Recent Results from RXTE Monitoring of Seyferts

Alex Markowitz (UCSD-CASS)

I: Linking X-ray/Optical Variability in Seyferts

Summary of talk by Ian McHardy (Univ of Southampton) @ Bologna, 09/2009

II: Broadband PCA + HEXTE Spectral Survey of Bright AGN

Elizabeth Rivers, Alex Markowitz & Rick Rothschild (UCSD-CASS)

III: New Direction for PSD Monitoring?

IV: Fe Kα Line Variability: Tracing the Line-Emitting Gas

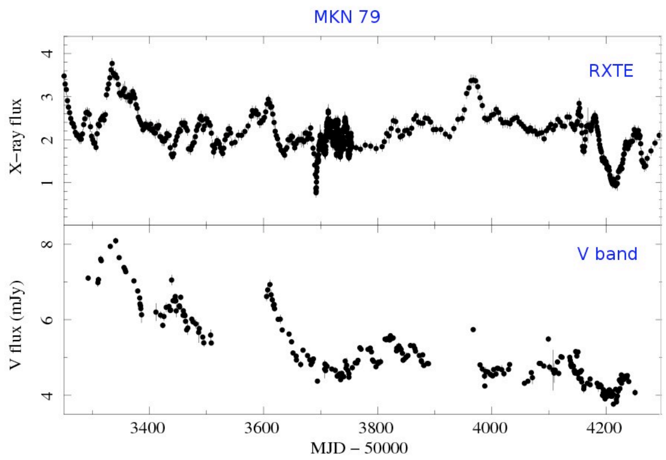
I: X/Opt Variability in Seyferts: Overview

From I.M. McHardy with E. Breedt, P. Arevalo, D. Cameron, P. Uttley, T. Dwelly, P. Lira, + collaborations with the Japanese Magnum & Crimean AGN monitoring groups

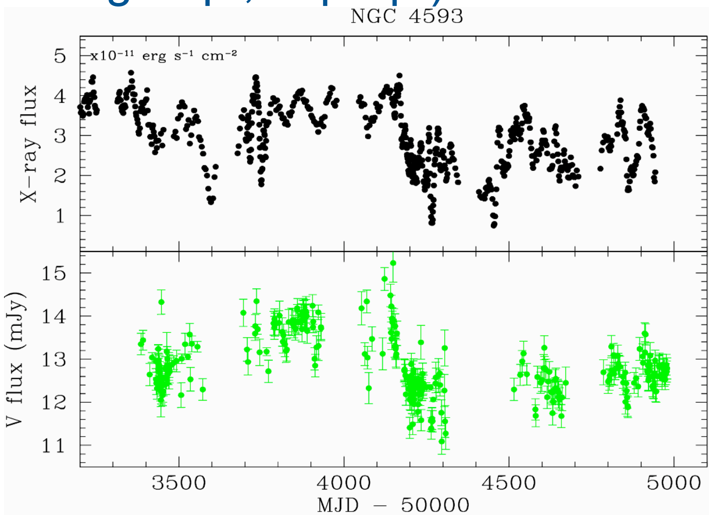
- Quantify X-ray (corona) + optical (thermal disk) continuum variability:
  - Constrain geometry via lags
  - Determine variability mechanism: is there X→O reprocessing and/or intrinsic disk variability?
  - *How do AGN system properties (M_{BH}) or disk properties (Temp.) govern X/O variability?*
- ***Long-term (years), continuous, contemporaneous RXTE + recent ground-based monitoring*** (e.g., Liverpool robotic telescope, SMARTS)

I: X/Opt Variability in Seyferts: sample light curves

Mkn 79, Breedt+ (2009)



NGC 4593 (Southampton group., in prep.)



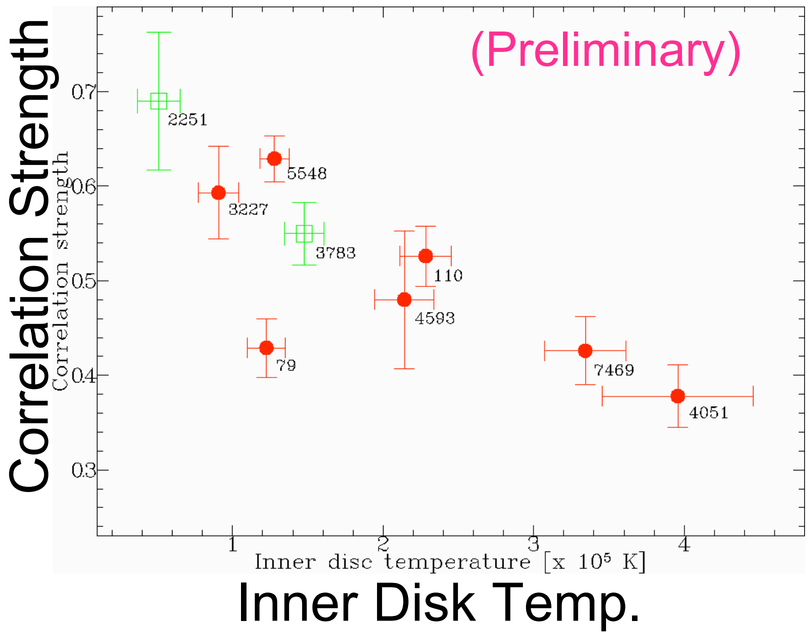
- Now: papers on individual Seyferts coming out (e.g., Breedt+ '09, Arevalo+'08,'09); number of good correlations has more than tripled!

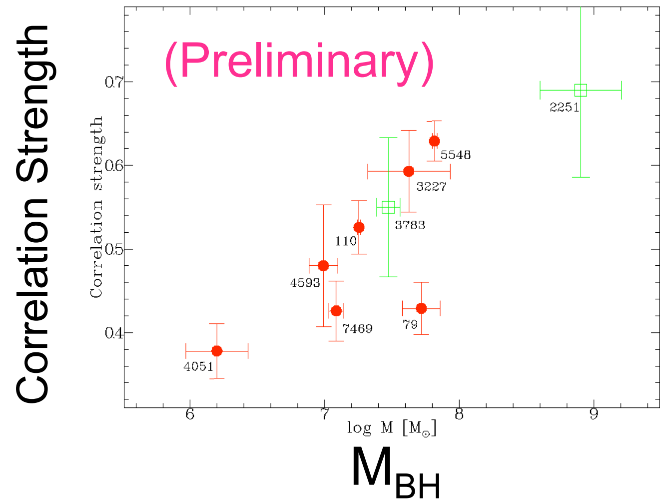
- Short-term correlations with X→O lags of ~1-2 days (reprocessing), but differing long-term trends

- Optical is a bit more variable than X-rays on long time scales in some targets; X→O reprocessing is not sole source of optical variability. Intrinsic m-dot fluctuations in the disc likely important on long time scales

I: X/Opt Variability in Seyferts: Cross-Correlation Peaks vs Inner Disk Temp. & M_{BH}

(Breedt et al., in prep.)





Though NGC4395/Swift: supports T_{disk} dependence

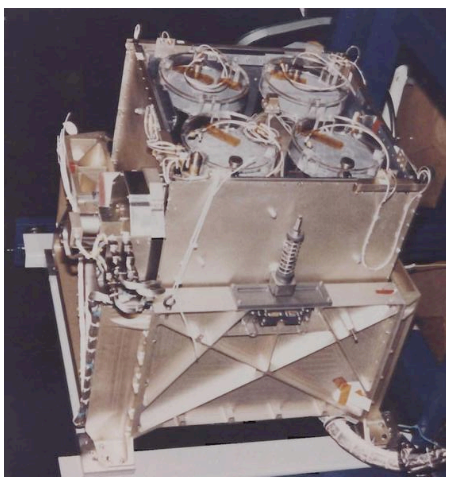
Picture emerging: X→O reprocessing is important source of short-tem optical variability; reprocessed component depends on T_{disk} (angle subtended by X-ray source).

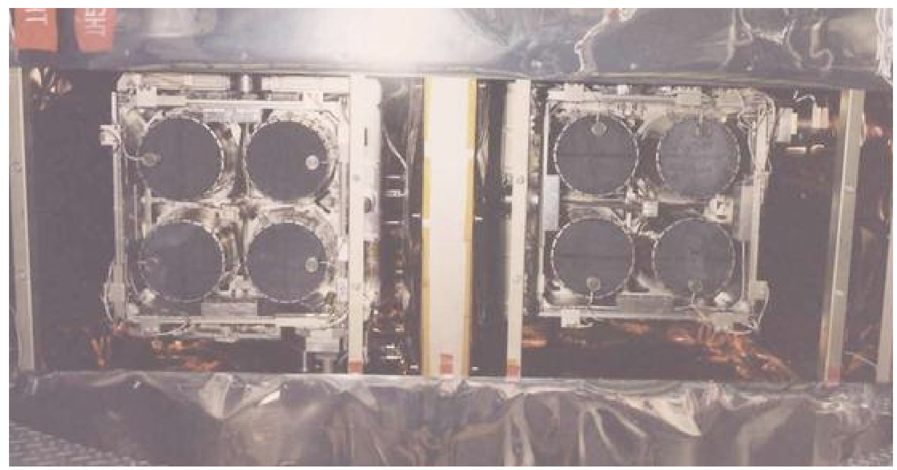
II: Broadband PCA+HEXTE Spectral Survey of Bright AGN

Elizabeth Rivers, Alex Markowitz, Rick Rothschild (UCSD-CASS), in prep.

•*Maximize AGN science return from HEXTE* with 3 to >100 keV summed, broadband spectra from 13 years of archival data

•Reference for long-term average spectral properties for 23 X-ray-bright AGN in the only-recently-well-explored ~20 to ~200 keV sky





II: PCA+HEXTE AGN Spectral Survey: Overview

•Summed spectra from archival data (PCA was usually primary instr.)

•Complementary to other X-ray missions' surveys of bright AGN, though with HEXTE, we get higher energy resolution than Swift-BAT, longer exposures than SAX in many cases, higher energy than Suzaku-PIN, lower background than INTEGRAL-ISGRI

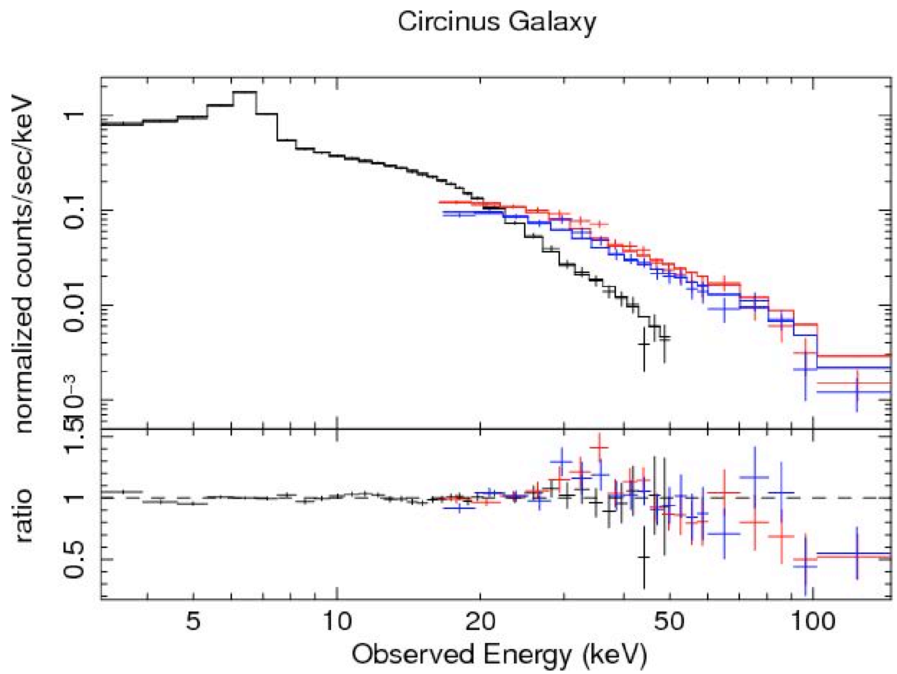
•Source selection: detection out to at least 100 keV in HEXTE: combination of being bright plus sufficiently long good exposure time (down to 0.8% of HEXTE bkgd in the best case)

•Sample consists of 9 RQ Sy 1-1.5s, 1 RQ QSO, 2 RL Sy1s, 3 Compton-thin Sy2s, 3 Compton-thick Sy2s, 1 NLRG, 2 FSRQs, 2 BLLACs

Avg. PCA good-time exposure per object: 774 ksec

Avg. HEXTE good time exposure per cluster per object: 219 ksec

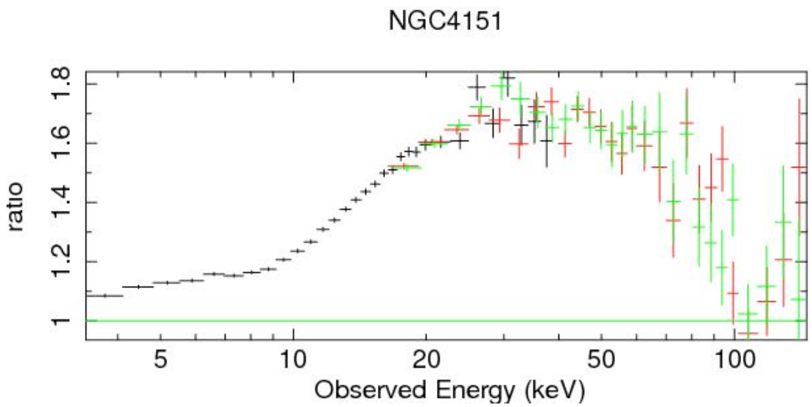
II: PCA+HEXTE AGN Spectral Survey: Preliminary Results



High-energy cutoff found in Circinus (54^{+15}_{-4*} keV)

Seyferts' Compton Reflection Hump strengths tend to be <~0.5

R=0	3/20
0 < R < 0.5	12/20
0.5 < R < 1.0	3/20
R>1	2/20



III: Cen A PSD (Preliminary)

Rothschild et al. (in prep.)

•One of RXTE's legacies: Measurement of PSD "breaks" at temp freqs $f_b \sim 10^{-(5\text{-}6)}$ Hz in Seyferts

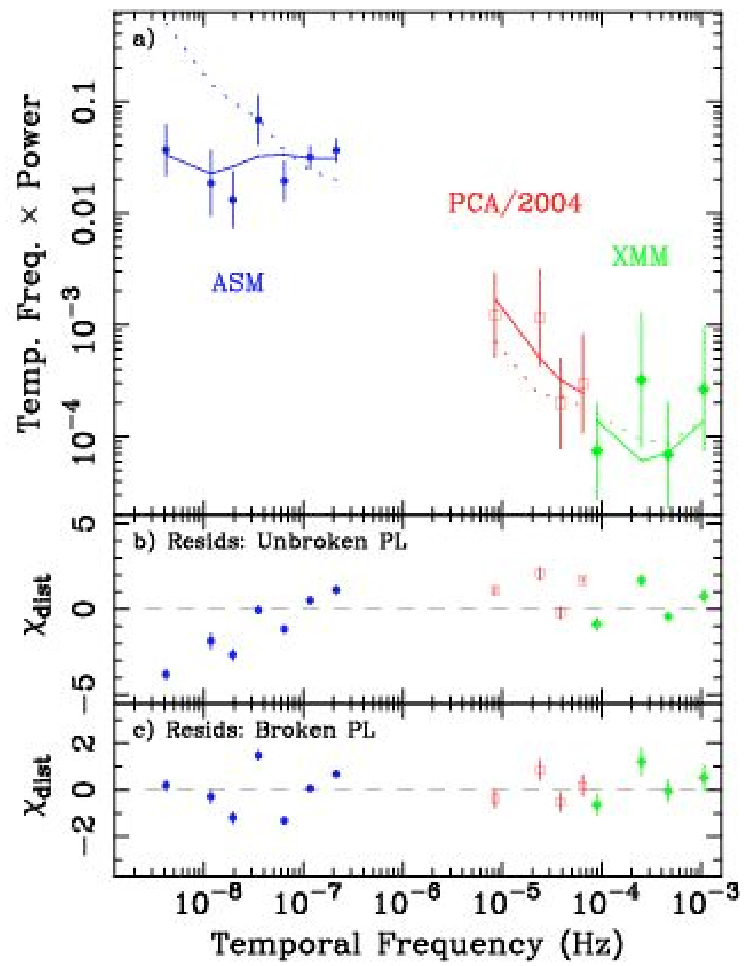
f_b depends on both M_{BH} and L_{bol}/L_{Edd} (summarized by McHardy+ 2006)

•Cen A: high M_{BH} (2e8 M_{sun}), low L_{bol}/L_{Edd} (0.002)

Cen A PSD from ASM + PCA + XMM light curves: $f_b = 6.3^{+3.7}_{-3.1}$ e-7 Hz

Factor of 35^{+21}_{-17} higher than predicted from the McHardy+ (2006) relation, which was derived for a sample of mainly RQ Seyferts.

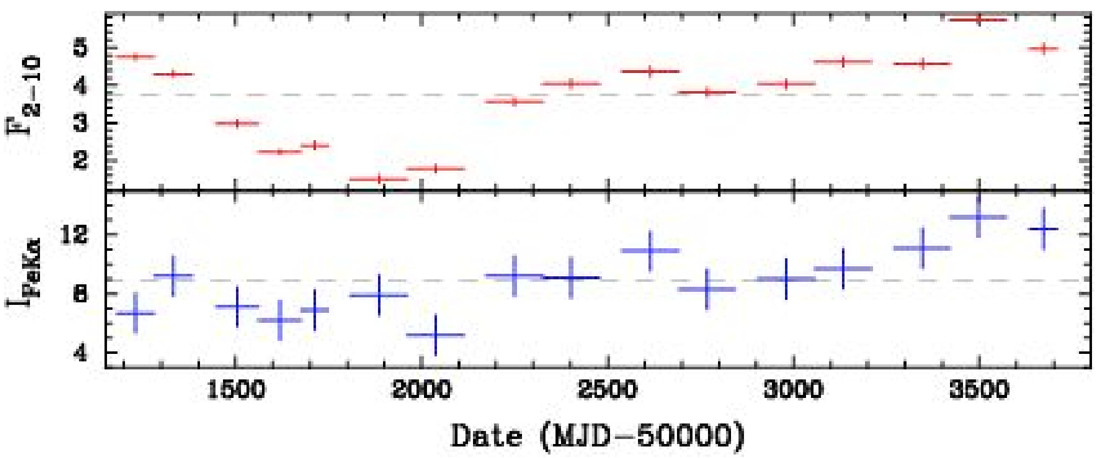
•Perhaps RL and/or low- L_{bol}/L_{Edd} srcs do not follow the relation…Need PSDs for more RL AGN and more low- L_{bol}/L_{Edd} sources!

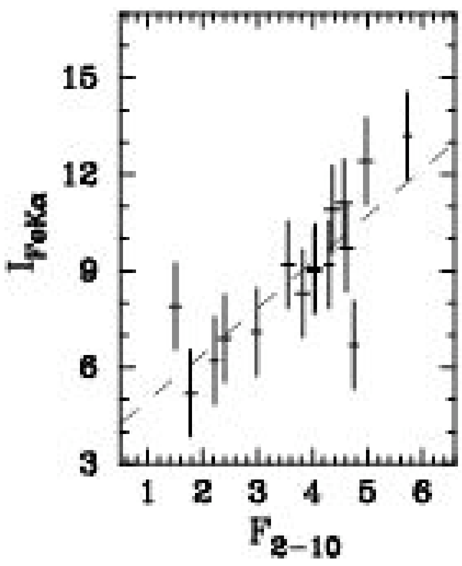


IV: Fe Kα line reverberation (sort of)

Long-term PCA monitoring reveals (narrow) Fe Kα line flux tracks X-ray continuum: upper limits on radial extent of bulk of narrow Fe Kα line emitting gas

NGC 3227 (Markowitz+ 2009)





X-ray-continuum src → Fe line src light travel time < 700 lt.-dys

Conclusions/ Prospects for the Near Future

•X-ray/Opt monitoring: Expand the sample to include more objects; critically test correlations as a function of M_{BH} & T_{disk} (no relation with L_{bol}/L_{Edd} seen…)

Additional monitoring over time scales of years could improve statistics on correlation coeffs; help pin down any long-term optical/X-ray lags and better define importance of intrinsic disk variability

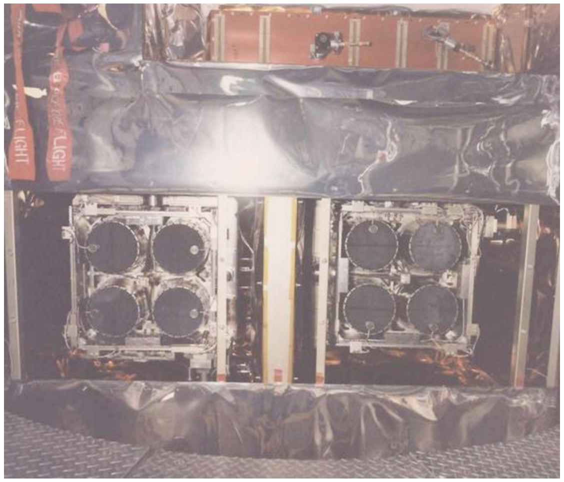
•Broadband spectra: Additional RXTE long-looks of 150-200 ksec good HEXTE exposure time can yield high-quality spectra (out to at least 100 keV) for ~8 additional Seyferts with data currently in the archive

•PSD Monitoring: More low- L_{bol}/L_{Edd} accretors and radio-loud targets needed

PCA+HEXTE spectral survey: supplementary info.

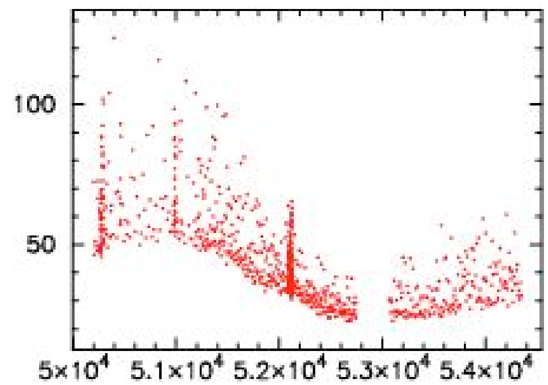
Source Name	Type	PCA expo (ksec)	HEXTE A + B expo (ksec)	F(20-100) observed (10^{-11} erg cm^{-2} s^{-1})	% of 20-100 keV bkgd	L(20-100) unabsorbed (erg s^{-1})
NGC 4151	Sy 1.5	562	165 + 165	43.03	6.3	1.47e44
IC 4329a	Sy 1.2	582	145 + 175	19.13	4.3	1.18e44
NGC 3783	Sy 1	1297	204 + 365	11.86	2.0	1.52e44
NGC 3516	Sy 1.5	947	293 + 292	8.87	1.1	6.80e42
Mkn 509	Sy 1.2	739	197 + 225	8.51	1.5	2.16e44
NGC 5548	Sy 1.5	927	294 + 312	8.47	1.0	5.48e43
NGC 3227	Sy 1.5	1030	283 + 284	8.19	1.1	3.45e42
MR 2251–178	Sy 1 / QSO	380	58 + 120	7.78	1.3	7.75e44
NGC 4593	Sy 1	960	168 + 282	6.35	1.4	1.10e43
NGC 7469	Sy 1.2	1064	243 + 305	4.63	0.8	1.81e43
3C 111	BLRG	808	127 + 238	8.64	1.6	4.68e44
3C 120	BLRG	2102	505 + 629	8.20	1.4	1.43e44
NGC 5506	C-thin Sy2	700	202 + 201	18.12	2.3	1.19e43
MCG–5-23-16	C-thin Sy2	180	55 + 55	14.43	1.8	2.20e43
NGC 4507	C-thin Sy2	145	47 + 47	14.41	1.8	5.77e43
Cen A	NLRG	563	110 + 198	68.91	11.8	1.45e42
Circinus	C-thick Sy2	97	33 + 32	20.60	2.8	2.32e41
NGC 7582	C-thick Sy2	139	43 + 43	6.53	1.5	9.56e41
NGC 4945	C-thick Sy2	100	208 + 307	19.41	3.7	4.17e41
3C 273	FSRQ	1843	430 + 530	19.46	3.2	1.11e46
Mkn 421	BL Lac	1662	476 + 433	10.36	2.5	2.33e44
1ES 1959+650	BL Lac	199	65 + 64	8.05	2.1	4.53e44

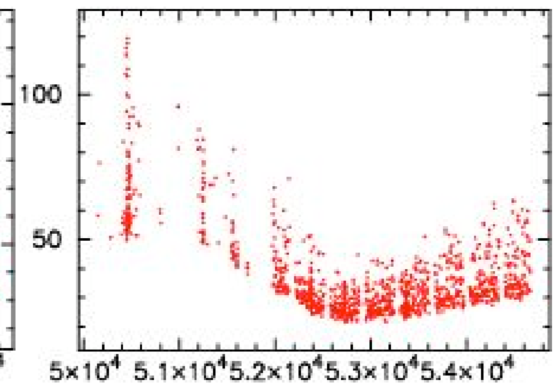
Note. — **All results are preliminary from Rivers et al., in prep..** F(20-100) = exposure-weighted average of fluxes determined from HEXTE clusters A and B independently. All luminosities are rest-frame; blazars' luminosities have not been corrected for anisotropic beaming.



HEXTE background rate over mission lifetime

Cluster B 20-100 keV Count rates: NGC 5548 (lt.) & 3C273 (rt.)





Can access fainter sources now! (average (for typical AGN monitoring obsns) 20-100 keV bkgd ~ 6e-9 erg/cm2/s)

Can achieve "GOOD" spectra out to at least ~100 keV…

With ~60 ksec expo, get down to 1.8% of background (F20-100 = 1.1e-10 erg/cm2/s)
With ~100-150 ksec expo, get down to 1.3% of background (F20-100 = 8e-11 erg/cm2/s)
With ~150-200 ksec expo, get down to 1.1% of background (F20-100 = 7e-11 erg/cm2/s)
With ~250-350 ksec expo, get down to 0.8% of background (F20-100 = 5e-11 erg/cm2/s)

(1 ct/s for cluster B013 = 1.5e-10 erg/cm2/s)

Rough estimate: (1/[%ofbkgd])^2 * 200 ksec