galaxy Clusters	7
AGN	**225**
Blazars, beamed AGN	32
CVs/stars	36
Pulsars, SNR	15
Binaries	117

Total	482



BAT sources are *optically bright <J>=11.2 and near <z>=0.026*

-X-ray follow-up with Swift, Suzaku, XMM for ALL AGN (Winter et al 2008b)

Most of the unidentified objects are at low galactic latitude

Objects labeled 'extragalactic' have a galaxy ID but are not classified as AGN in the catalogs (e.g NGC 0973)

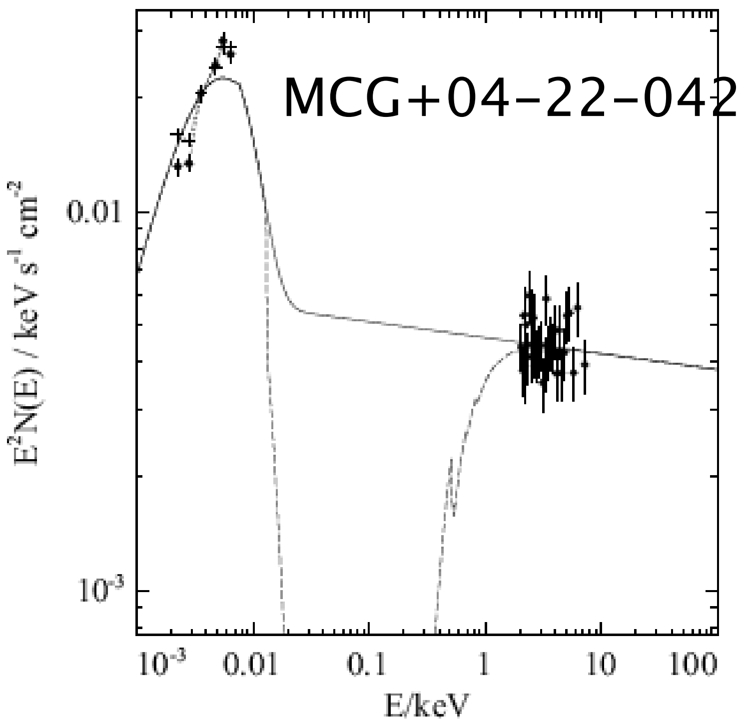
IDS are mostly based on Swift XRT follow-up observations

Markwardt et al 2005, Tueller et al 2008,2009, Winter et al 2008ab, Mushotzky et al 2008, Melendez et al 2008a

“Optical” Data

- 5 color SDSS photometry with Kitt Peak 2m (**Lisa Winter + Mike Koss**- U of Md) and optical spectra
- Swift OM data to get optical/UV (**R. Vasudevan et al 2009) simultaneously with x-rays**

Optical and IR spectroscopy
•Kitt Peak 2m and SAAO spectra
•6dF and SDSS data
•~110 objects with Spitzer (M.Melendez, K.Weaver)



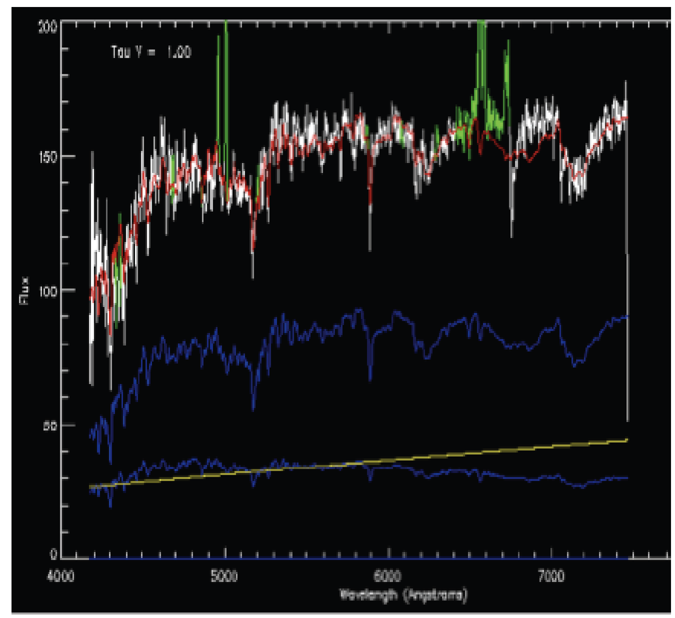
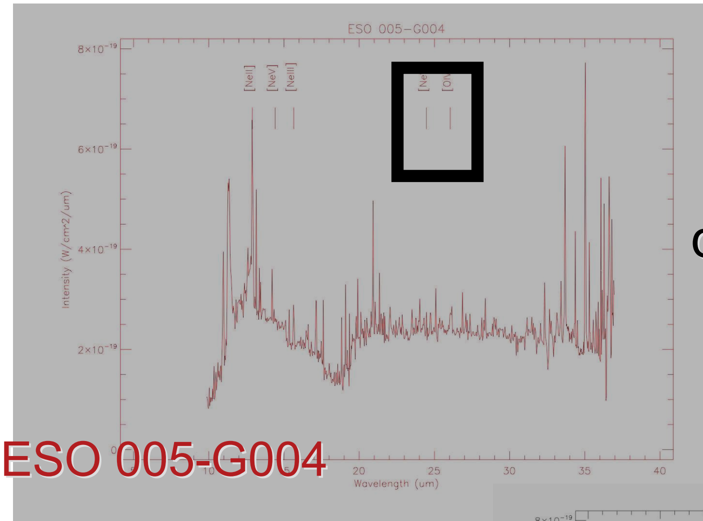


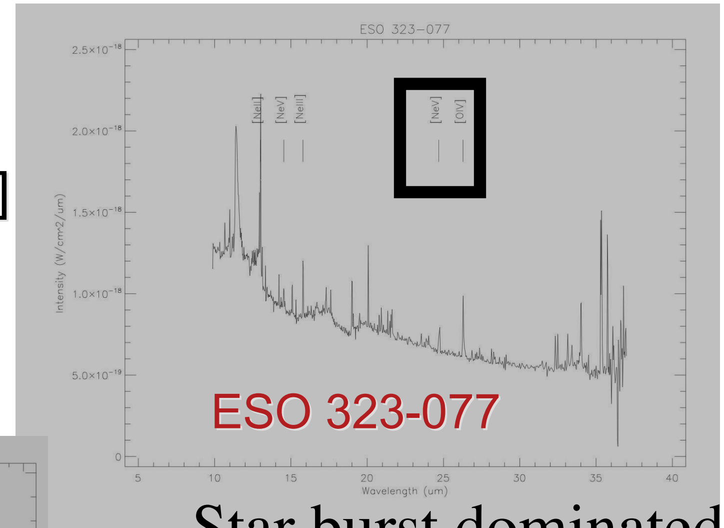
Fig. 12.— On left, gri image of UGC 12741 from Kitt peak 2.1m telescope. The galaxy is spiral in shape and has a NED galaxy classification of Sa. On right, fitting of stellar models and AGN power law to the spectra of UGC 12741. Galaxy spectra is shown in white.

Spitzer IRS
High resolution spectra- diagnostic [NeV] and [OIV] lines

Melendez et al 2009



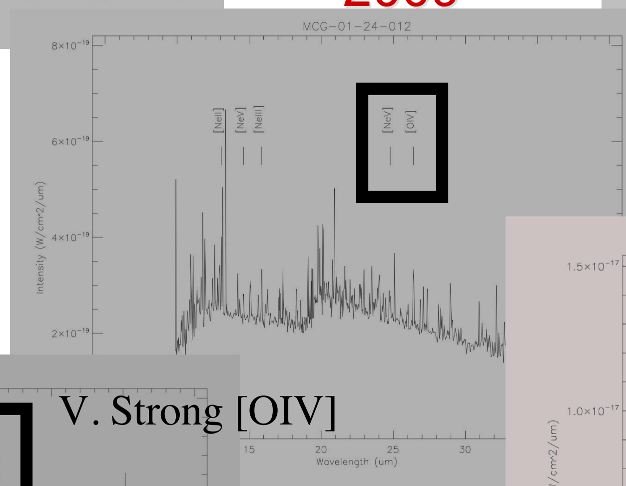
ESO 005-G004

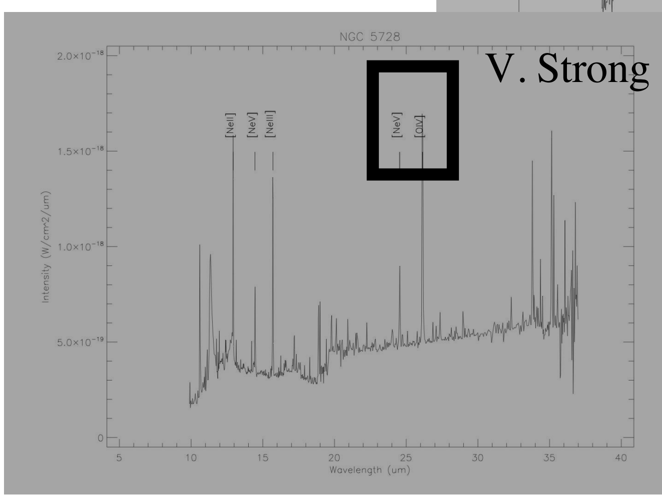


ESO 323-077

Star burst dominated

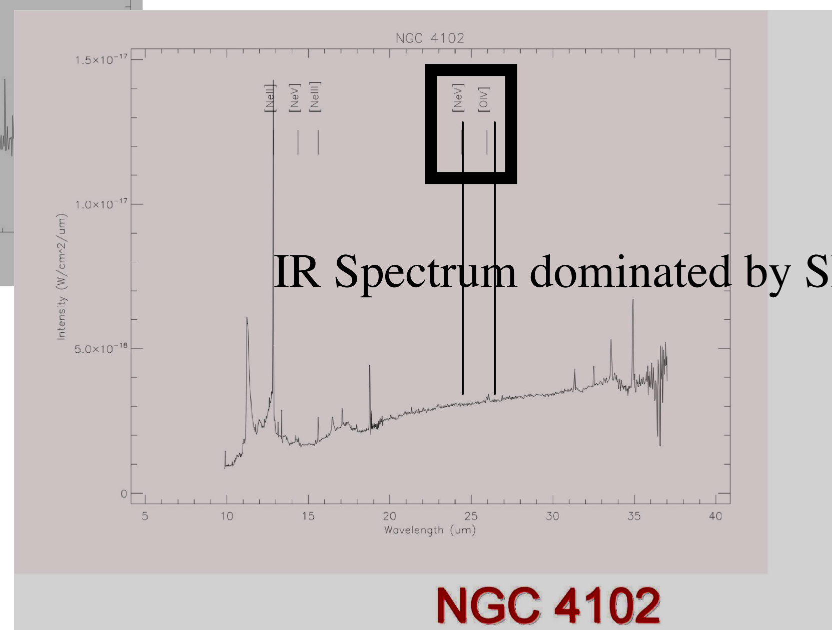
MCG-01-24-012





V. Strong [OIV]

NGC 5728



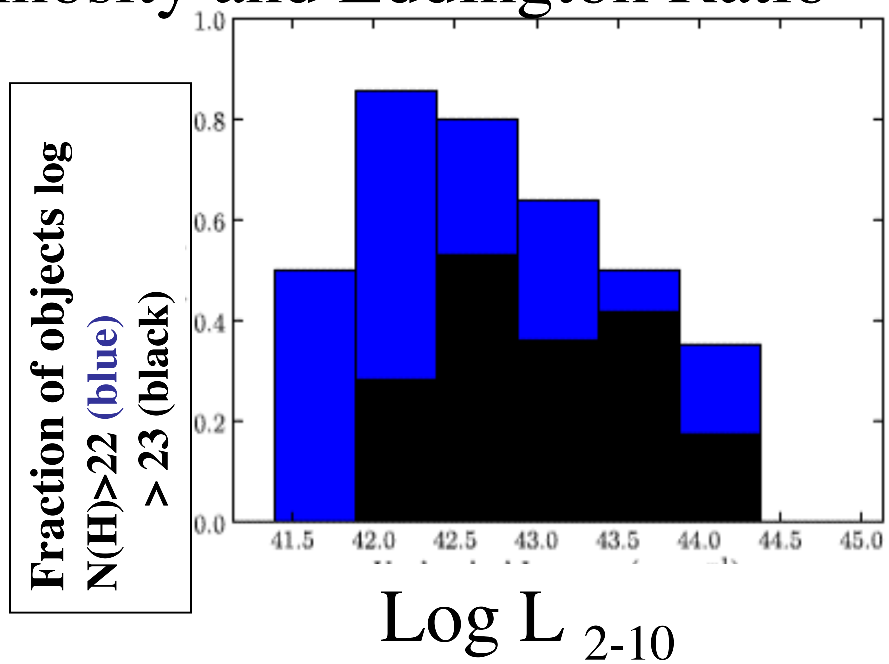
IR Spectrum dominated by SF

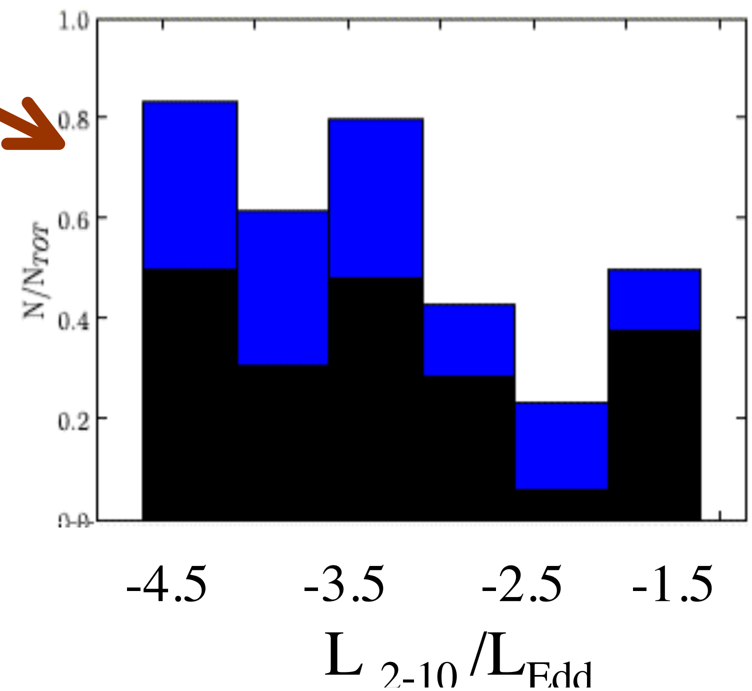
NGC 4102

Notice very wide range of continum shapes, EWs and absolute fluxes

Relation of Absorption, Luminosity and Eddington Ratio

- For 22<log N(H) <23 (blue) anticorrelation of probability of absorption and luminosity (Steffen et al 2003)- violation of unified model
- There is a less significant anti-correlation with Eddington ratio
- For log N(H) >23 (black) there is not a significant anti-correlation
- Wide range in L/L_{Edd} (compared to optical QSO samples)





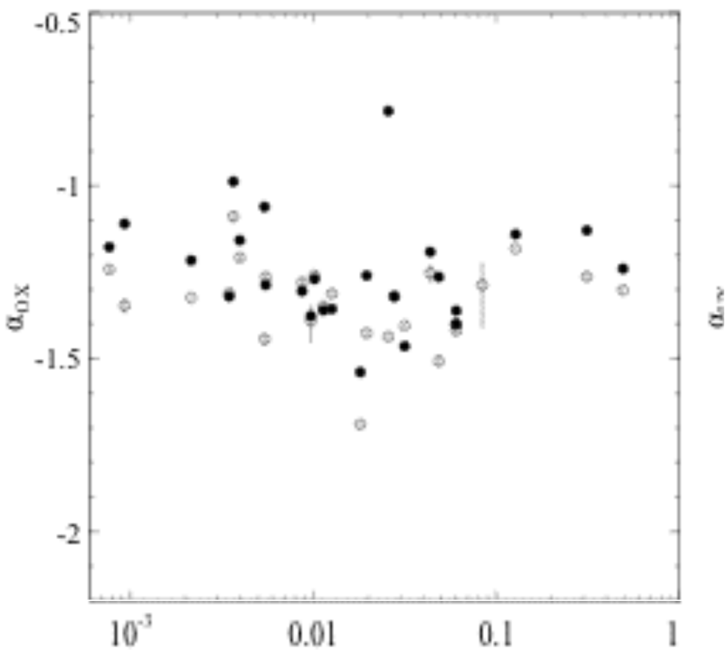
Winter et al 2008b

Eddington Ratios and Bolometric Corrections

- As opposed to an 'optical' sample the BAT sample shows only weak relation of bolometric correction to Eddington ratio
- Opposed to other samples little relation of x-ray to 'optical' ratio as a function of Eddington ratio

Vasudevan et al 2009a

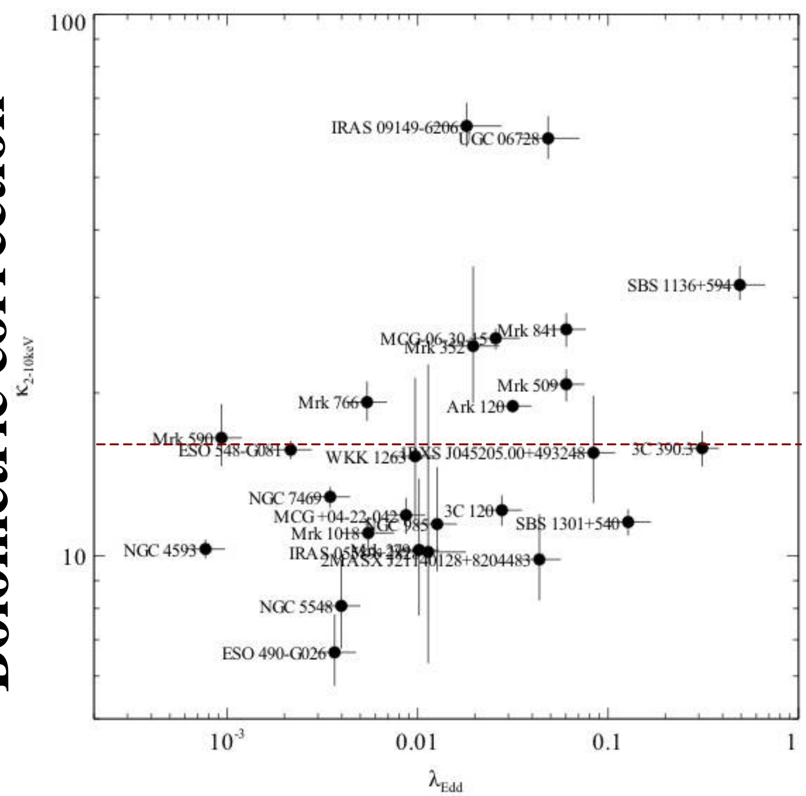
Log x-ray to 'optical' ratio



.001 0.01 0.1 1

Eddington ratio

Bolometric correction

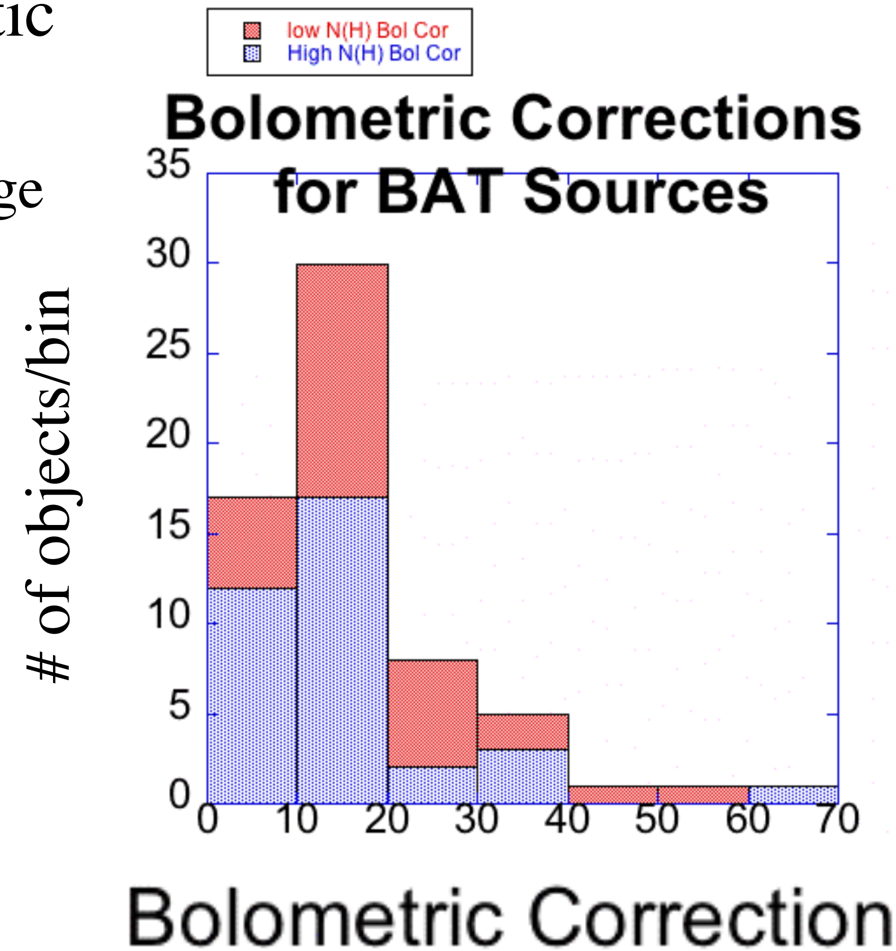


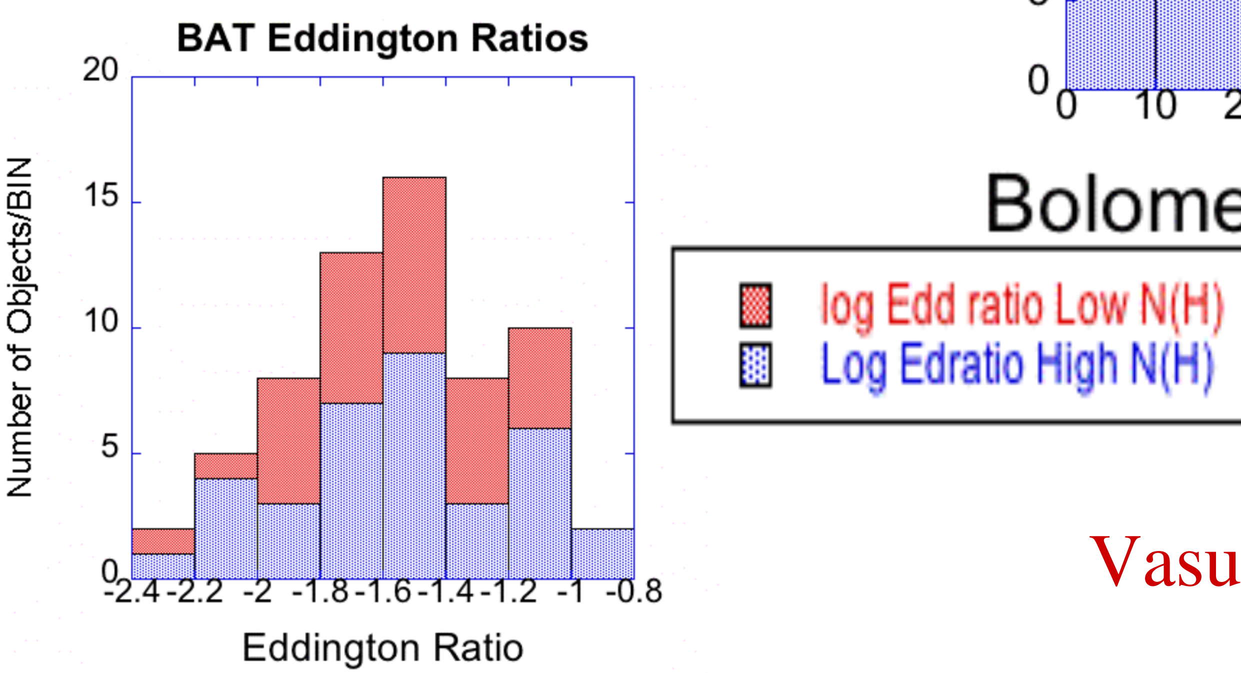
0.001 0.01 0.1

Eddington ratio

Eddington Ratios and Bolometic Corrections

- Vasudevan et al show a narrow range of bolometric corrections and Eddington ratios.
- No significant differences between type Is and II.
- No correlation of Eddington ratio with BH Mass

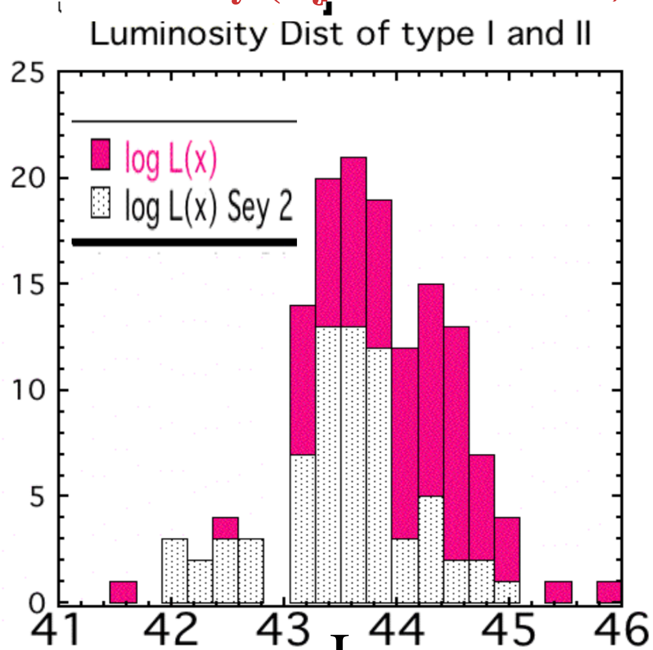




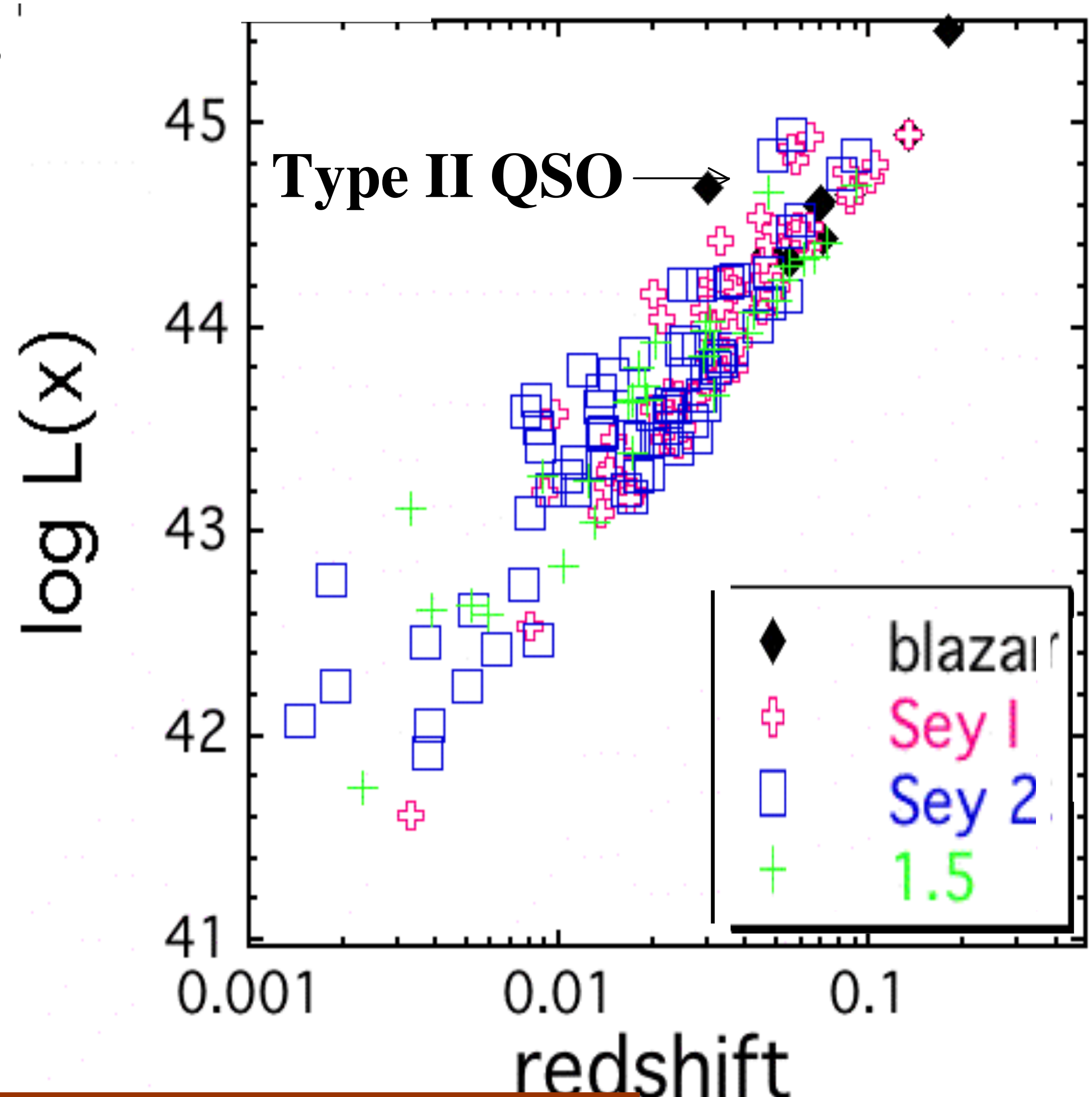
Vasudevan et al 2009b

Luminosity dependencies

- At log L<43 most hard sources are Seyfert IIs/1.5
  - low end of the luminosity function is dominated by absorbed AGN-
  - but there are highly luminous Sey II (the 6 most luminous are all radio loud)
- The change in character at same luminosity for the Chandra CLASX survey with <z>~0.8
- **No Blazars with log L(x) <44.2 in BAT survey (Ajello et al 2009)**



L_{BAT}

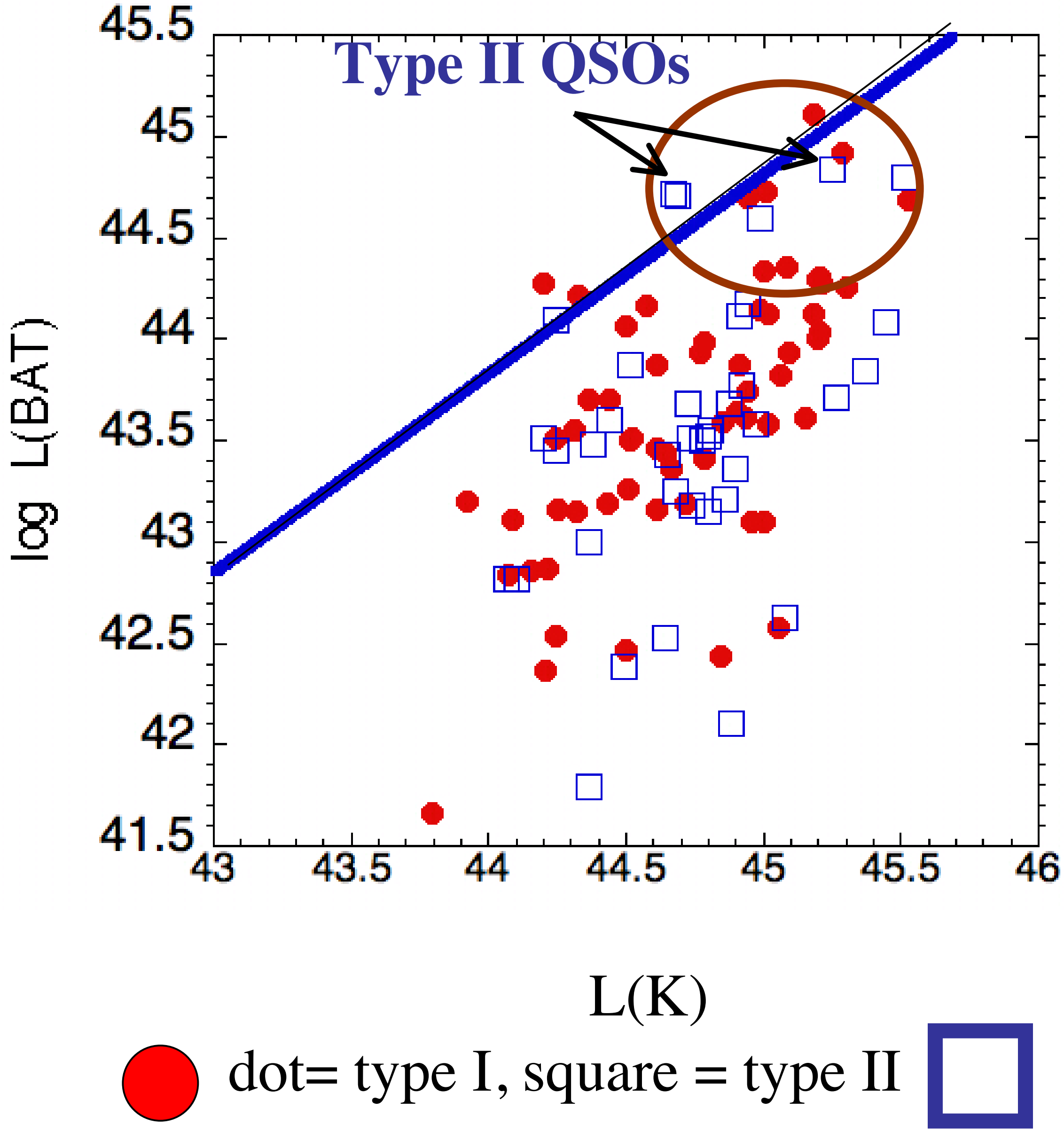


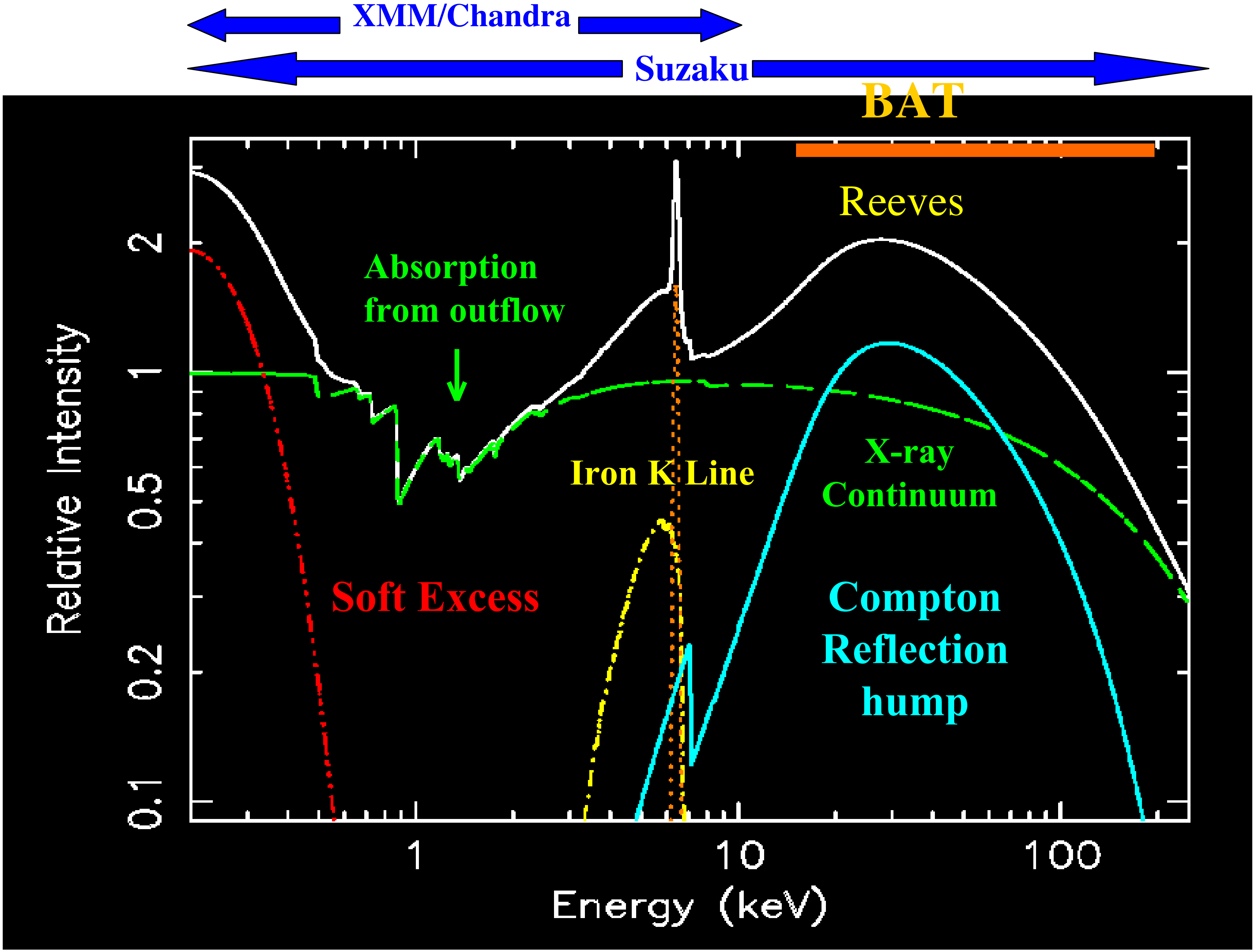
Ratio of I/II is 1:1- **but strongly luminosity dependent a violation of the unified model**

The Most Luminous Objects in the BAT Sample

- The most luminous type II objects in the BAT sample are Cyg-A, PKS 0442-28, **3C452***, 3C105, Swift 0318*, Swift 0918*.
- Of these **one** 3c452 is **Compton thick**
  - Near by (z=0.0811) FRII Radio galaxy with optical spectrum consistent with SyII
    - [OIII] luminosity = 2×10^{41} erg s^{-1} (observed)
    - Luminosity = 3×10^{43} erg s^{-1}

    - ***luminous Compton thick objects exist***

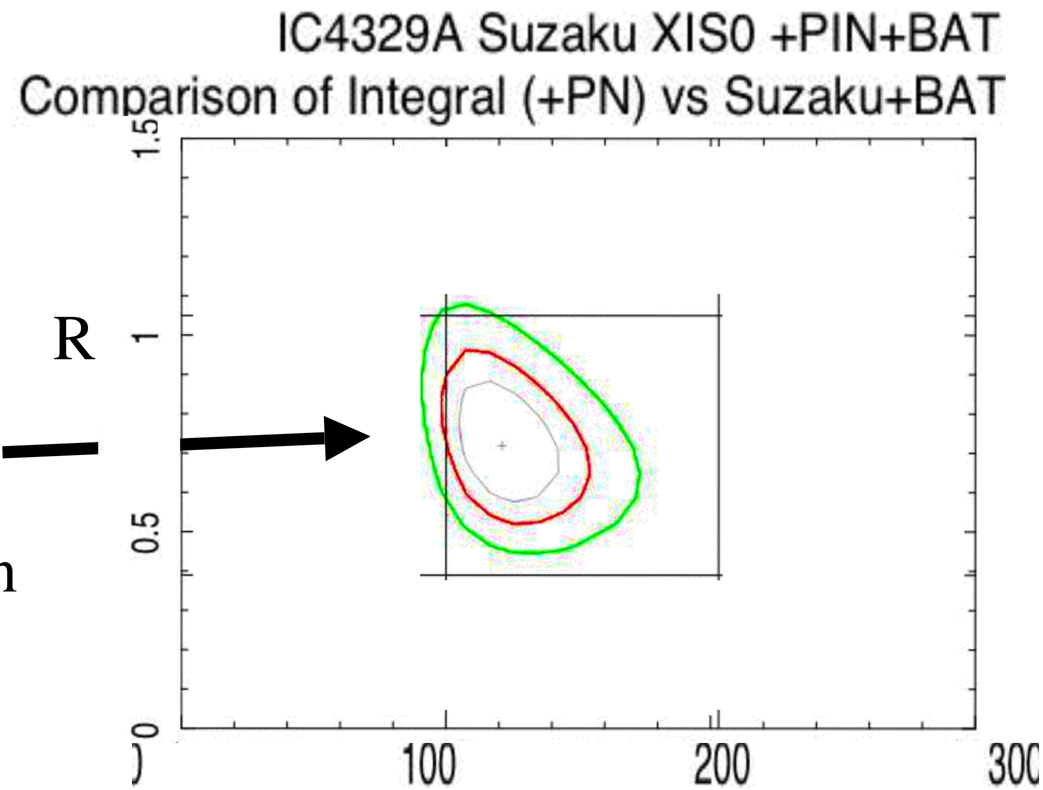



XMM/Chandra
Suzaku
BAT
Reeves
Absorption
from outflow
Iron K Line
X-ray
Continuum
Soft Excess
Compton
Reflection
hump
Relative Intensity
0.1
0.2
0.5
1
2
Energy (keV)
1
10
100

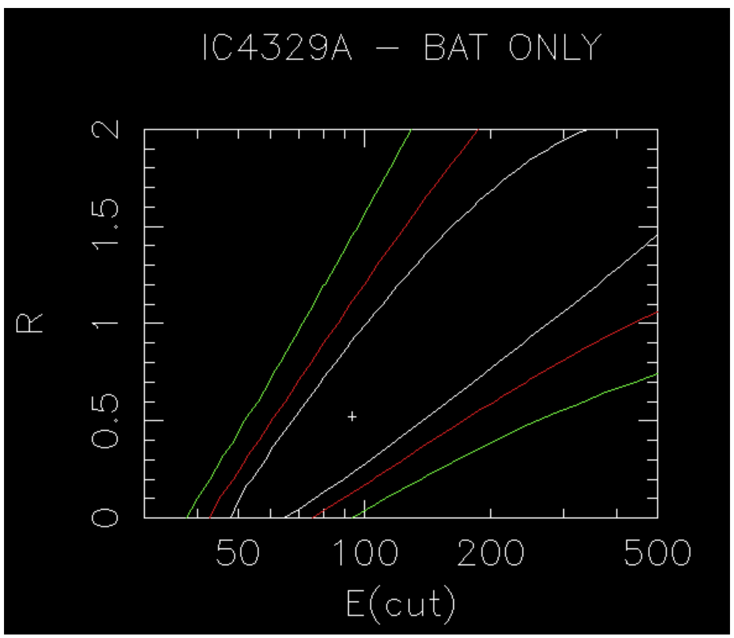
Properties of the high energy Continuum

- BAT is giving a large sample of sources, spectra and light curves.
- The combination of BAT and Suzaku gives the best constraints on the shape of the continuum (slope and cutoff) and on the amount of reflection

R



E_{cut}



Without Suzaku the BAT data can only constrain 2 out of 3 of the reflection Model parameters (R, E(cut), Γ)

Precise Measures Of Reflection and Cutoff

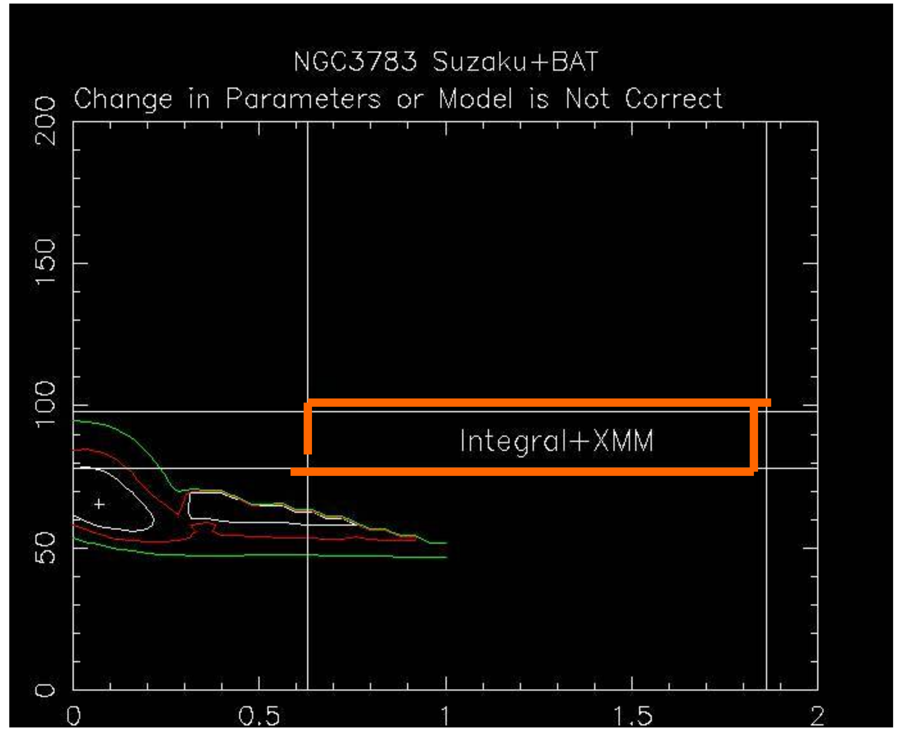
- Integral +XMM results (Molina et al 2009) - precise measures of reflection and cutoff for ~20 objects using archival data -*assume* - source spectrum does not change with time

  Not necessarily valid

compare Suzaku and BAT with these results- *remove assumptions*

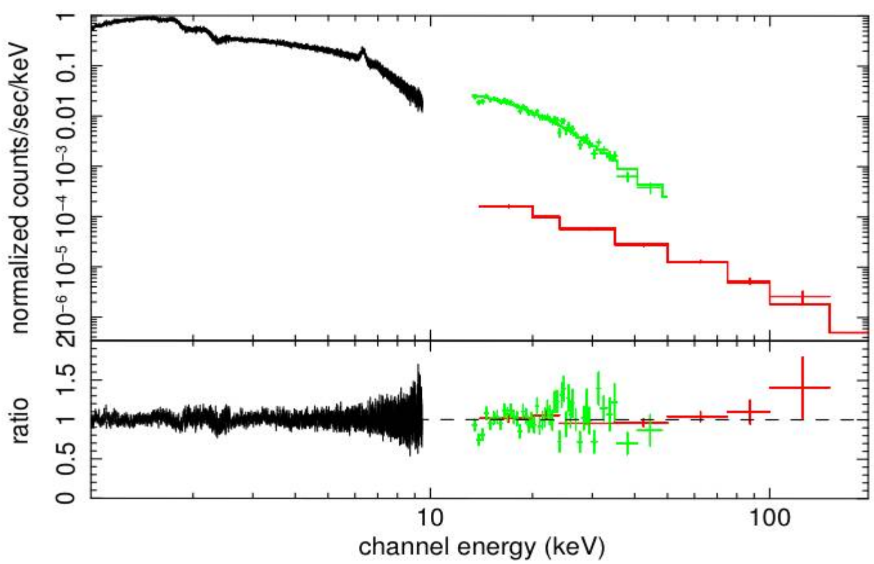
- For NGC3783 the results seem to disagree- but only the high precision data could have detected this.

E(cut)



R

NGC3783 Suzaku+BAT



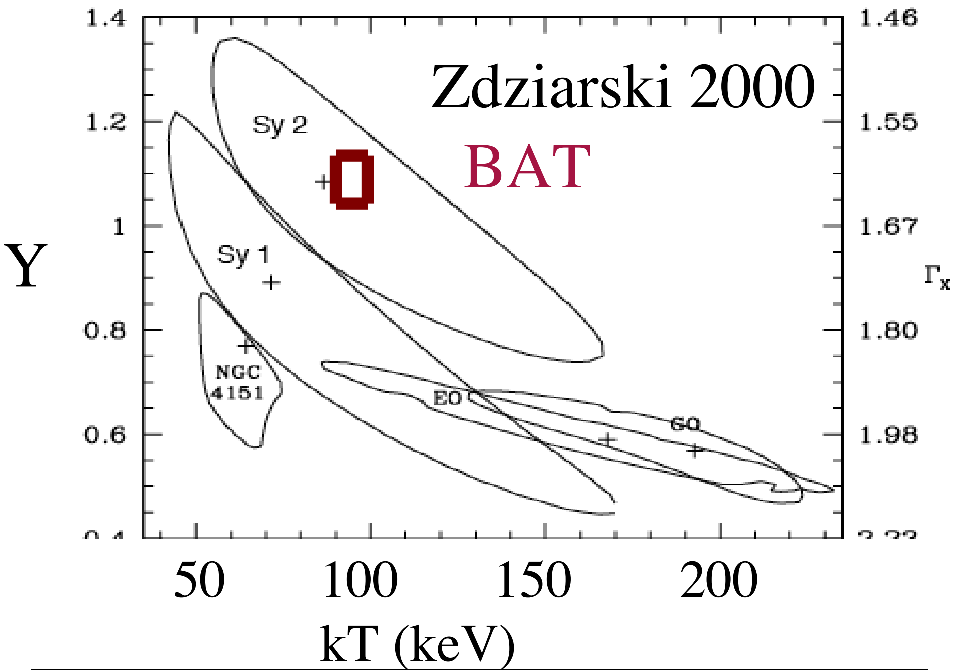
Have the parameters changed ? or does the different response of the instruments to the models produce *apparently* different results

Physical Model of Hard Continuum

- Classical free parameters are R (reflection fraction) (τ,T_e)

$y=\max(\tau, \tau^2)4kT_e/mc^2$

The BAT data ALONE allow the determination of these parameters ***for the population***



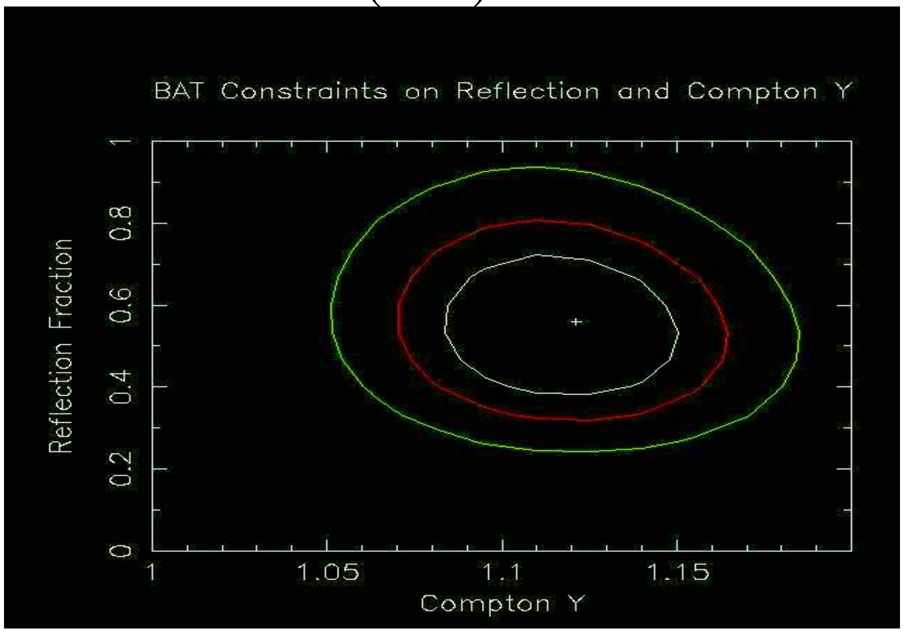
Best fits:

y=1.12(1.06,1.16)

kT_e=94 (90, 97)

R=0.55 (0.36, 0.725)

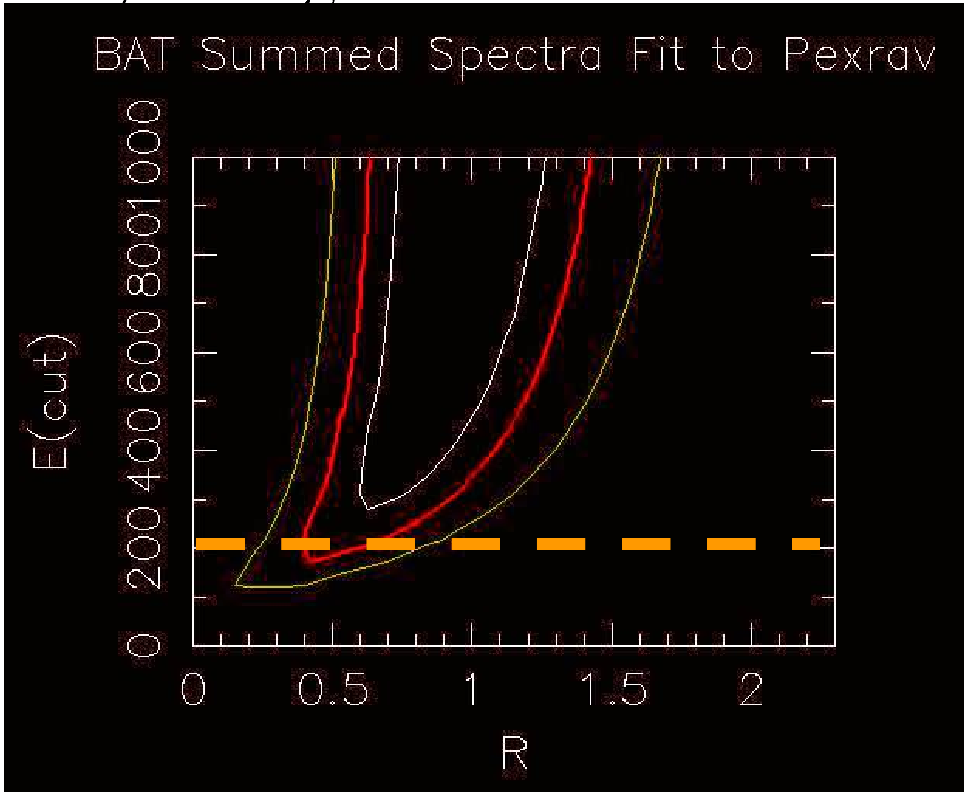
Similar to conclusions of Zdziarski et al 2000 FROM OSSE+Ginga!

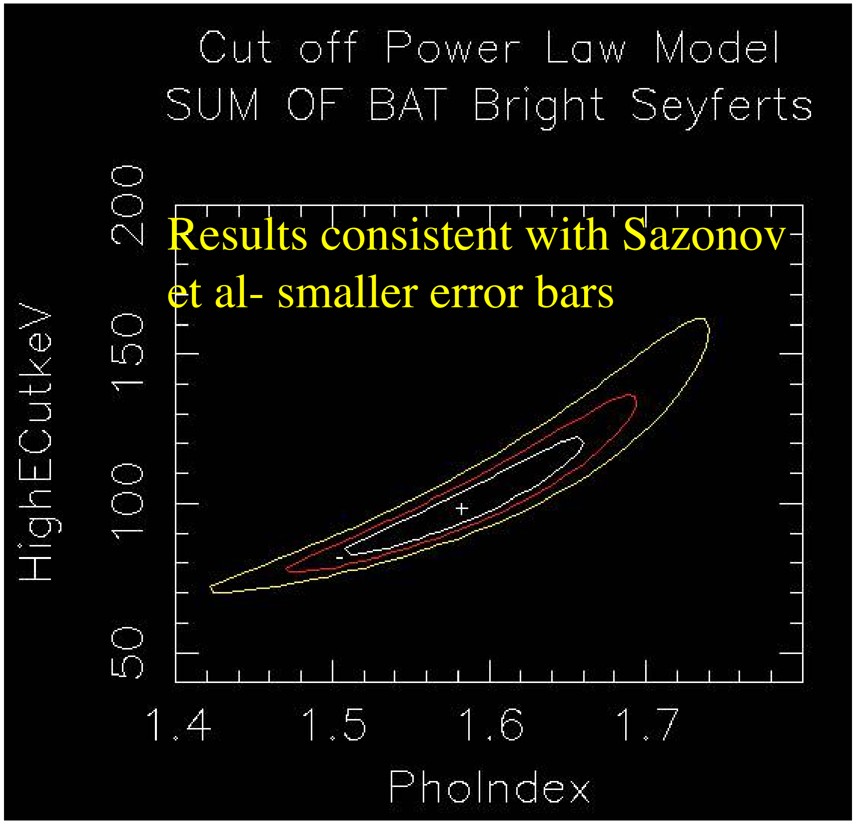


The value of R depends on the input continuum model (e.g which comptonization model, cutoff PL etc)

What about the X-ray Background?

- There are a wide variety of cutoffs
- The population is consistent with a ***reflection model*** with R~1, Γ ~2 $E_{(cut)}$~>200 keV OR
- *cutoff powerlaw* with Γ~1.6 and $E_{(cut)}$~100 kev OR
- ***broken PL*** Γ_1 ~1.75, Γ_2 ~2.2 and E_B~33

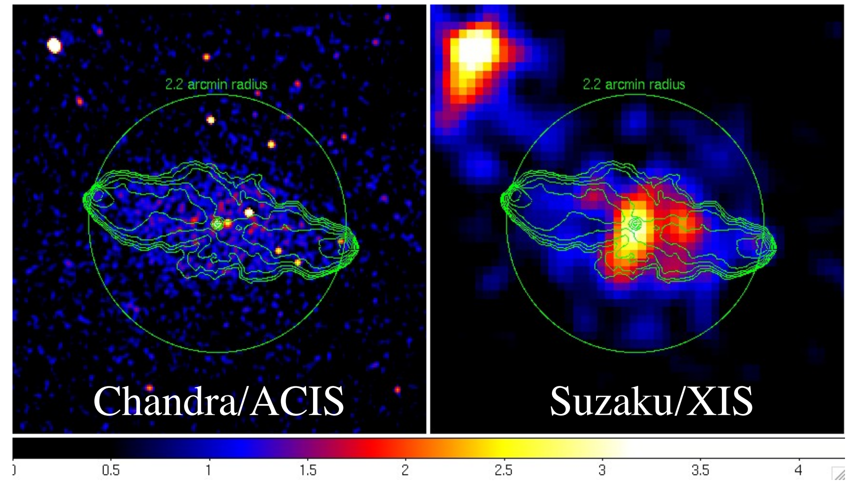




These results are **not** consistent with the spectrum of the XRB- UNLESS the median redshift is ~1-$E^{obs}_{(cut)} \sim E_{(cut)}/(1+z)$-
slope maybe too steep in either the broken PL or cutoff PL model fits
Effect of Compton thick objects appears to be small

Harvest from the BAT Survey- 3C 452 a Compton thick **High Luminosity** AGN

V. Fioretti et al in prep

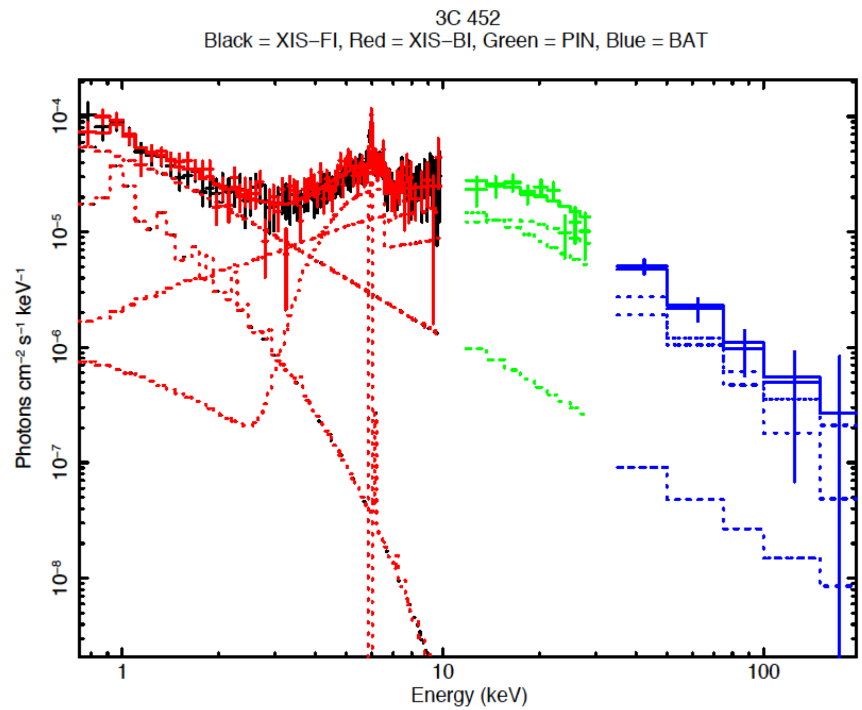


Suzaku data show:

- ***A Compton Thick AGN***
  - High column density (Log N_H > 23.5 cm^{-2})
  - **Relative Reflection (Ω/2π) >>1**
  - Γ < 1.7
- ***But low Fe K EQW (180 eV)***

…. predictions expect Fe K EQW > 1 keV for CT AGN (Ikeda et al 08, Levenson et al 02)

Fe <0.8 in pexrav model

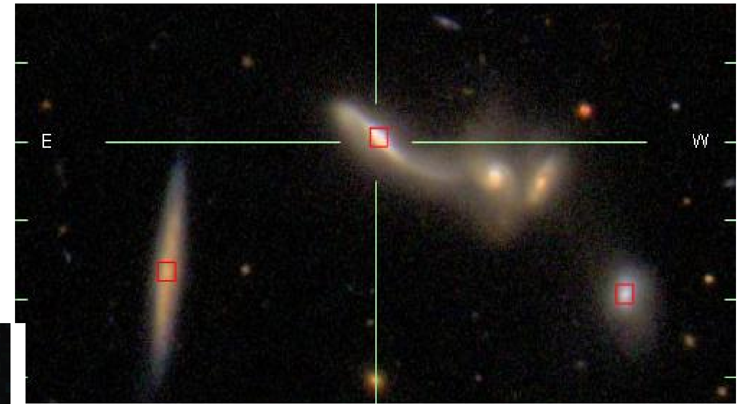


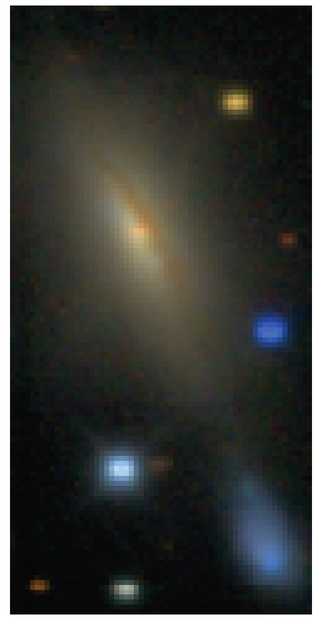
3 Other Luminous narrow line 3 Objects selected from the BAT survey show low FE EQW but no significant Reflection signal

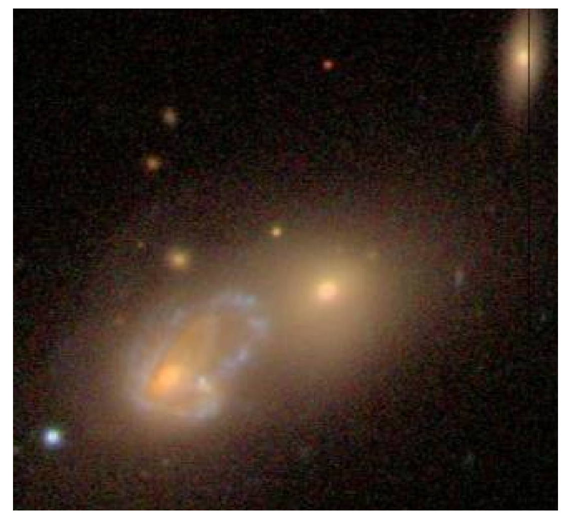
The Nature of AGN Hosts

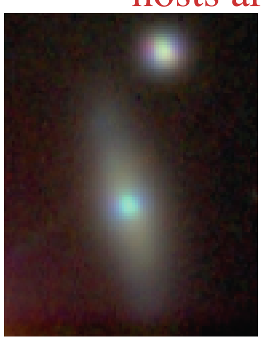
Koss et al 2009

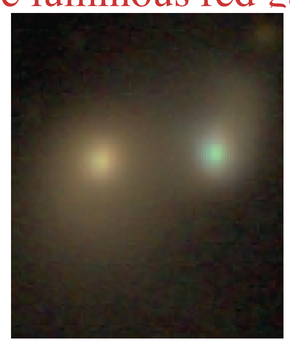
- Theory - AGN strongly influences galaxy formation - BAT sample perfect for testing this idea
- The BAT sample - hosts of most AGN are spiral and irregular galaxies > 30% involved in mergers or interactions (~2% for ‘normal’ galaxies)
- The ‘colors’ of the hosts are mid-way between that of ‘red’ and dead galaxies and active star forming galaxies -BAT AGN at higher stellar masses are much bluer than the comparison sample.
  - Chandra/XMM selected AGN at z~1 hosts are luminous red galaxies

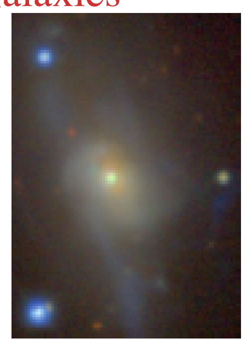


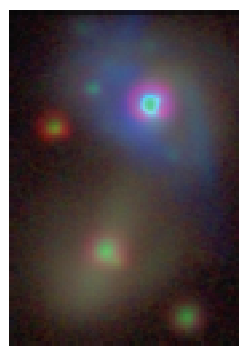








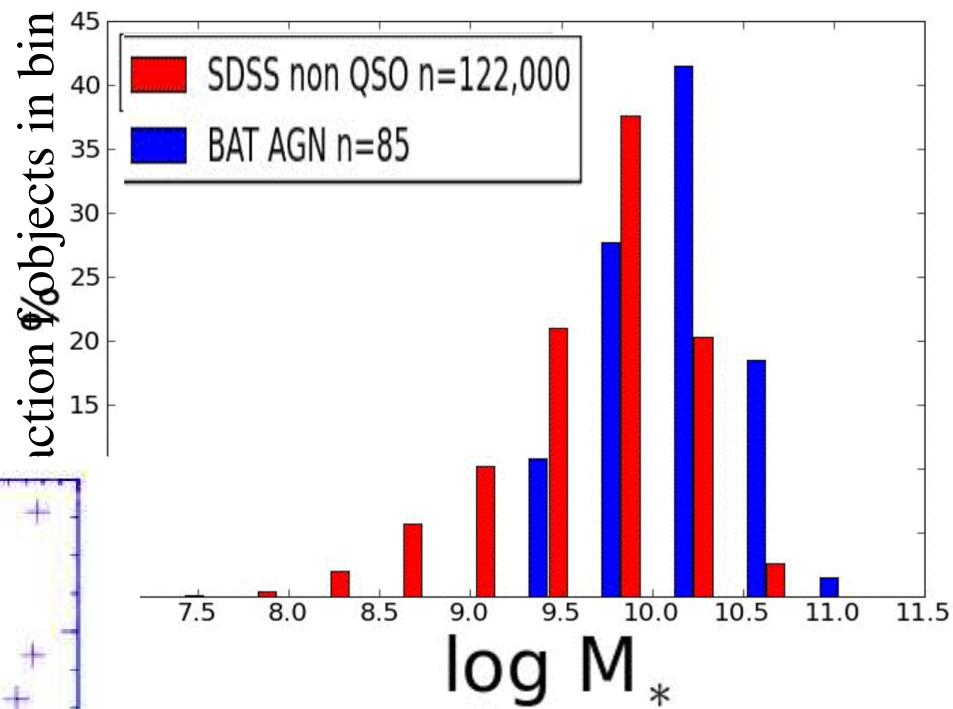


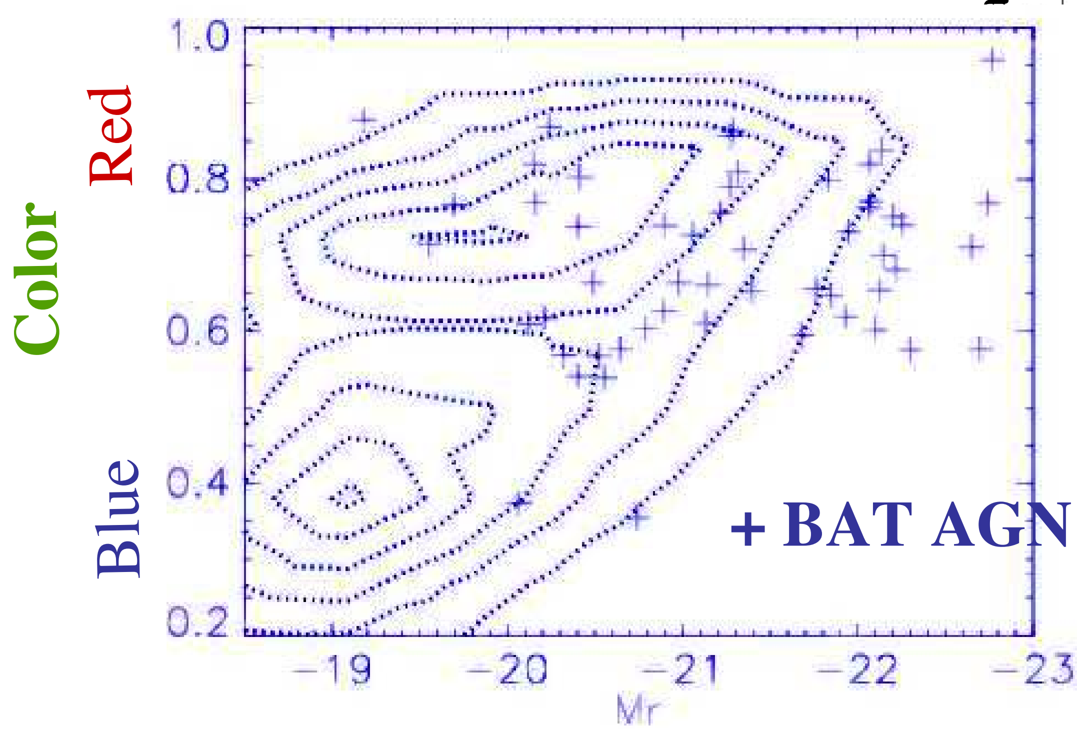


<u>Some</u> of the optical images of interacting galaxies from the BAT sample

What Makes a Galaxy an AGN?

- The median luminosity of BAT AGN hosts is 1.1 mag brighter than for normal galaxies–BAT AGN have bluer colors and more star formation than the SDSS AGN, but both SDSS AGN and BAT AGN are found in more massive galaxies compared to an inactive sample...
- AGN Hosts preferentially live in 'green valley'– luminous galaxies with star formation–**Does AGN cause star formation or turn it off?- (cf. Schawinski et al 2009)**
-





Blue line/contour - field galaxies
Red Boxes/+ AGN Hosts
log stellar masses of 10.28 BAT, 10.12 SDSS AGN, 9.82 sdss inactive

Koss et al 2009

- Large samples of hard x-ray selected AGN (>250) Identification requires x-ray follow-ups
- Almost all heavily absorbed sources show complex spectra and tend to be low luminosity objects

- Can now measure E(cut) and R very accurately combining Suzaku and BAT and *identify Compton thick objects from high E continuum shape*

The Results

- High fraction of BAT AGN in interacting galaxies and/or peculiar systems
  - More massive, bluer than normal galaxies
  - Lie in spectral region (green valley) which normal galaxies avoid

- Low z objects with no signature of an AGN in optical or IR exist

- Sum of 0.5-10 spectra of BAT selected objects looks like x-ray background spectrum- maybe 15-200 also

- Seyfert Is and IIs have different luminosity distributions and/or Eddington ratio distribution or different bolometric corrections
- OIV is a very good indicator of ‘AGNness’

Bottom Line- The Multi-wavelength Approach

- Now have data to strongly constrain models of AGN for brightest sources
- Very Hard x-ray selection with follow-up in the
  - X-ray
  - Optical
  - IR
  - Radio

Are necessary to understand the properties of AGN