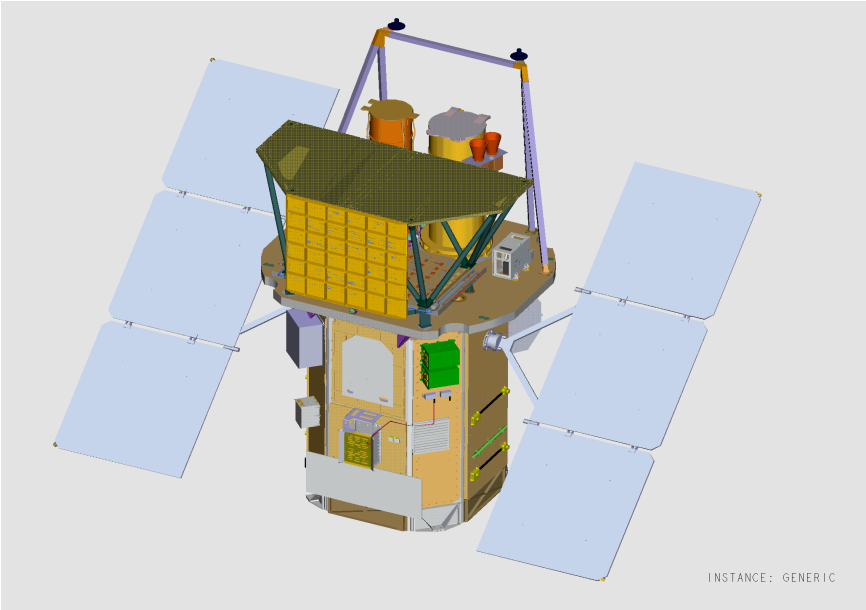
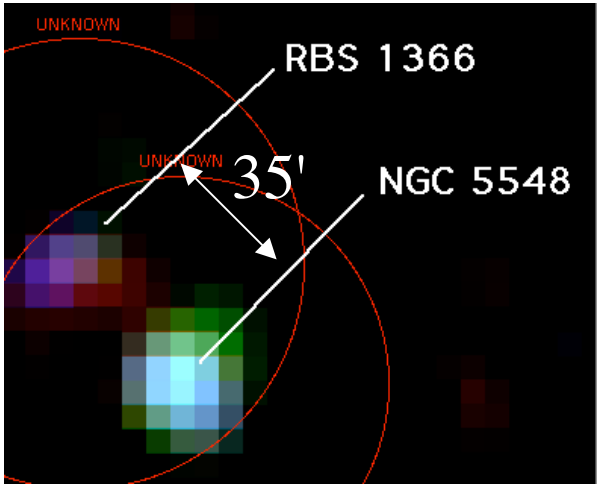
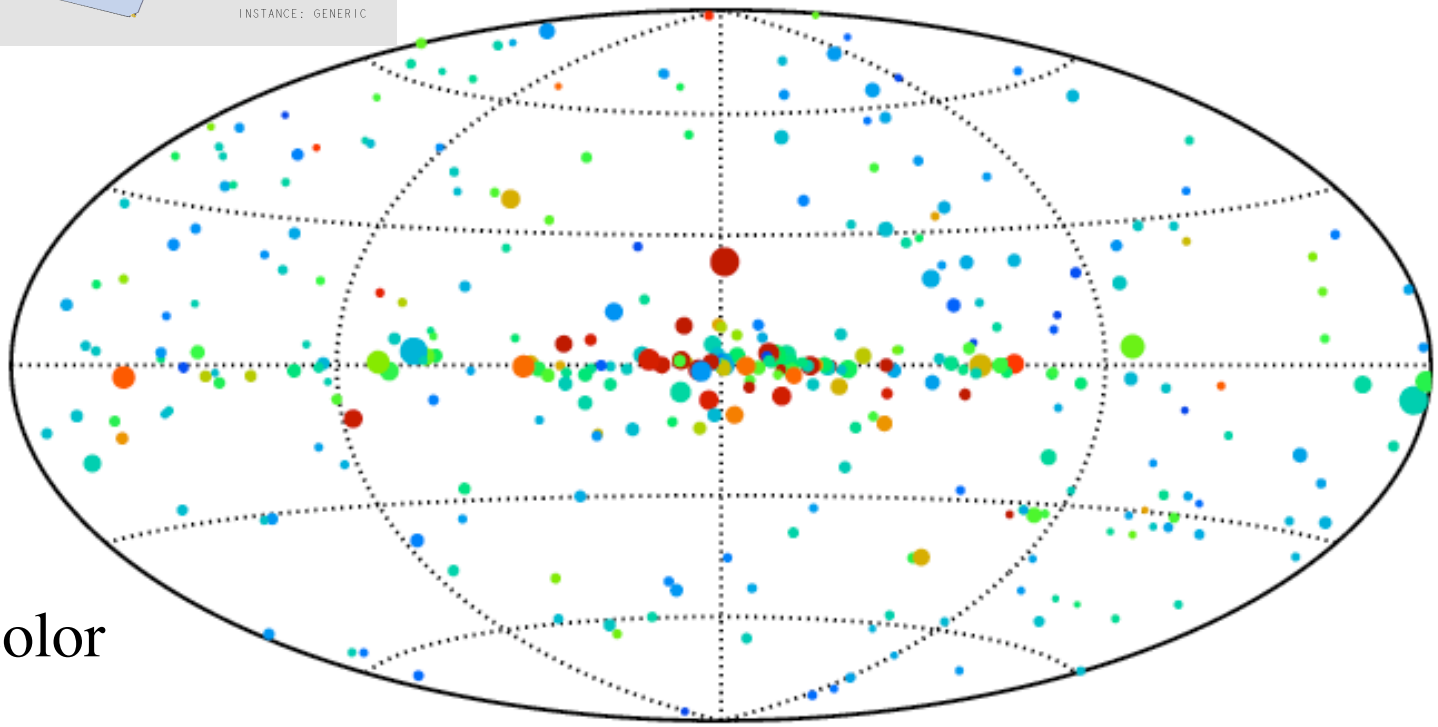
Swift/BAT Hard X-ray Survey





Preliminary results in Markwardt et al 2005



energy coded color

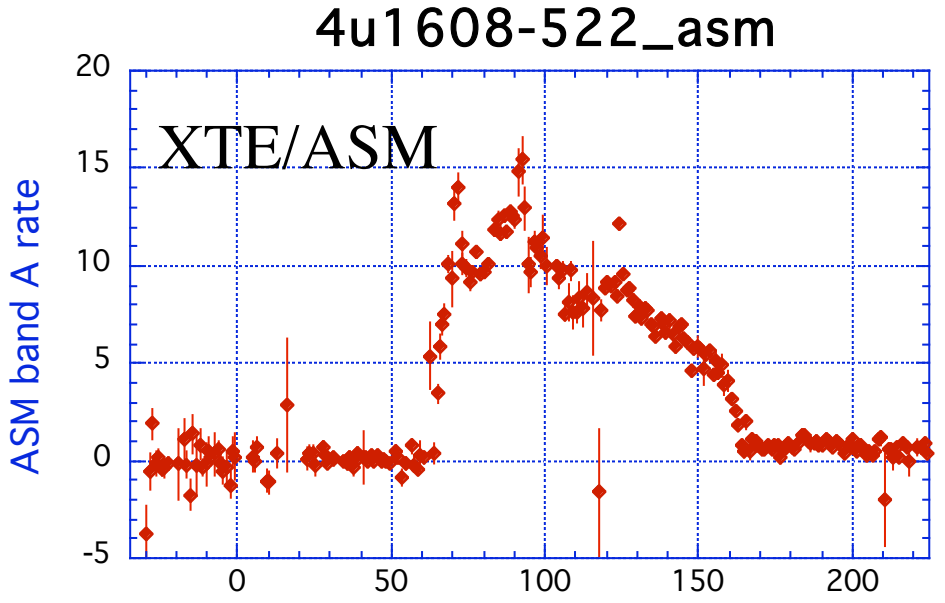
BAT Instrument Parameters

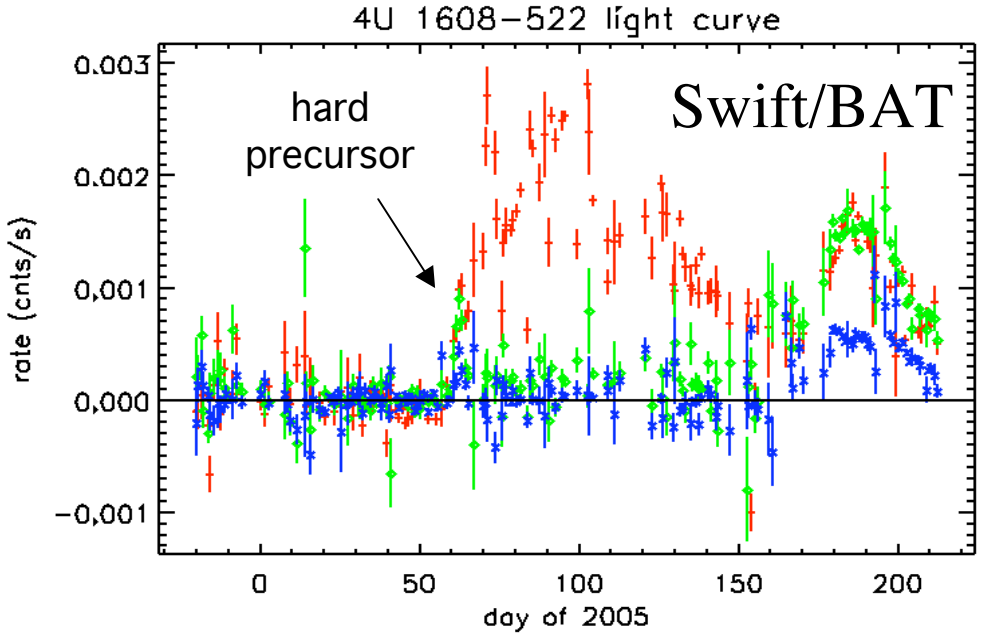
- **Energy Range** — **14 - 195 keV**
- **Area** — **5200 cm^2 (x 50% open fraction)**
- **Field of View** — **2 Steradian, partially coded**
- **Background** — **10,000 ct/s (cosmic diffuse dominated)**
- **Spatial Resolution** — **21' sky pixel, centroided to <1-3'**
- **Spectral Resolution** — **6 keV FWHM @ 60 keV, average**
- **Sensitivity** — **0.2 photons/cm^2/sec**
- **Timing Resolution** — **100 usec**
- **Observing Strategy** — **"Random" (piggy-back Swift GRB observing plan)**

QX Nor/4U 1608-522 LMXB outburst

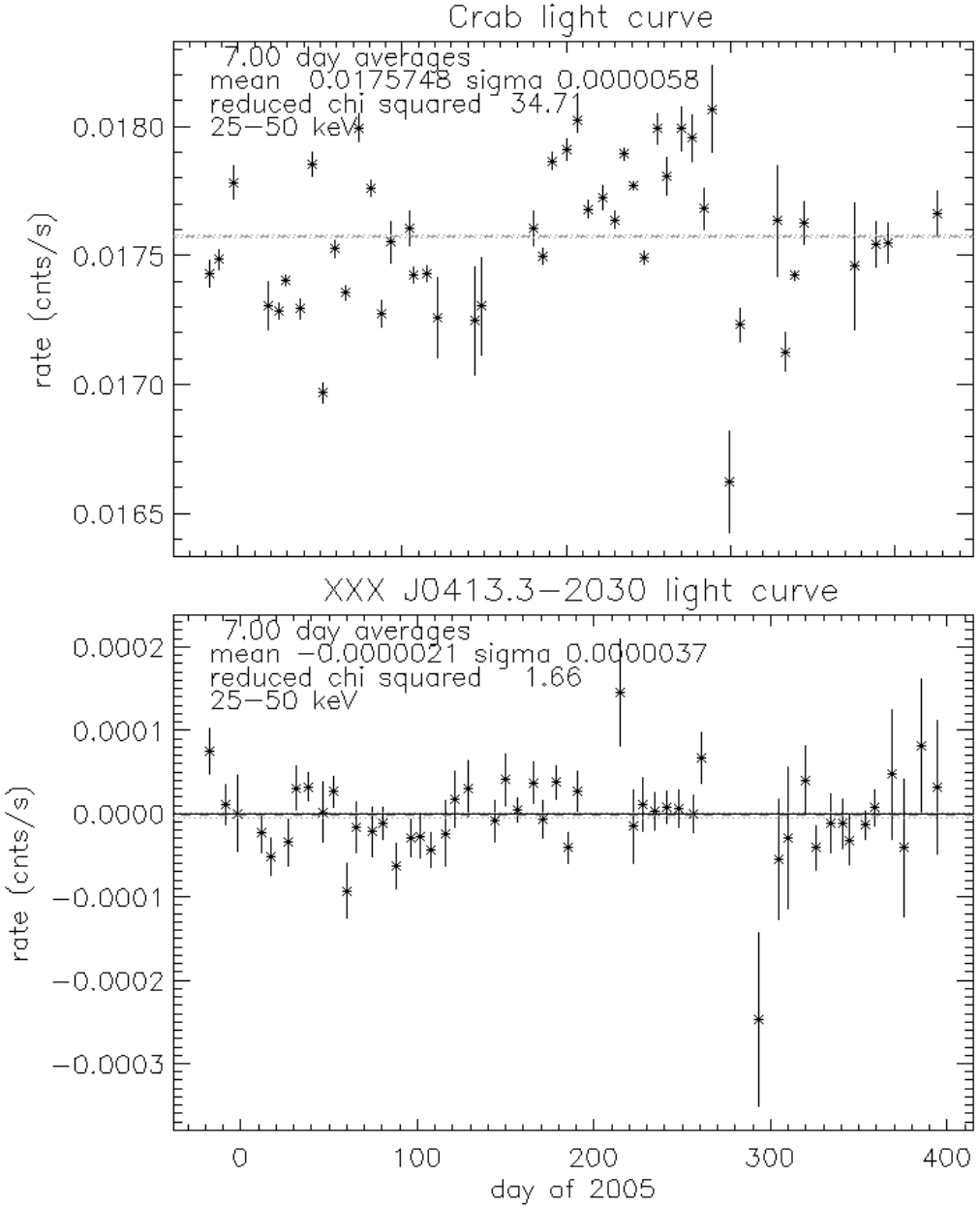
BAT Survey

- long term broadband spectroscopic monitoring (14-200 keV)
- ~70% sky coverage each day
- transient detection within minutes
- immediate follow up with XRT provides x-ray identifications
- Hard x-ray lightcurves tell new stories



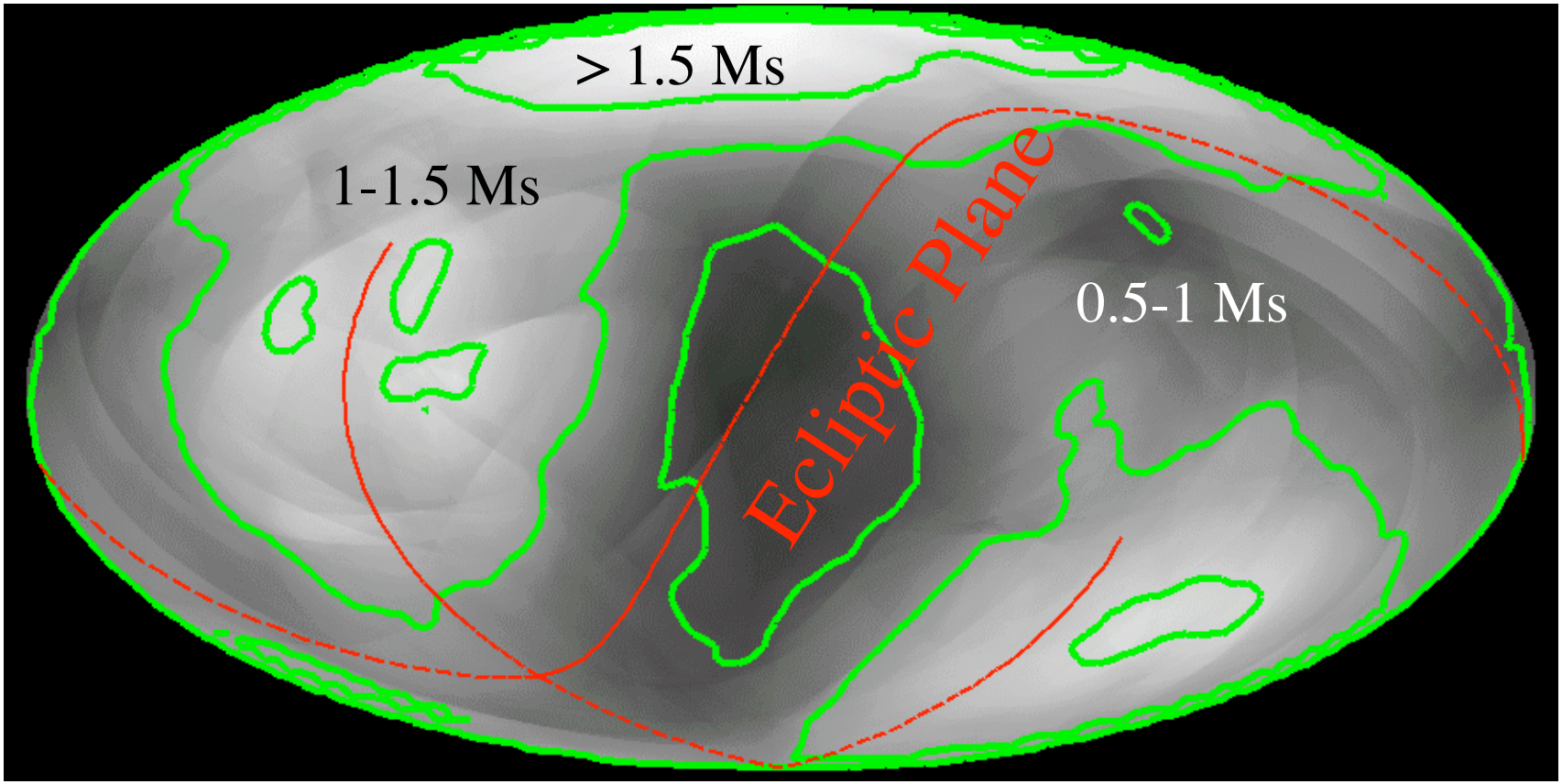


Systematic Errors

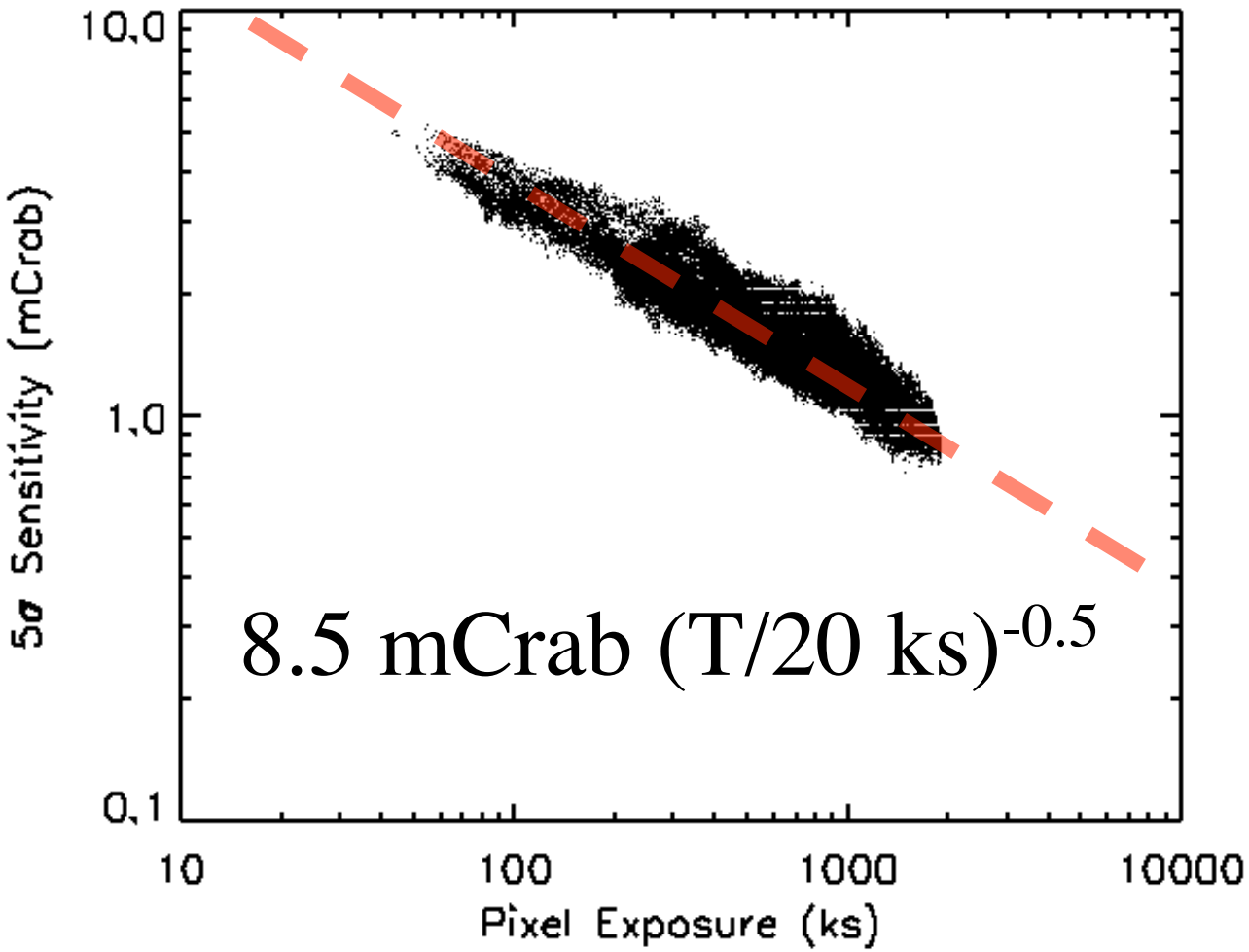


- Crab shows residual variations of 10%
- Reduced Chi Squared for random pointings is between 1.2 and 2.0 for 7 day averages
- Long term averages of random pointings are consistent with no flux

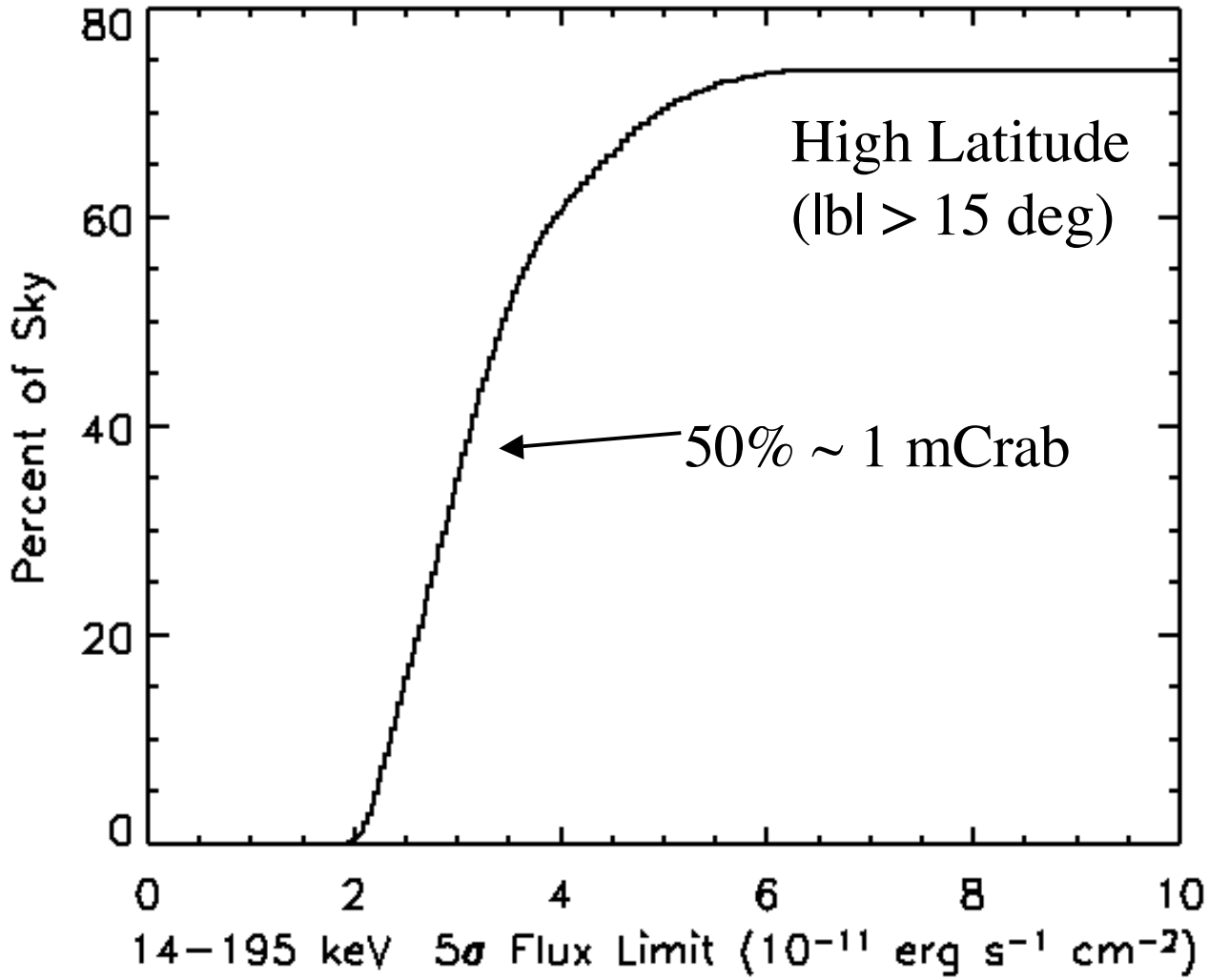
9-month Survey Sky Coverage



9-month Sensitivity vs. Exposure



9-month Survey Completeness



BAT Source Detections

9 months

- 328 sources
- 14 unidentified sources
- 159 galactic
- 6 galaxy clusters
- 158 AGN
  - 15 beamed

|Galactic b| >15 (74%)

- 159 sources
- 5 unidentified sources
- 28 galactic
- 3 galaxy clusters
- 126 AGN
  - 14 beamed

already the most sensitive all-sky hard x-ray survey
At 3 years expect 450 AGN.

BAT Galactic Sources

Breakdown of 9 month list

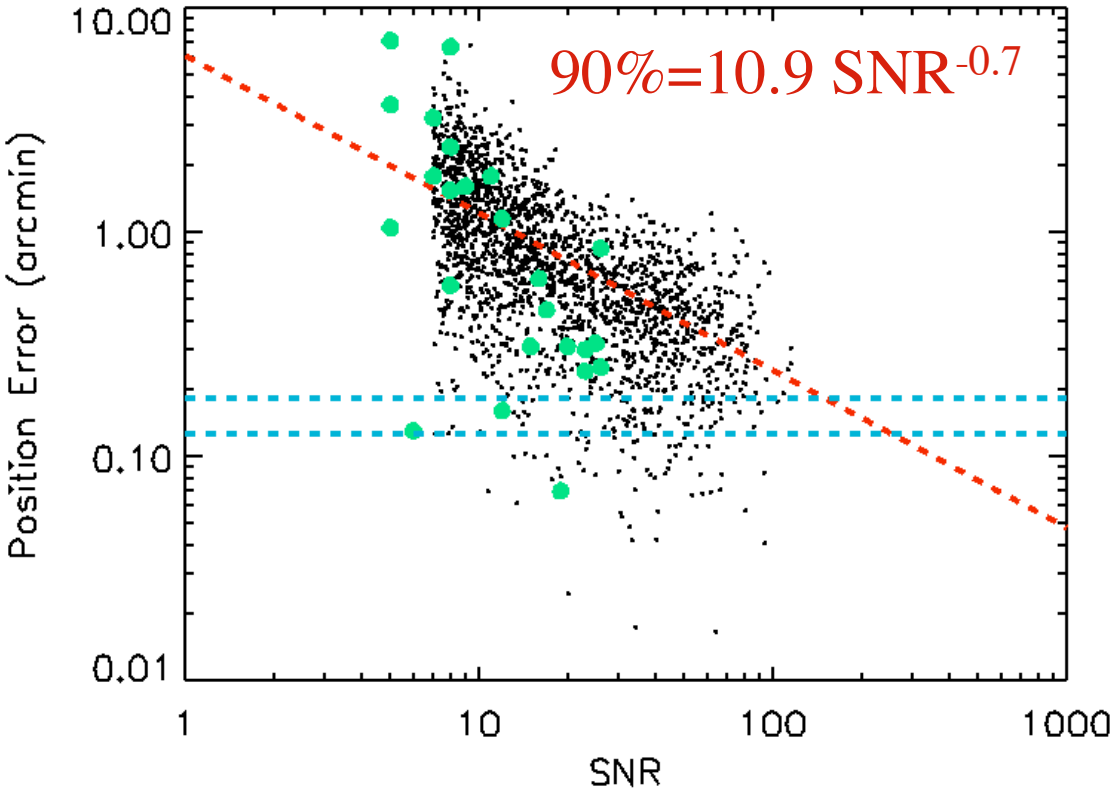
- 15 CV
- 3 symbiotic stars
- 6 pulsars
- 35 HMXB
- 59 LMXB
- 3 SNR
- 1 star
- 37 galactic unknowns

Variable sources at low galactic latitude usually with ROSAT or INTEGRAL counterparts are labeled "galactic"

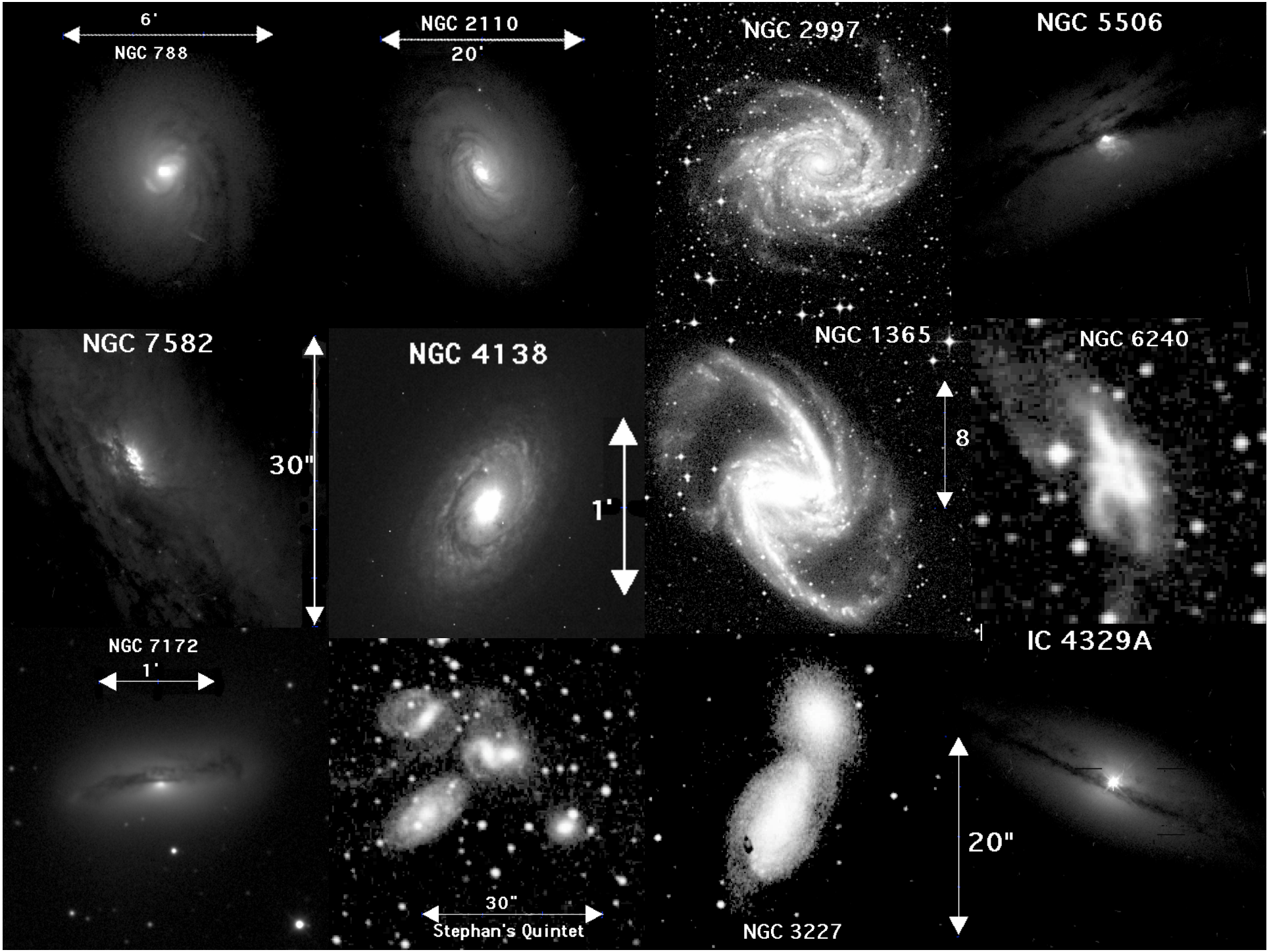
already the most sensitive all-sky hard x-ray survey

How good are the BAT IDs?

- BAT sources are usually very easy to ID
  - <13 J mag galaxies
  - low redshift
  - x-ray sources
  - optical AGN
  - high absorption
- Weak x-ray counterparts usually have no photons <3 keV
- Very few source confused fields



- Position resolution of <6 arcmin for near threshold sources confirmed by many IDs


6'
NGC 788
NGC 2110
20'
NGC 2997
NGC 5506
NGC 7582
30"
NGC 4138
1'
NGC 1365
8
NGC 6240
IC 4329A
NGC 7172
1'
30"
Stephan's Quintet
20"
NGC 3227

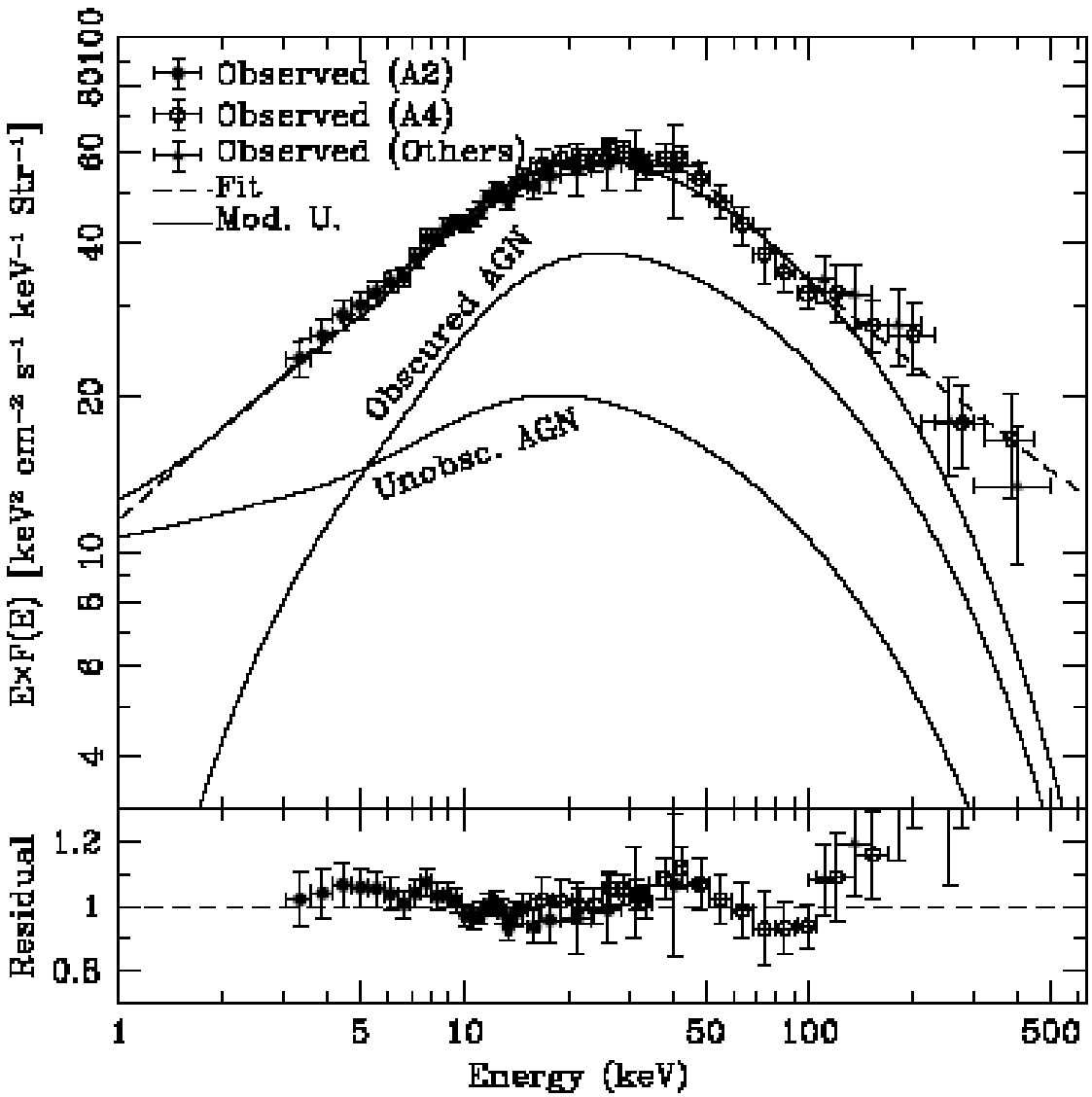
Hard X-Ray Survey of AGN

- AGN are thought to be the dominant source of the X-ray background (CXB)
- Many AGN have high absorbing columns
  i.e. they can be “hidden” from line of sight in optical, UV, soft X-ray
- Hard X-ray band (> 15 keV) is one window where opacity is low for all Compton thin AGN
- A complete census of AGN is possible
- Motivation for Hard X-ray surveys by Swift/BAT, INTEGRAL, EXIST, Con-X, NEXT

Background Modeling

- x-ray hump in the CXB thought to be reflection component from AGN
- 14-200 keV standard model gives obscured to unobscured ratio 3:1
- Many undetermined parameters beyond this are within the grasp of BAT
  1. LogN/LogS
  2. hard x-ray spectrum
  3. luminosity function
  4. beamed sources

Treister,Urry,&Lira Astro-ph/0512008



BAT GALAXY Identifications

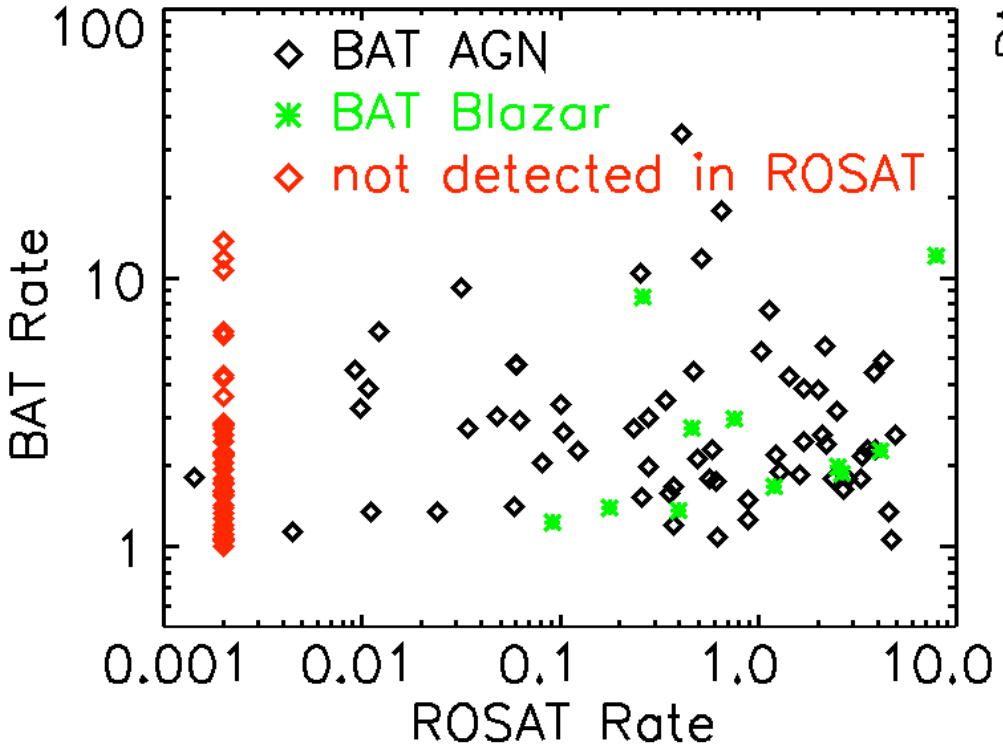
absorbed
Log nH > 22
|Gal b| >15

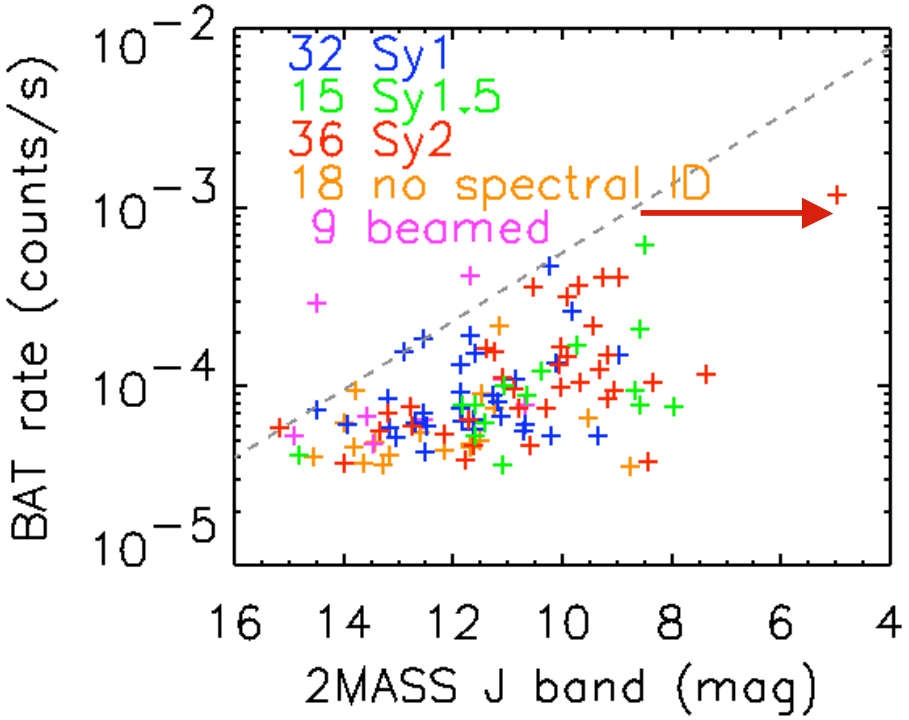
	abs	unabs	noabs	total
Sy1	2	28	4	34
Sy1.5	4	11	0	15
Sy2	29	3	6	38
no Sy ID	**8**	**3**	**9**	20
total	43	45	19	107

- Most if the galaxies with no Sy classification are absorbed.
- Therefore, the unknown galaxies will be mostly absorbed and Sy2's or edge on spiral galaxies with no lines
- 50% of galaxies are Sy2 and 56% are absorbed confirms Markwardt et al 2005 (14% Sy1.5)
- Much lower than 75% predicted by the standard model for the CXP

Correlations of BAT Rate with other Bands

- no correlation between BAT and ROSAT count rates
- 44 BAT sources not detected by ROSAT

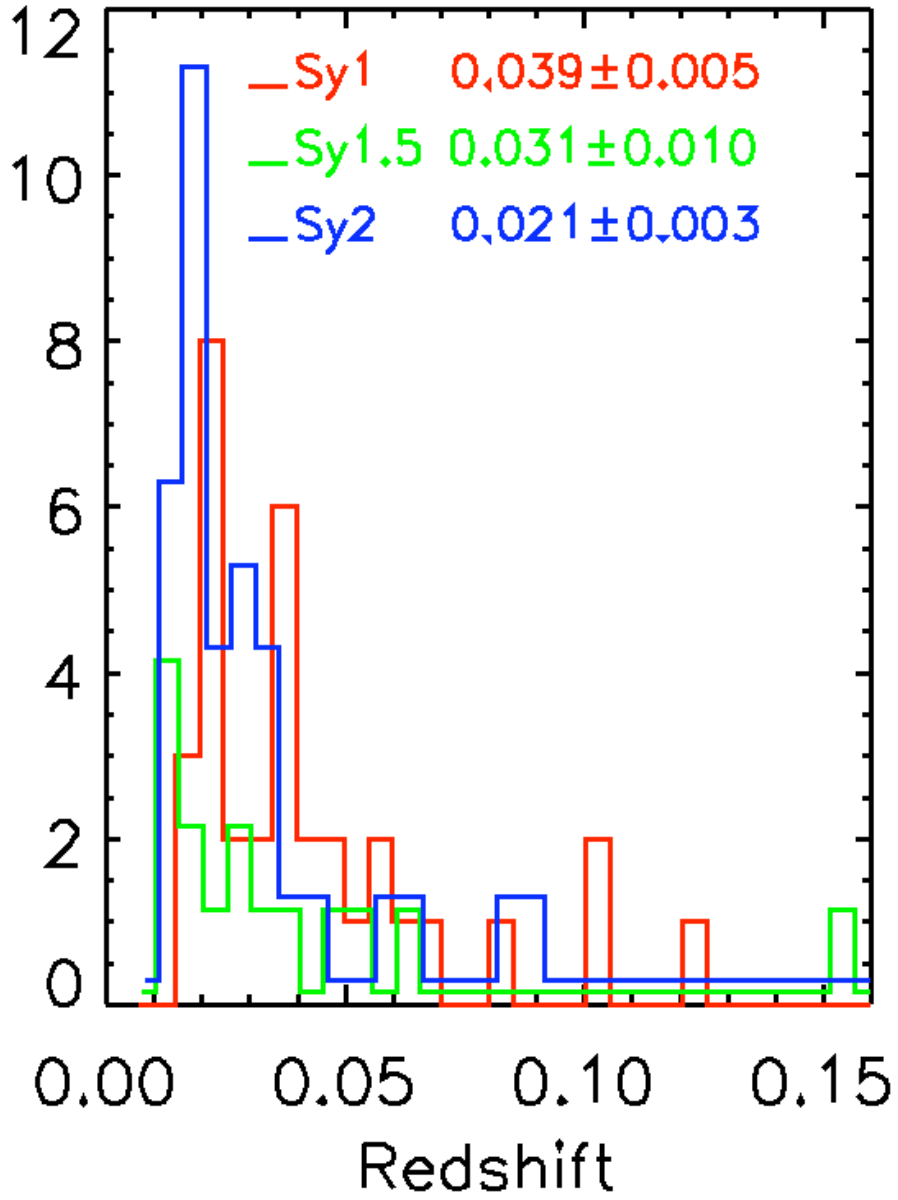




- no close correlation with total 2MASS J band
- soft x-ray and IR do not measure true AGN luminosity or complete populations

Redshifts of BAT Selected Non-Blazar AGN

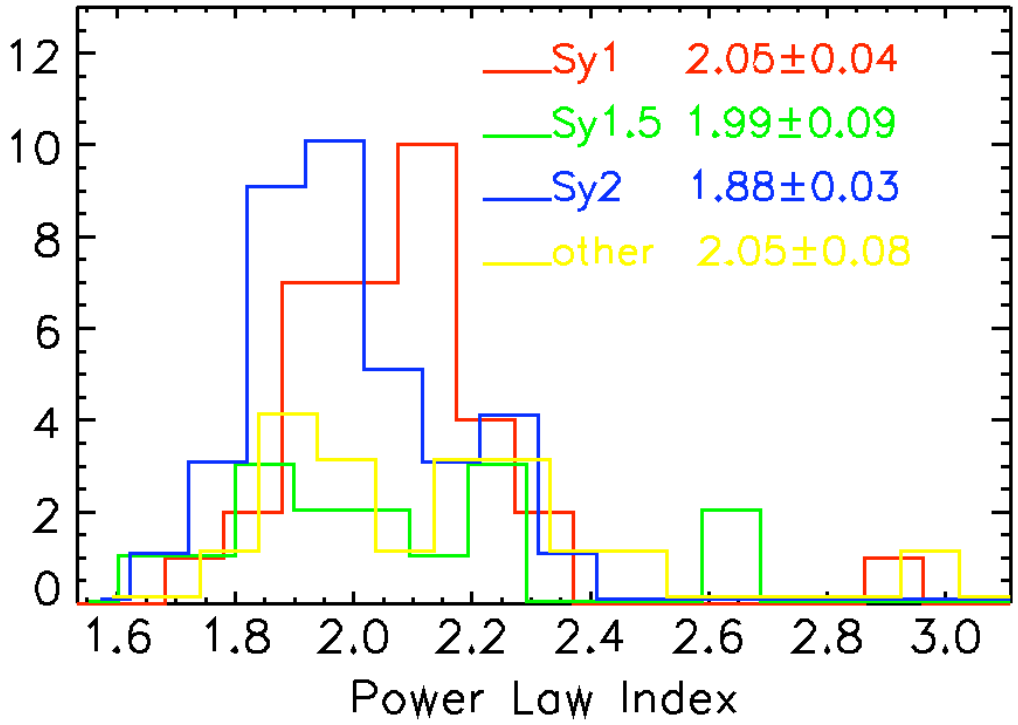
- Median redshift of identified sources is ~0.025- this is a very low Z sample
- Sy1's have greater redshifts than Sy2's thus higher luminosity in the 14-200 kev band

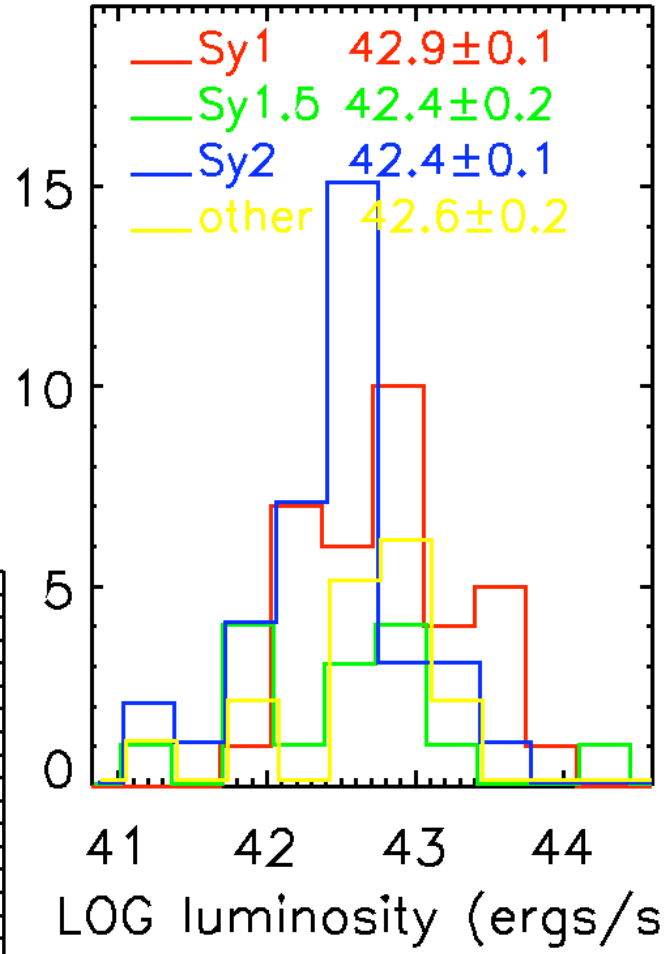


Tests of the Standard Model

With <E>~50 kev BAT measures the true nature of the continuum relatively unaffected by absorption or scattering

- BAT selected Sy1's have softer spectra than Sy2's (p=0.0016)

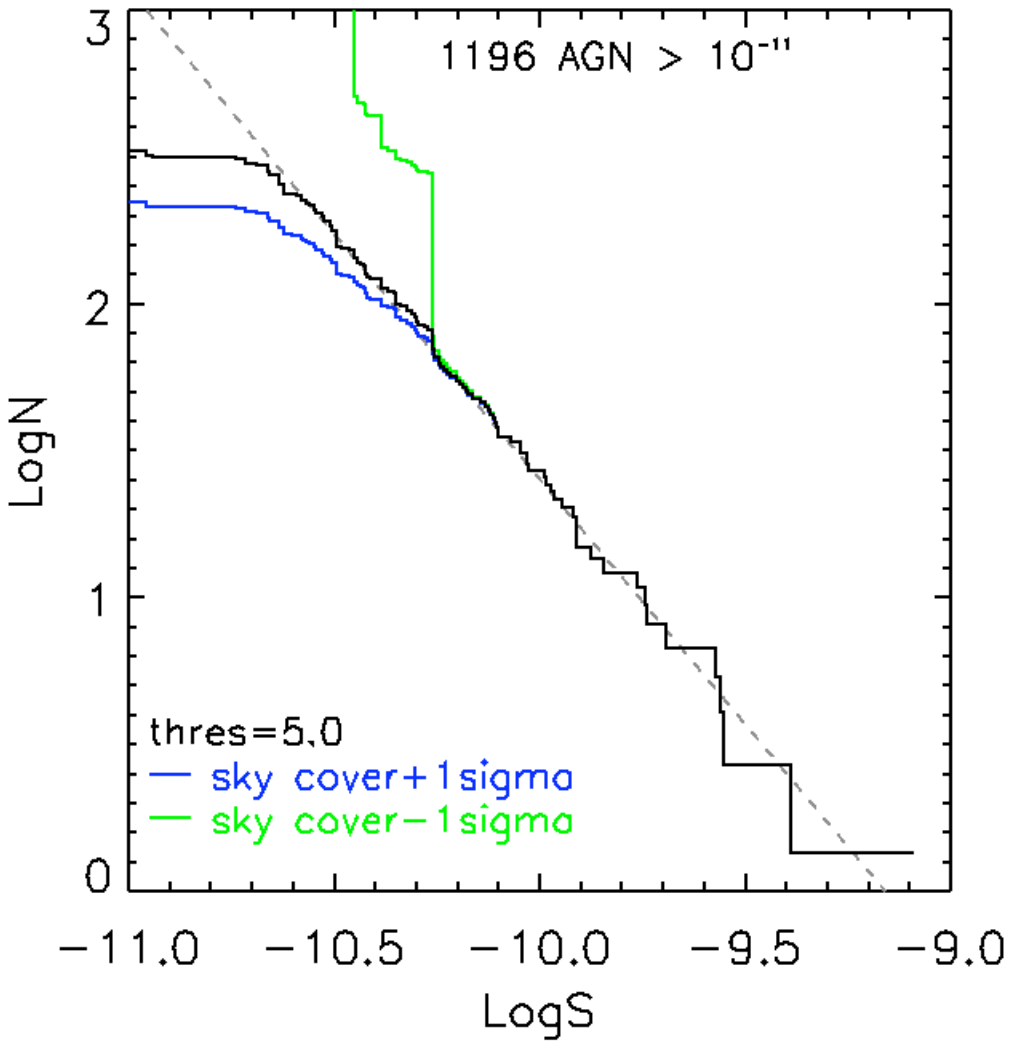




- BAT selected Sy1's have higher luminosity than Sy2's (p=0.006)

Log N Log S

- for BAT energy band 14-195 keV
- Based on the largest sample of hard X-ray selected AGN ever available!
- Current sample: 158 AGN, predicted at 3 years 446 AGN

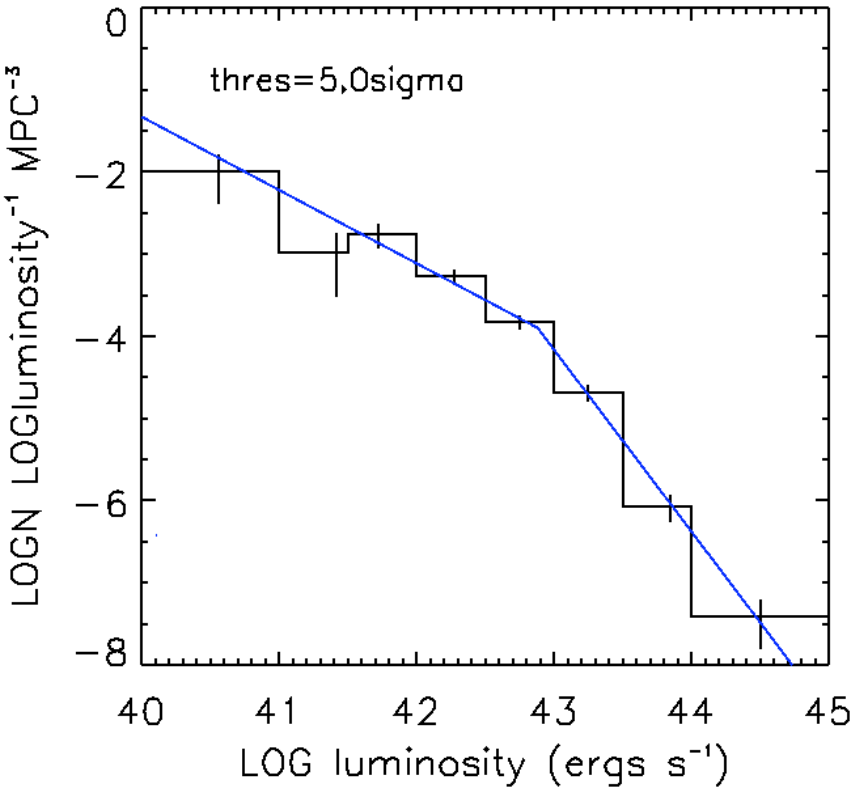


AGN Number Counts from Background Models

- Treister, Urry, and Lira: standard unified AGN model
  2500 AGN, $L_{BAT}>10^{-11}$ergs cm^{-2} s^{-1}
- BAT measures
  1100 AGN, $L_{BAT}>10^{-11}$ergs cm^{-2} s^{-1}
- Pashak Ghandi
  800 AGN, $L_{BAT}>10^{-11}$ergs cm^{-2} s^{-1}

- BAT AGN count is a crucial new constraint on CXB modeling

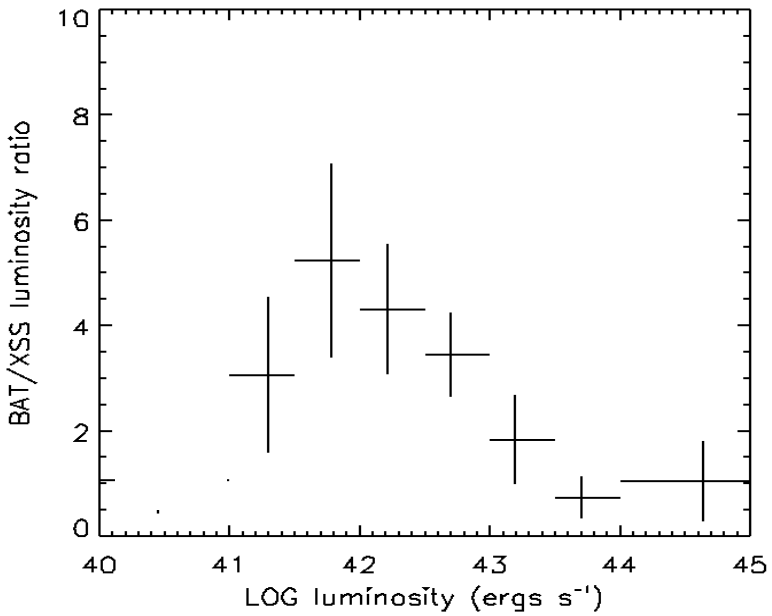
Luminosity Function

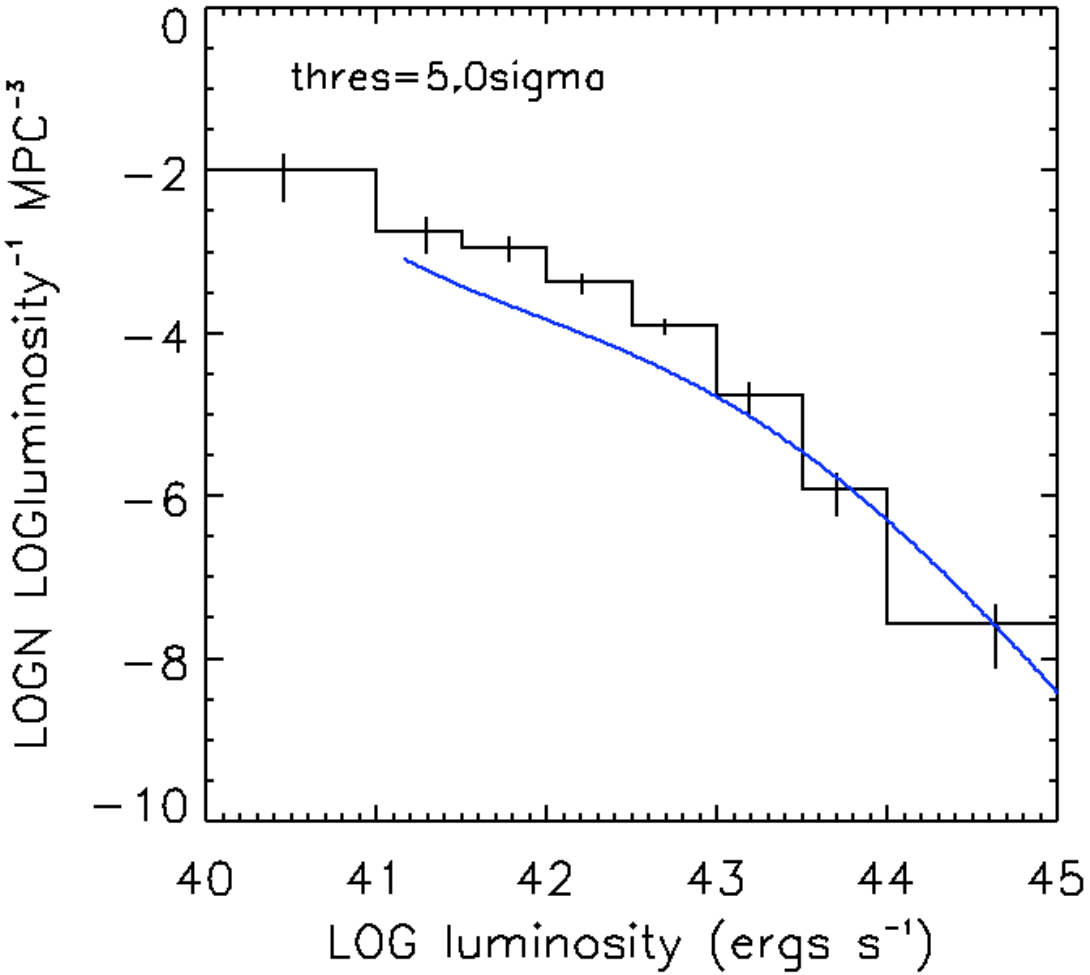


- break at 10^{43} ergs/s
- slope -1 below the break
- slope -2 above the break
- errors of 10% in slope and 35% in break
- New, much tighter constraints will test CXB models

BAT and XTE Slew Survey

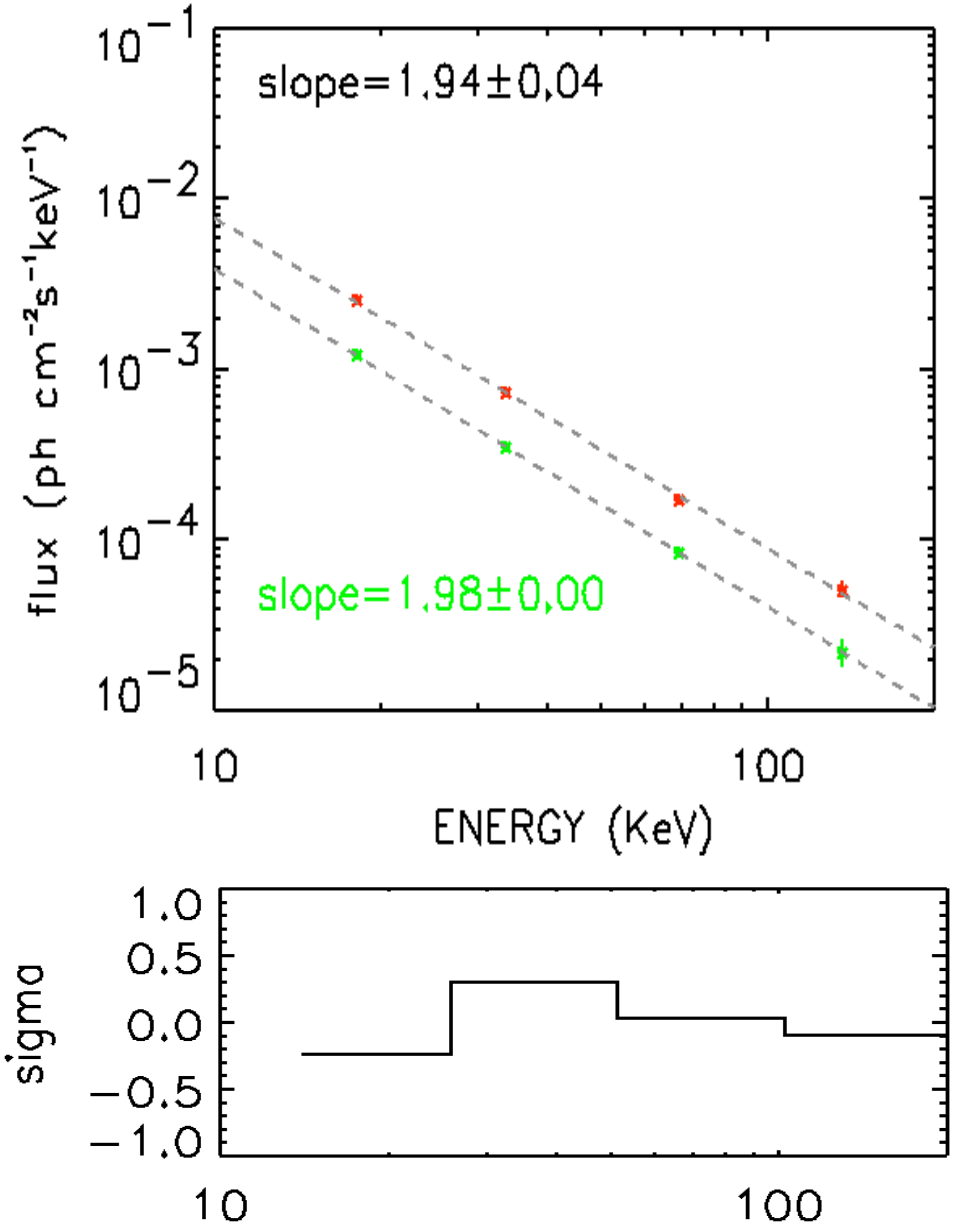
- Same result at high luminosities
- More AGN at low luminosities (~5X)
- E >10 keV required for unbiased sample





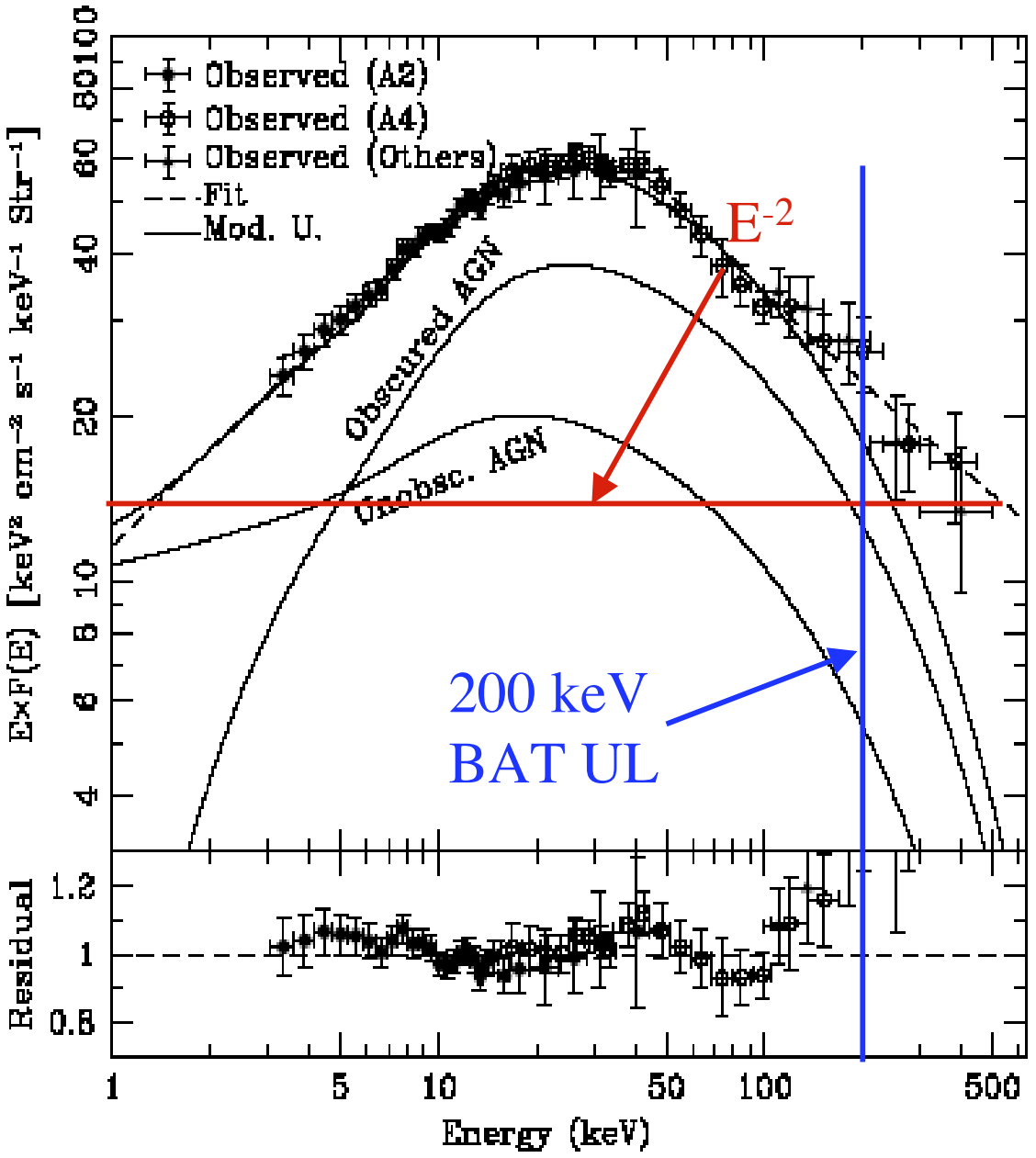
Average BAT AGN Spectrum

- no evidence for a break below 200 keV
- same with brightest 36 AGN removed
- Same for luminosity $<10^{43}$ or $>10^{43}$
- Contrast with strong break at 40 keV in CXB
- spectrum is much flatter than CXB (slope = 2.75) above the break



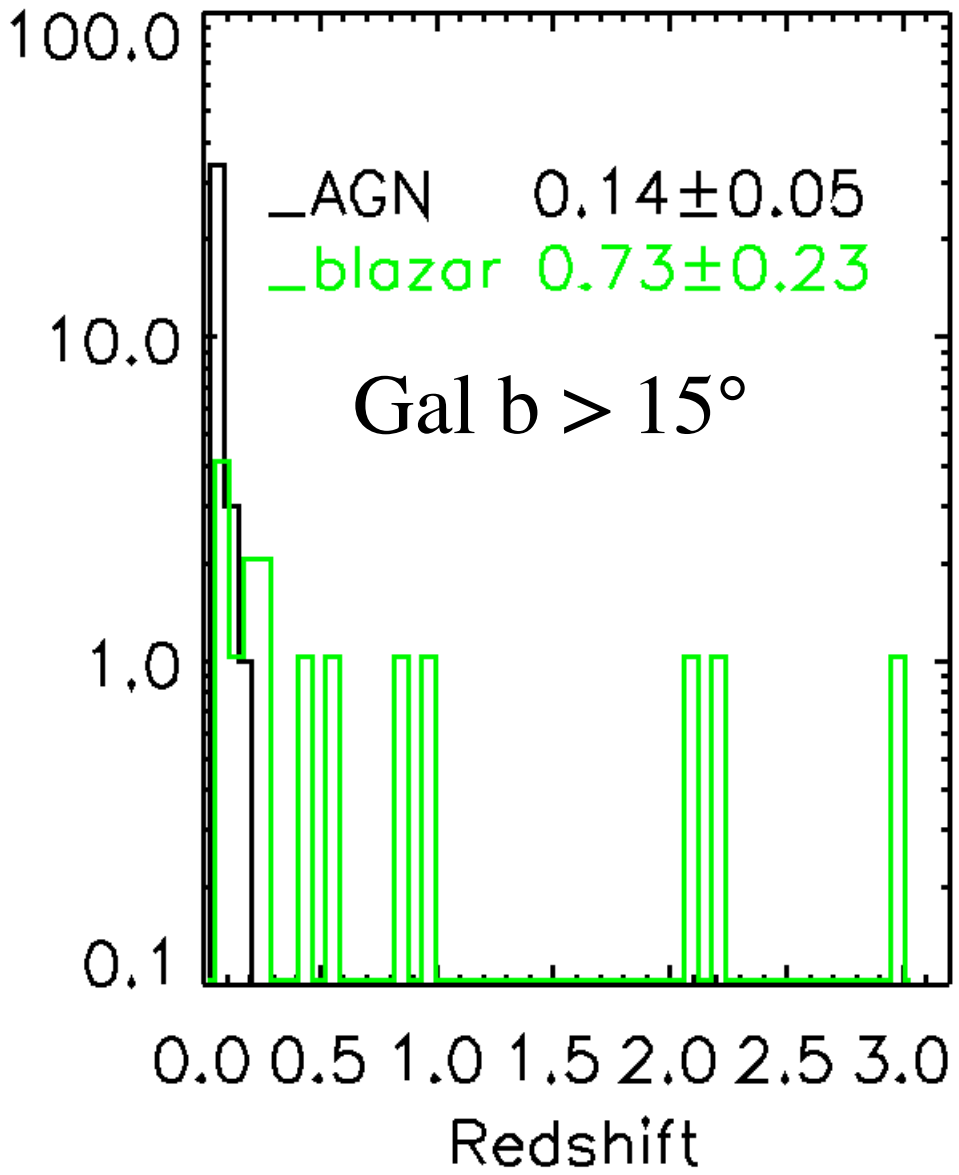
Background vs BAT AGN Spectrum

- BAT AGN spectrum is a bad fit to CXB for E>40 keV
- Soft x-ray surveys put source of CXB at Z=0.7
- to fit the CXB the BAT AGN must be at Z > 1 or show strong evolution



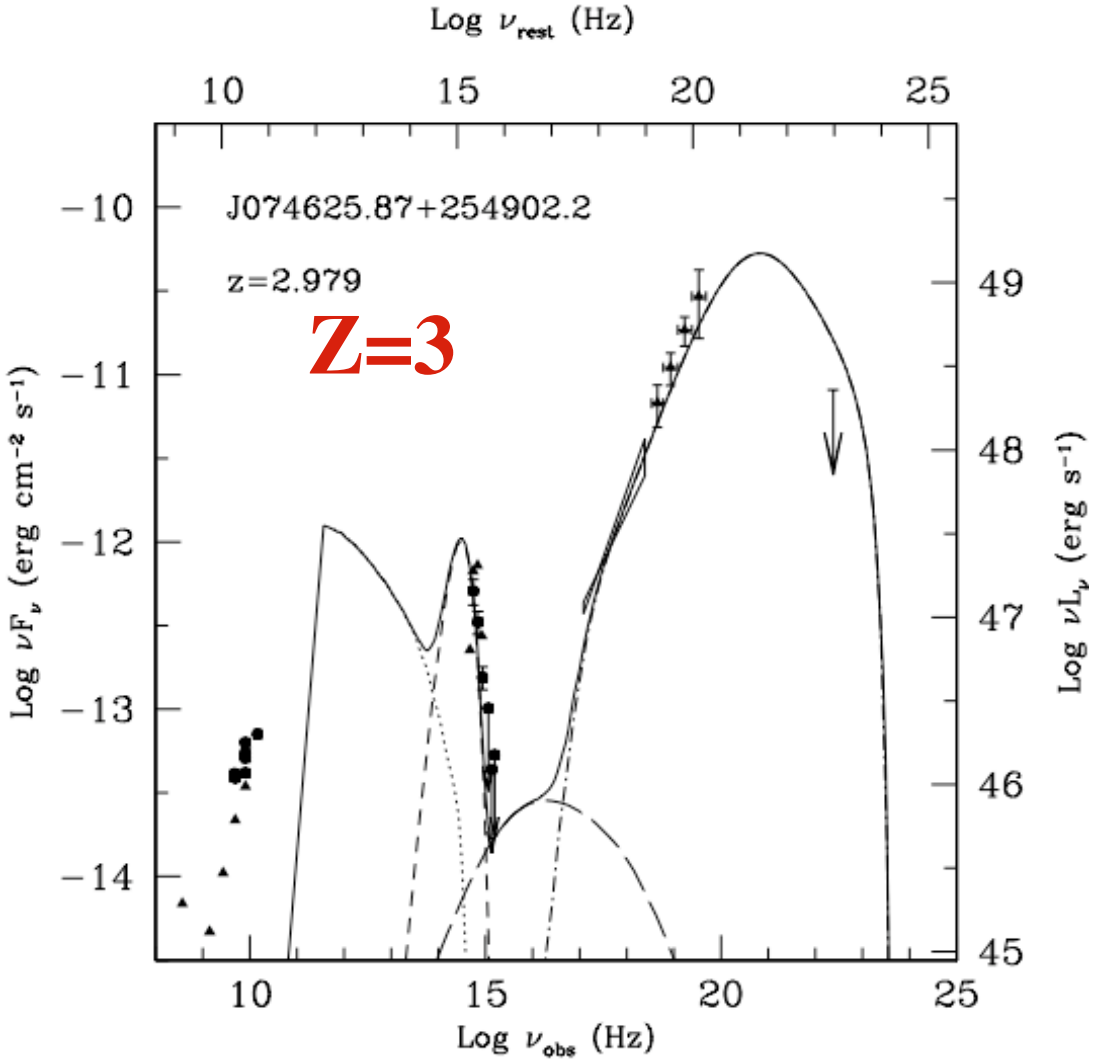
Redshift of BAT Beamed Sources

- 17 BL Lac, QSO, and blazars (all-sky)
- Blazar redshift distribution very different from Seyfert population
- 4 high redshift blazars detected (Z >2), 3 not previously identified



Why Does BAT See So Many High Z Blazars?

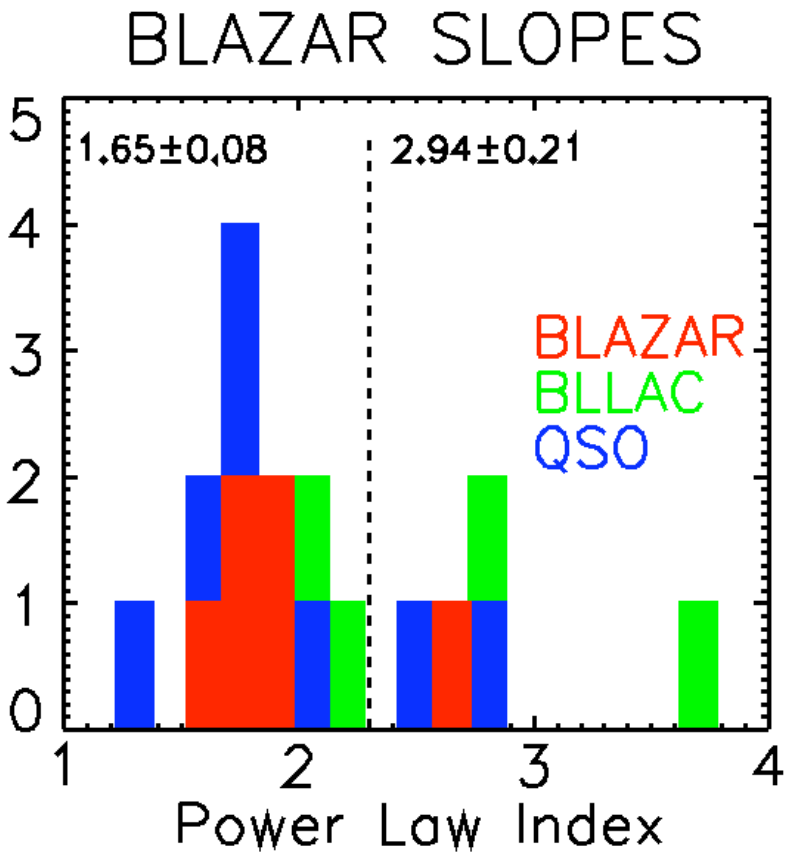
- for EGRET blazars the BAT band is between the two peaks in the SED
- at high Z the gamma peak is shifted into the BAT band
- As the Z increases, the BAT luminosity increases compensating for the greater distance
- BAT detects EGRET blazars at Z > 2

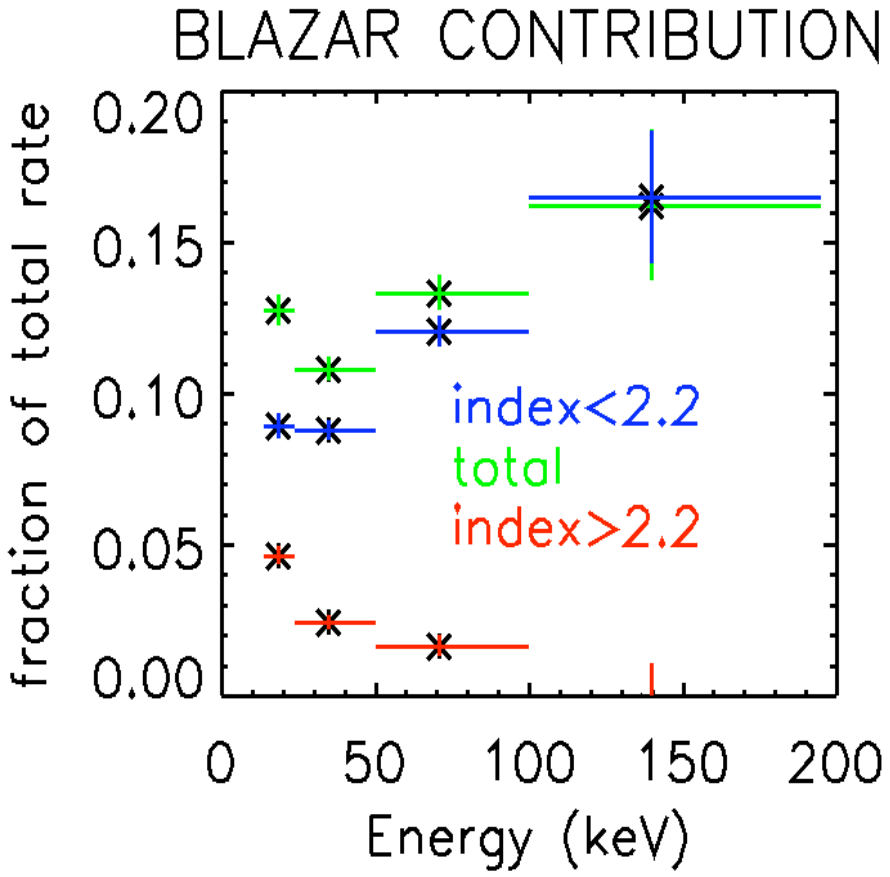


SWIFT J0746.3+2548
Rita Sambruna (submitted)

What is the Blazar Contribution to the CXB?

- Blazar contribution to BAT sum spectrum is 10-16%





- BAT blazar survey can answer this question.

Conclusions

- The first complete AGN survey is answering many of the old questions about AGN and their contribution to the CXB.
  - What are the numbers of hard x-ray AGN?
    - 1100 AGN, $L_{BAT}>10^{-11}$ergs cm^{-2} s^{-1} 14-200 keV
  - Are the hard x-ray AGN and CXB spectra the same? No
  - Does the standard unified model explain all? No
  - How many of the AGN are absorbed? ~0.6 not 3/4
  - What is the blazar contribution to CXB? 10-15%
- Follow up of the BAT selected AGN offers many exciting new opportunities.

We are just getting started!