TDEs in context of TDA with X-ray (and Hard X-ray) Surveys

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Talk Outline

- Motivation: origin and nature of “hard” X-ray TDFs (Grindlay 2004)
- Past/present TDE surveys with focusing (narrow-field) X-ray telescopes: ROSAT, XMM/slew, Chandra/archival
- Current wide-field X-ray (MAXI) and hard X-ray (Swift/BAT, INTEGRAL/IBIS) surveys and followup capability with XRT
- BAT Slew Survey has revealed a population of luminous, short duration transients (mostly stars, but also *possibly* AGN and TDEs?)
- What’s needed to optimize X-ray TDE surveys and relate the physics to AGN and TDA, generally? *MIRAX-HXI* mission

What *were* previous X-ray surveys for Transients?

- All sky monitors are essential for finding rare/bright objects – as needed for discovery and understanding of Jet-TDFs
- The ASM on the UK satellite Ariel-V discovered (1975) AO620-00, which ~10y later *enabled* the first dynamically demonstrated black hole LMXB (McClintock et al)
- No further "dedicated" X-ray (~2-10 keV) ASMs until RXTE, which provided lightcurves on many LMXBs and HMXBs and discovered many new transients *but no TDE candidates*
- BATSE on GRO (50-300 keV) was first *Hard X-ray* ASM and discovered new BH transients (GRS1915, GROJ1655, etc)

Followed by *ROSAT* all-sky survey…

- Which with focusing optics provided first sensitive soft X-ray (0.3-2.5keV) survey, full sky *but low cadence: given source or region observed <5days every 6mo*

- And discovered first convincing evidence for TDEs (Komosa et al 1999 & talk yesterday) and many followup papers

- And now XMM/slew survey (Saxton & Esquej talks yesterday)

- And Chandra archival studies (e.g. Maksym, today)

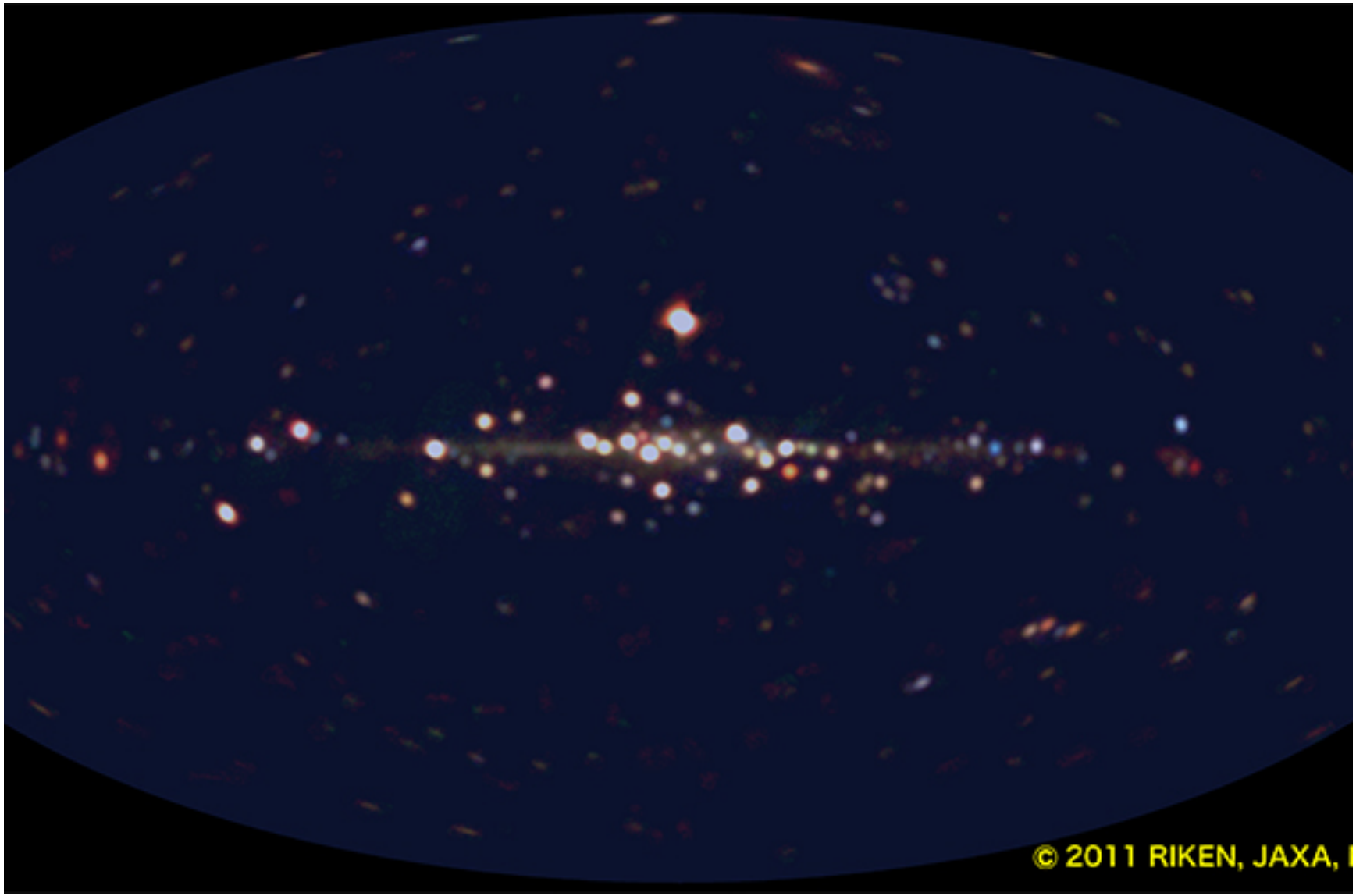
What's operating *now*, to give a Wide-field *X-ray* view of the Transient and TDE population?

- MAXI on the ISS is now the *only* X-ray (0.5-20keV) monitor, with its two (Prop. counter and CCD imager) "slit" cameras that view ~80% of the sky each orbit

- Limited by high backgrounds in the high inclination ISS orbit; and by ~0.5deg positional resolution, but a powerful tool and has discovered new Transients, including several new BH-LMXBs (e.g. MAXI J1659-152)

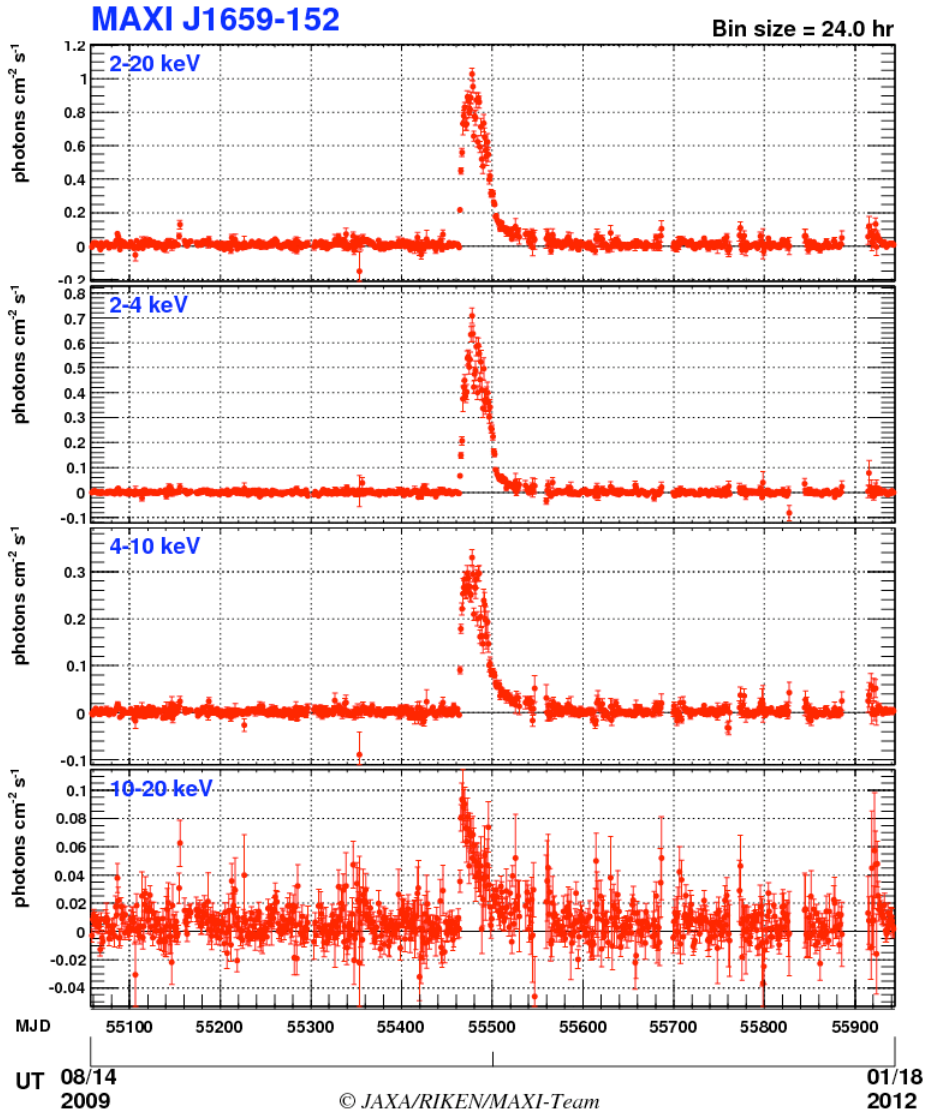
- eROSITA (2014 launch?) will follow with ROSAT-like cadence but broader bandwidth (0.3 – 10 keV) *and ~10X more sensitive: on second sky pass, MANY TDEs will be discovered!*

MAXI's all sky view (2y source distribution)



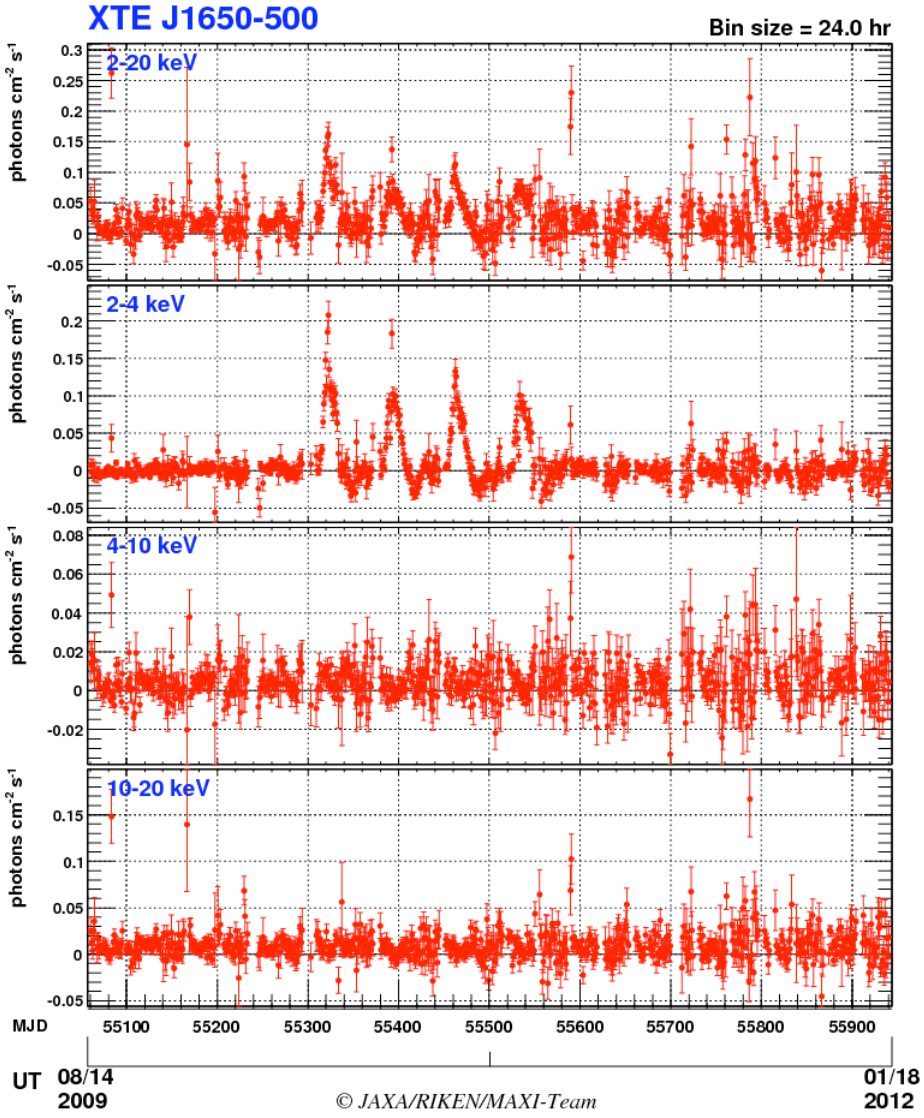
Some MAXI lightcurves…J1659, a new BH-LMXB

- Very bright:
- Spectral evolution consistent with BH
- Followup showed ~2.4h orbital period implying very low mass companion
- Halo object (3rd found) implying peculiar origin: ejection from disk?



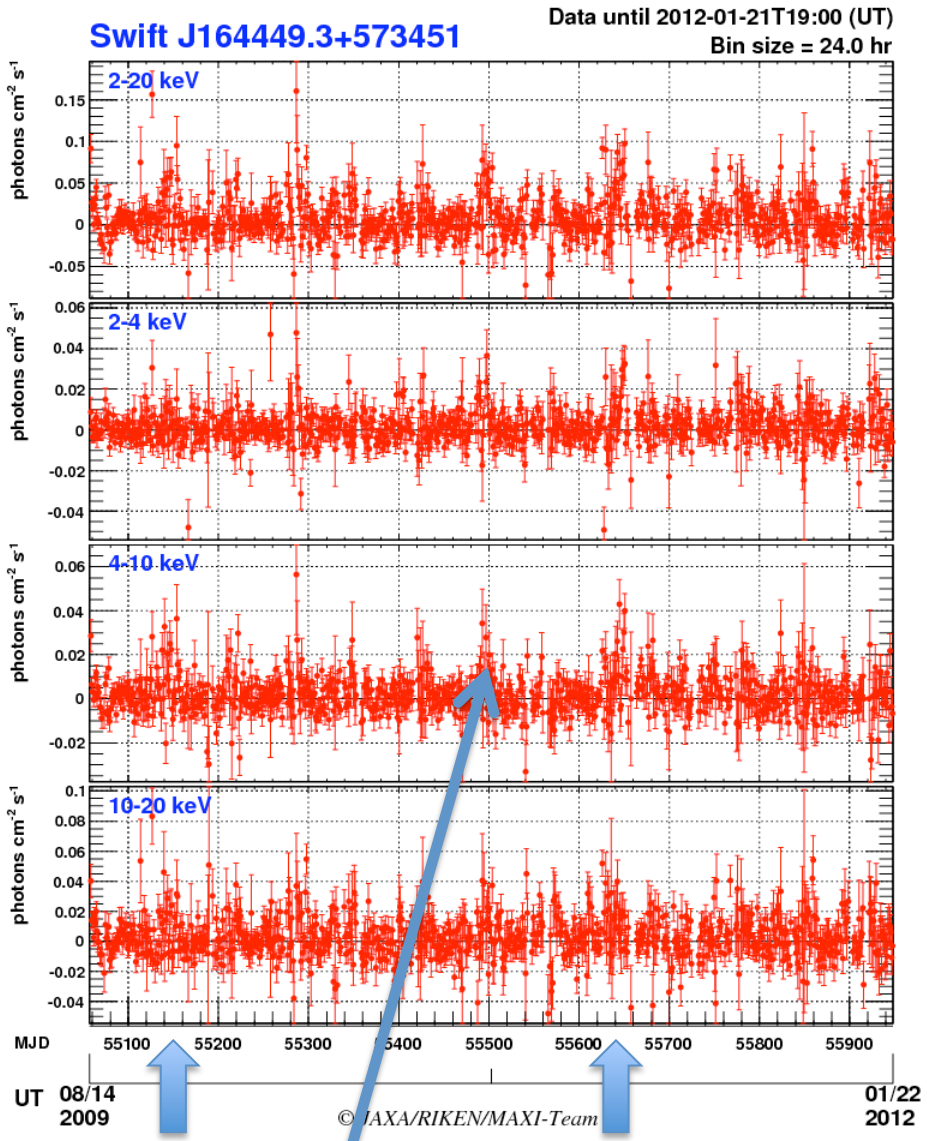
MAXI lightcurve of XTE J1650, a low-mass (3.8Msun?) BH

- Multiple outbursts over past 2y; soft/thermal spectrum
- Quasi-periodic? Not seen in other "single" outbursts of most BH-LMXBs
- Indicative that we don't yet understand BH-LMXBs: would an "isolated" soft outburst like this be mistaken for a TDE?



And strangest of all: the Swift TDF source J164449+573

- As pointed out in Burrows et al, MAXI likely did see the initial flare
- But equally "bright" flares even before the outburst (MJD55150, 55500?) ? (though Burrows+ Fig. 9, Suppl., doesn't show this)
- The "Flares" are less significant than the TDF at MJD55648, but still…(?)



Recent study of Sw J1644 *longterm XRT-LC*

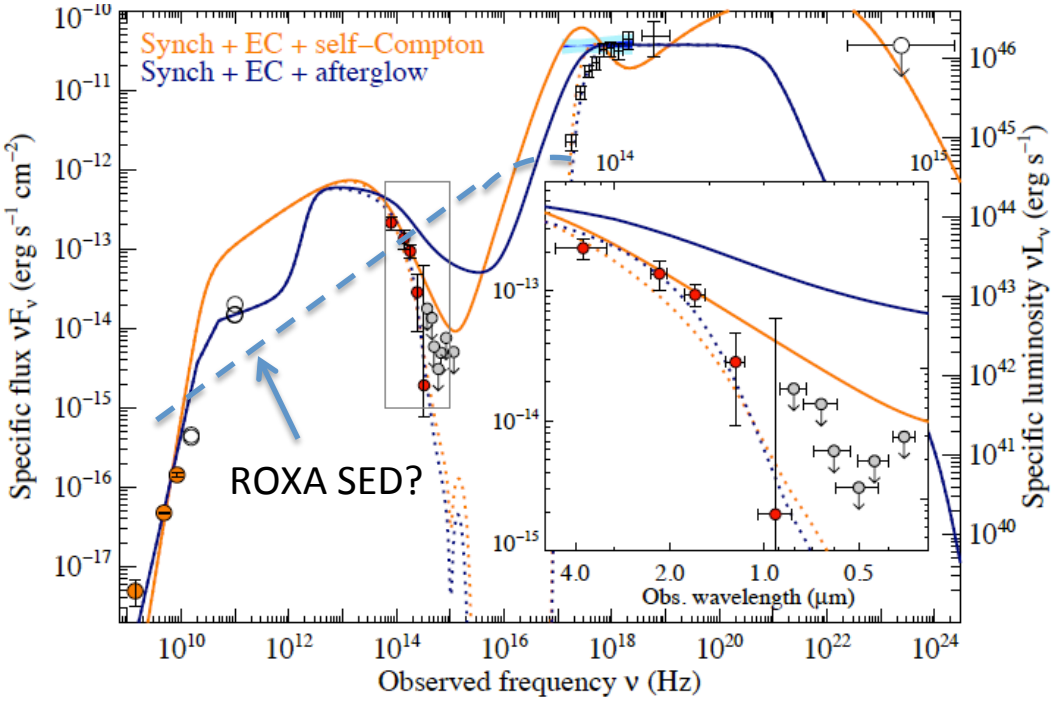
(and comparison to Blazars…)

- Motivated by the bizarre early (discovery) spectacular flares of Sw J1644, we (F. Massaro and I) began a longterm study of the LC and spectral evolution of Sw J1644 (in prep)

- The peak X-ray luminosity of Sw J1644 (Lx ~10^{48} erg/s) is "only" ~8X higher than that of a remarkable Blazar identified by Swift with a ROSAT source as ROXA J081009.9+384757.0 (ROXA J0810) at z = 3.9 and at ~const. flux from ROSAT to Swift era (Giommi et al 2007, A&A)

- Could Sw J1644 be an extreme (factor >100) flare of a Blazar into a "ROXA-like" SED?

Comparison of Sw J1644 vs. ROXA J0810 SEDs



Bloom et al SED for Sw J1644

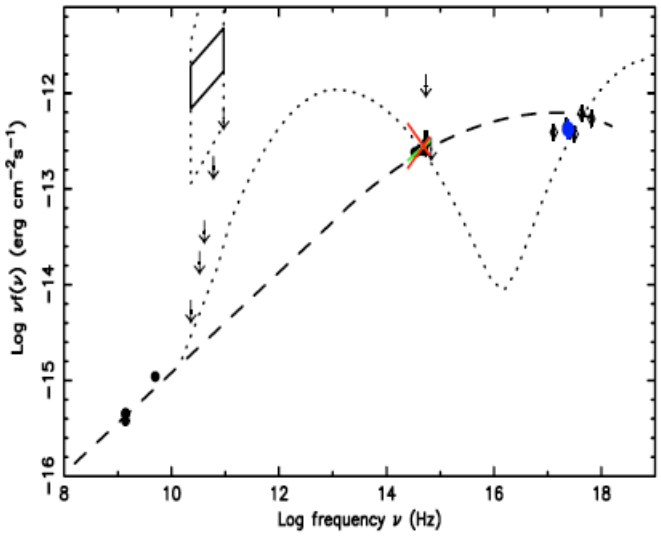
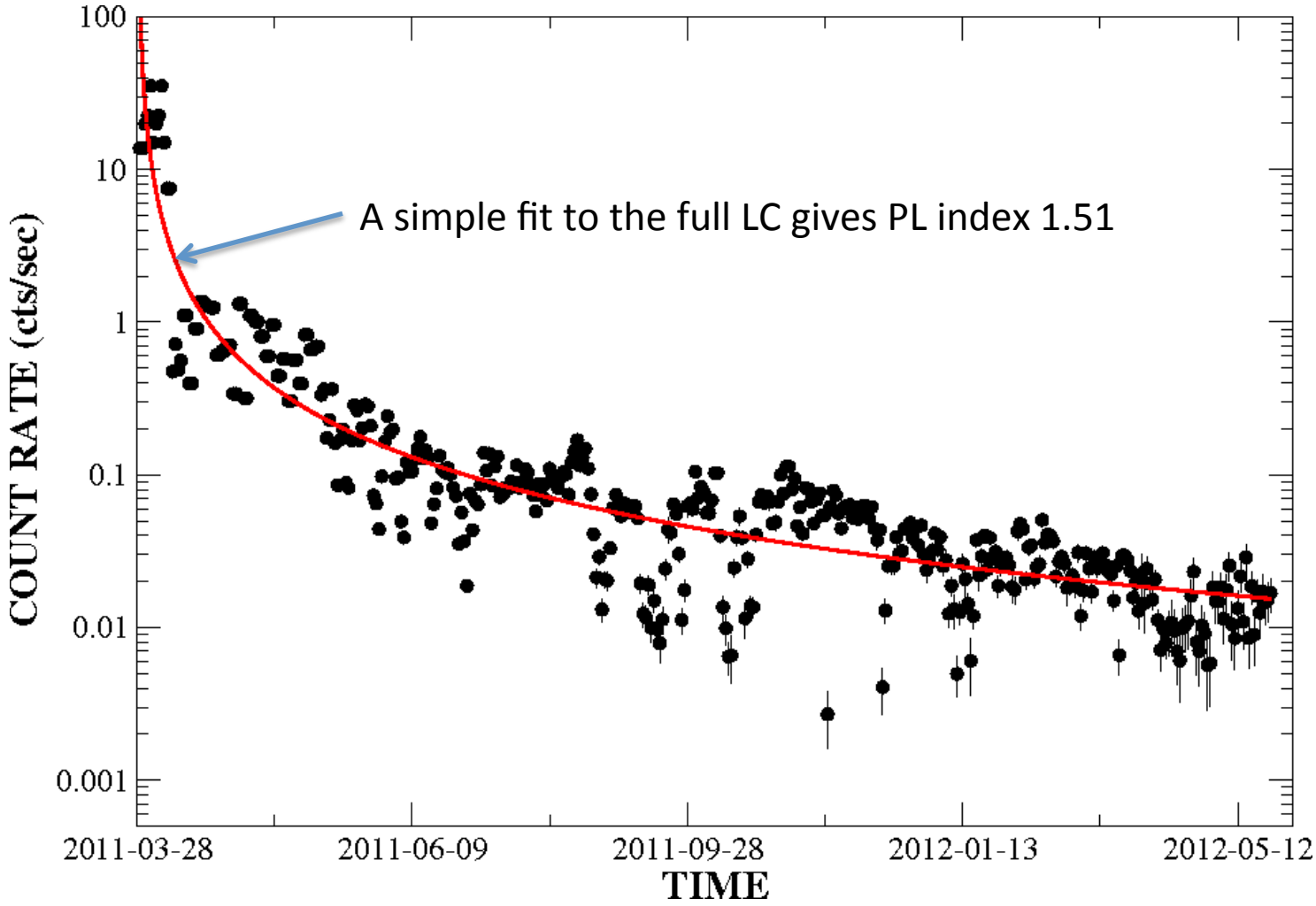


Fig. 3. The SED of ROXA J081009.9+384757.0 built using the radio data from the NVSS, FIRST and GB6 radio surveys, microwave upper limits (at 23, 33, 41, 61 and 94 GHz) from WMAP 3-yr data, optical photometry from the SDSS survey, ROSAT (filled circle) and Swift XRT X-ray data (open diamonds) and UVOT upper limits in the *V* and *B* filters. The boxes drawn at microwave frequencies represent the 1σ and the maximum observed flux range from blazars where the X rays are due to inverse Compton radiation (see text for details). The solid lines in the optical band represent our best estimate and conservative upper limits to the slope of the continuum (see also Fig. 1).

- The ROXA source Fx/Fr and Fx/Fopt are "extreme" for Blazars and suggest the X-ray is synchrotron (from radio-IR-X-ray; dashed curve)
- *But the radio for Sw J1644 has not decayed with the X-ray, suggesting a distinct, probably external, source (Zauderer talk) – where is central source?*

What about the XRT *longterm countrate* LC of SwJ164449+573 ?

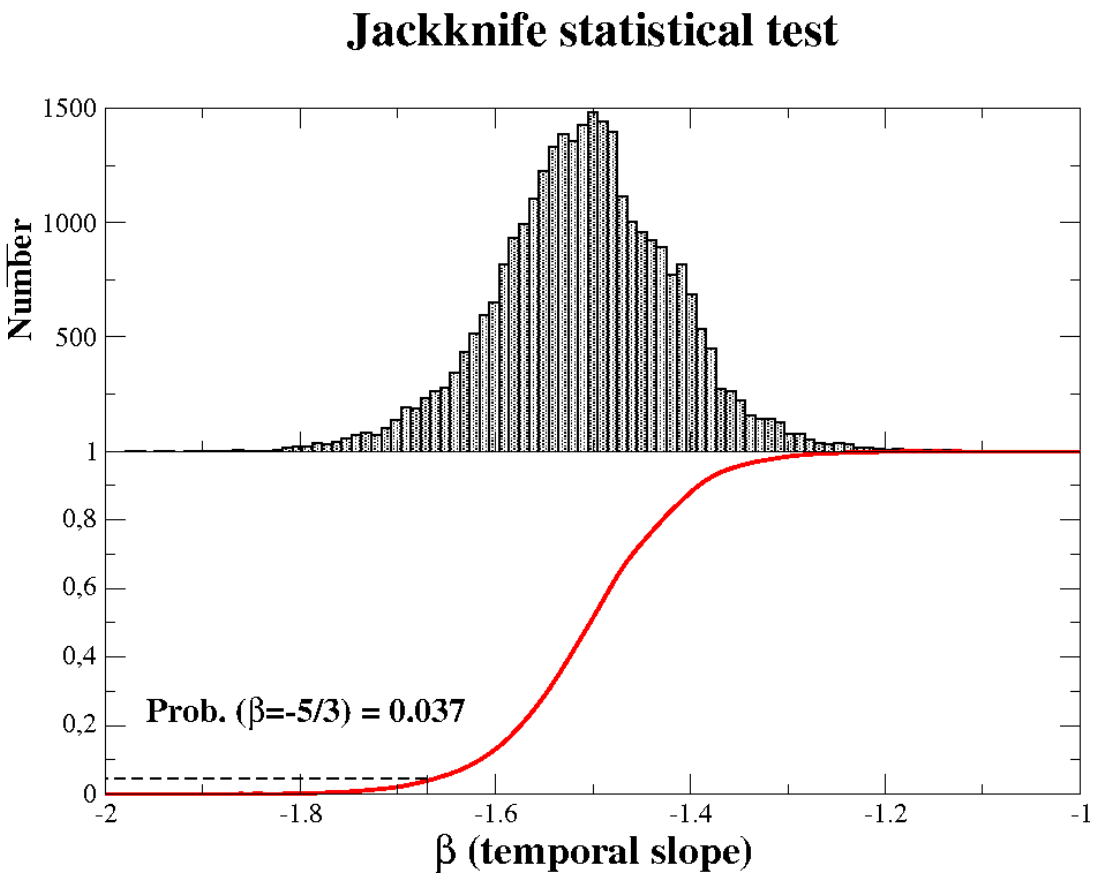
Repeated flaring and slope flatter than TDF value (5/3)



Slope of full LC decay (trigger to ~June 2012): 1.51

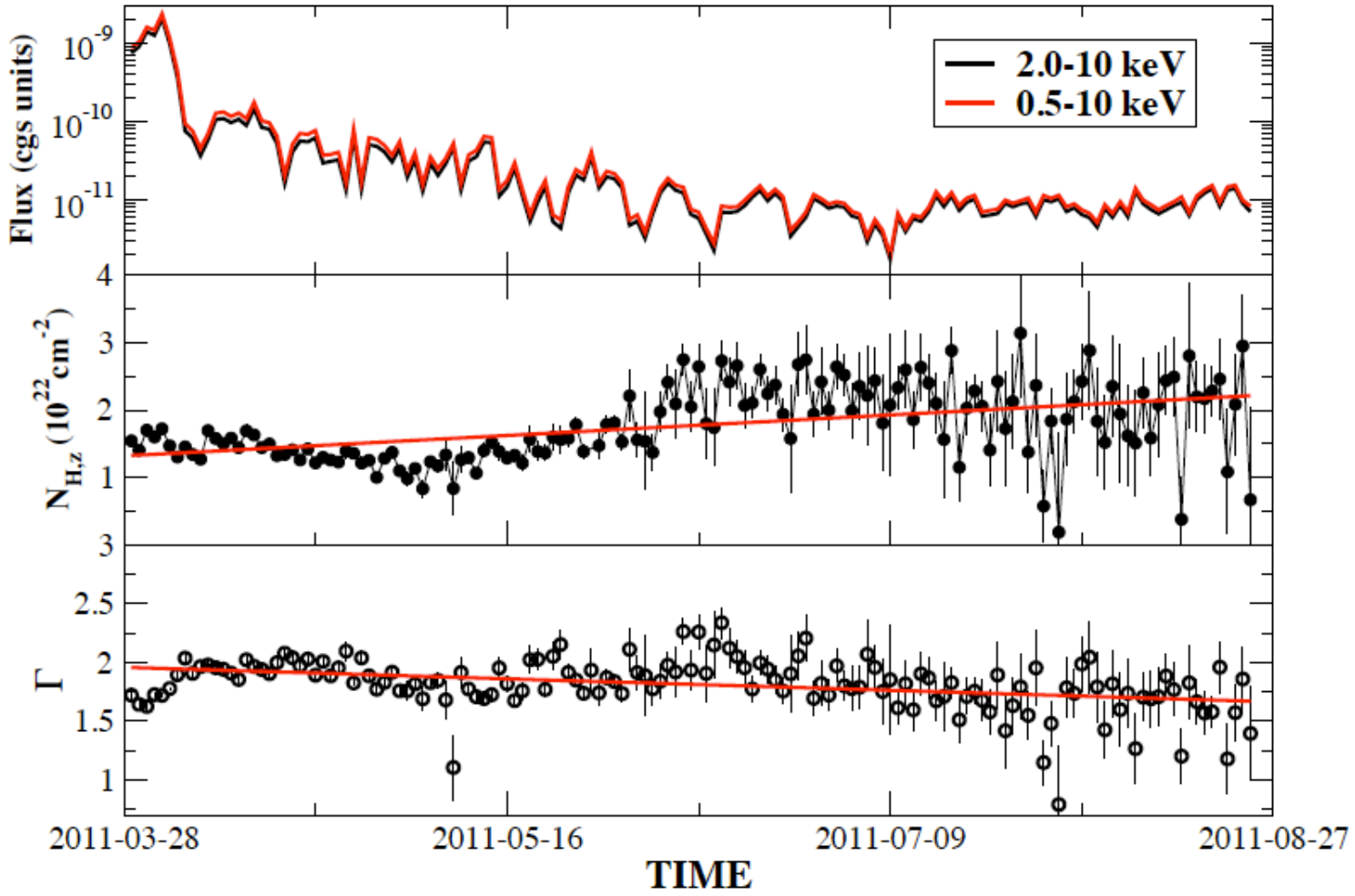
(but dominated by initial fast decay)

- Use countrate to be independent of pileup
- "Jacknife" test using all LC points to derive slope: 1.5, with ~3.7% match to 5/3
- Ongoing jet activity powering flares and flattening slope from "expected" accretion value?



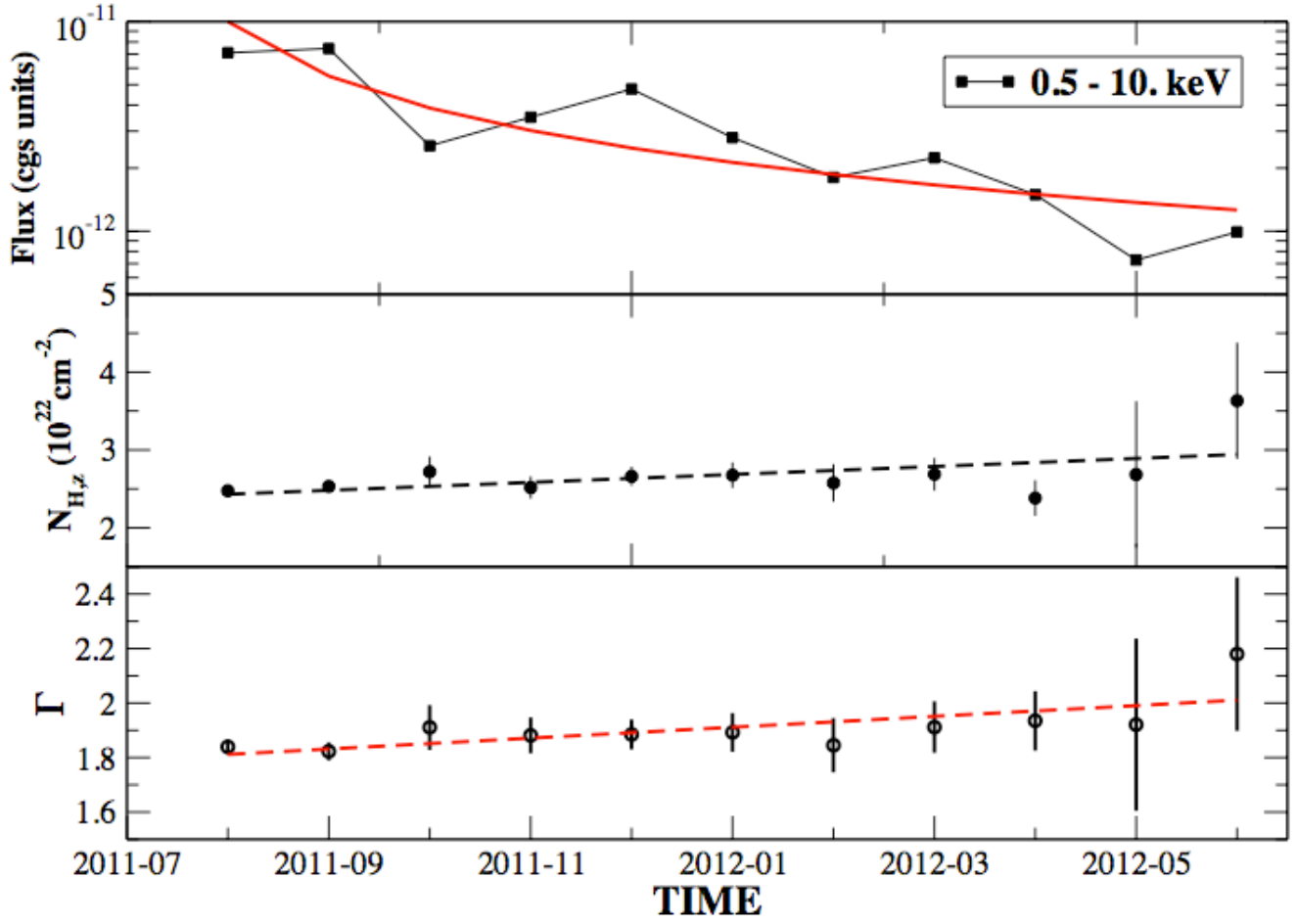
But *flux* decay after flaring in first 1mo. is flatter

(and spectral PL index and NH approximately constant after initial decrease…)



And after first 5mo., temporal decay index is 0.9±0.2

(and both Γ and NH remain constant)



Thus ~1.3 y after its TDF, the jet contintinues to be powered. HOW ?

TDEs (vs. Blazars) among BAT Slew Survey (BATSS) transients ?

- BAT slew survey (BATSS) has ~3.5y of slew imaging data; massive catalog (Copete, Grindlay et al, in prep.)
- BATSS has discovered ~25 new GRBs (many GCNs)
- It has also found new flaring activity from both “known” BAT survey (e.g. 22mo.) survey and NEW sources
- Several examples follow

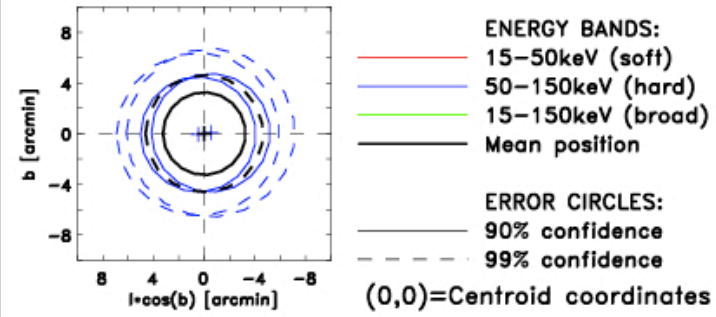
A “random?” P = 0.95d Algol system detected on 2 adjacent Swift orbits…

BATSS Trigger: 200636

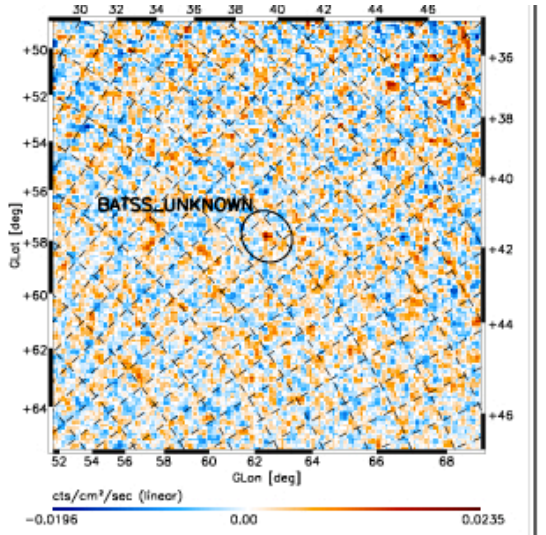
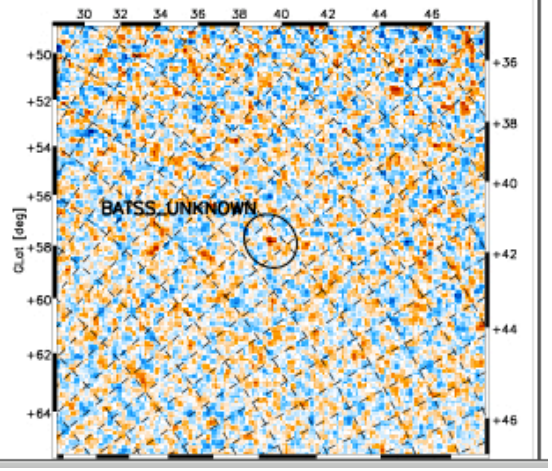
Processing version: 1
Trigger time **T = 221216342.0 MET (2008-01-05 08:58:59.5 UT)**

Coordinates:
RA, Dec (J2000) = 15h 52m 19.7s, +30d 37' 23"
l,b = 49d 05' 19", +50d 30' 29"
Radius (90.0%) = 3.3 arcmin

Candidate criteria satisfied:
Index 7: Non-simultaneous coincidence (S/N>4.0) over less than 2 spacecraft orbits
Index 5: High-significance (S/N>5.5) single-band detection

Local chart of detections	Catalogued Source Matches
	None

…with images that are significant detections of ~400mCrab flux (lasting <50min)

RA (J2000): 15h 52m 20.2s **Dec(J2000):** +30d 37' 51" **l:** 49d 06' 04" **b:** 50d 30' 25" **Offset:** 0.47 arcmin	**S/N:** 5.8 **Obs. start:** 2008-01-05 08:04:49.0 UT **Exposure:** 146.80 sec **Coding fraction:** 71.3% **Radius (90.0%):** 4.5 arcmin **Energy band:** 50-150keV **Est. Flux:** 435±67 mCrab **Observation results:** orbital_080105_08h04m49s (50-150keV)	
RA (J2000): 15h 52m 19.1s **Dec(J2000):** +30d 36' 54" **l:** 49d 04' 32" **b:** 50d 30' 33" **Offset:** 0.51 arcmin	**S/N:** 5.6 **Obs. start:** 2008-01-05 08:59:12.5 UT **Exposure:** 115.80 sec **Coding fraction:** 74.5% **Radius (90.0%):** 4.7 arcmin **Energy band:** 50-150keV **Est. Flux:** 430±70 mCrab **Observation results:** slew_080105_08h59m00s+186s (50-150keV)	**50-150keV (hard)** 

… and Blazar flares(?) in BATSS?

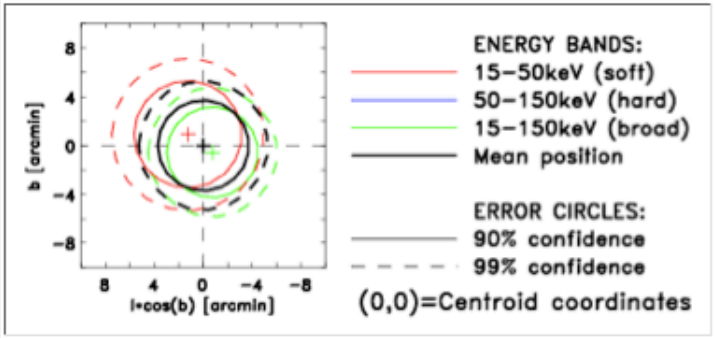
e.g. a significant (~6-8σ) source in 2-bands…

BATSS Trigger: 102096

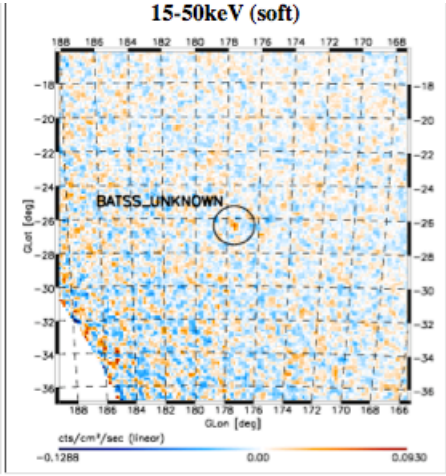
Processing version: 1
Trigger time **T = 310446297.0 MET (2010-11-03 03:04:50.7 UT)**

Coordinates:
RA, Dec (J2000) = 04h 07m 50.8s, +15d 00' 49"
l,b = 177d 31' 42", –26d 24' 08"
Radius (90.0%) = 3.7 arcmin

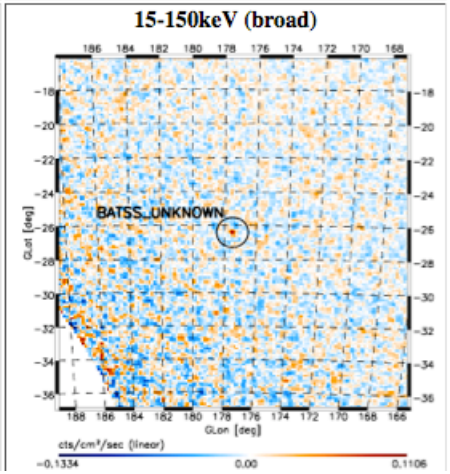
Candidate criteria satisfied:
Index 9: Simultaneous Single-band (S/N>4.0) + Broad-band (S/N>5.0) coincidence
Index 5: High-significance (S/N>5.5) single-band detection

Local chart of detections	Catalogued Source Matches
	None

S/N: 6.1
Obs. start: 2010-11-03 03:04:50.7 UT
Exposure: 52.40 sec
Coding fraction: 40.8%
Radius (90.0%): 4.4 arcmin
Energy band: 15-50keV
Est. Flux: 346±61 mCrab
Observation results:
slew_101103_03h03m56s+155s (15-50keV)



S/N: 7.9
Obs. start: 2010-11-03 03:04:50.7 UT
Exposure: 52.40 sec
Coding fraction: 40.8%
Radius (90.0%): 3.7 arcmin
Energy band: 15-150keV
Est. Flux: 423±60 mCrab
Observation results:
slew_101103_03h03m56s+155s (15-150keV)



Bright (170 mJy) 320MHz source (TXS 0405+148) in 95% error box!

What's needed for more TDEs?
High Cadence, High resolution imaging Hard X-ray (5-200 keV) survey

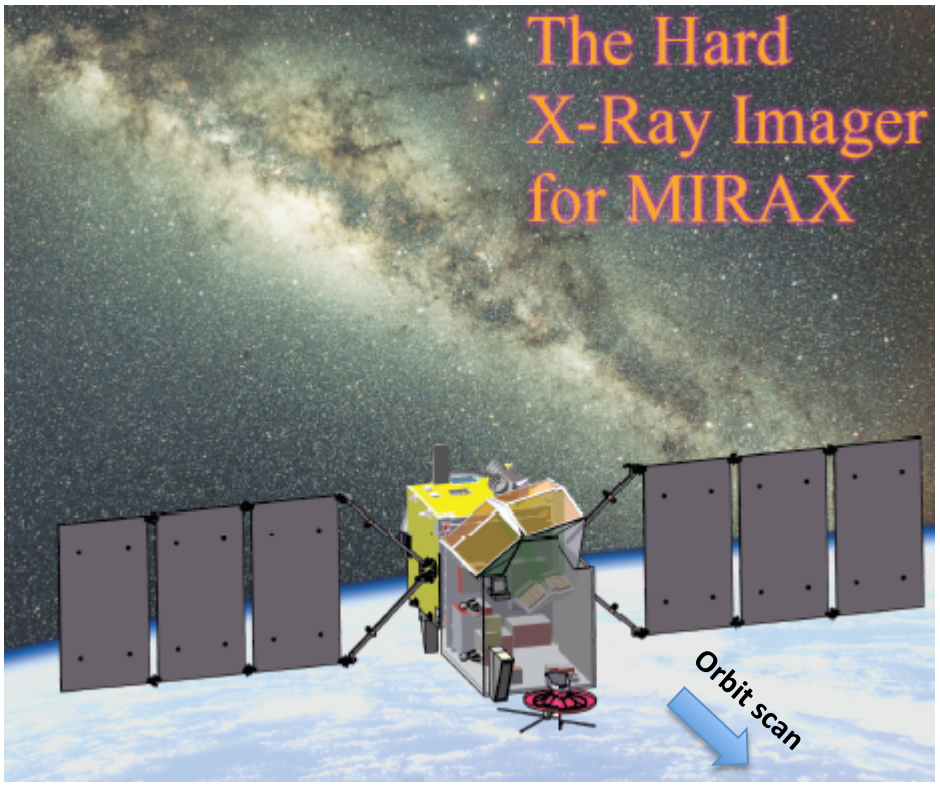
- Swift/BAT and INTEGRAL have localized new transients but BATSS (and MAXI) show that there is a large population of short-duration (~5-50 min?) flaring sources

- MAXI positions very poor (0.5deg); BATSS positions (~3arcmin) are often not able to identify likely counterpart

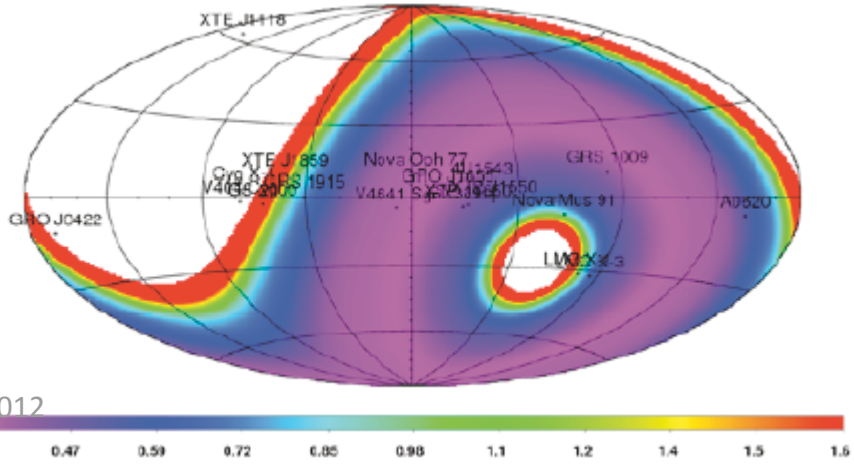
- Need <1arcmin positions AND *high cadence* to increase sensitivity and temporal coverage: *maximize Jet-TDF discovery!*

MIRAX-HXI: *US imager on Brazil X-ray TDA mission*

- ***MIRAX*** is *approved* first Astronomy mission from Brazil, 2016 launch
- ***HXI*** (Hard X-ray Imager) is CfA designed/built instrument: 4 coded mask telescopes (5-200 keV, 4' resolution across 60° x 60° FoV, ≤30" positions with sens. 0.3mCrab/y
- **Science Goals:**
  - **1. Galactic Center/Bulge Hard X-ray black hole and transients survey *every 96min: SgrA* flares!***
  - **2. Time Domain Astrophysics of BHs, NSs and jets – from NS, BH binaries to Blazars & TDEs !**
  - **3. Long and Short Gamma-ray bursts, including polarization, and GW-EM physics/cosmology sGRBs with Advanced LIGO**



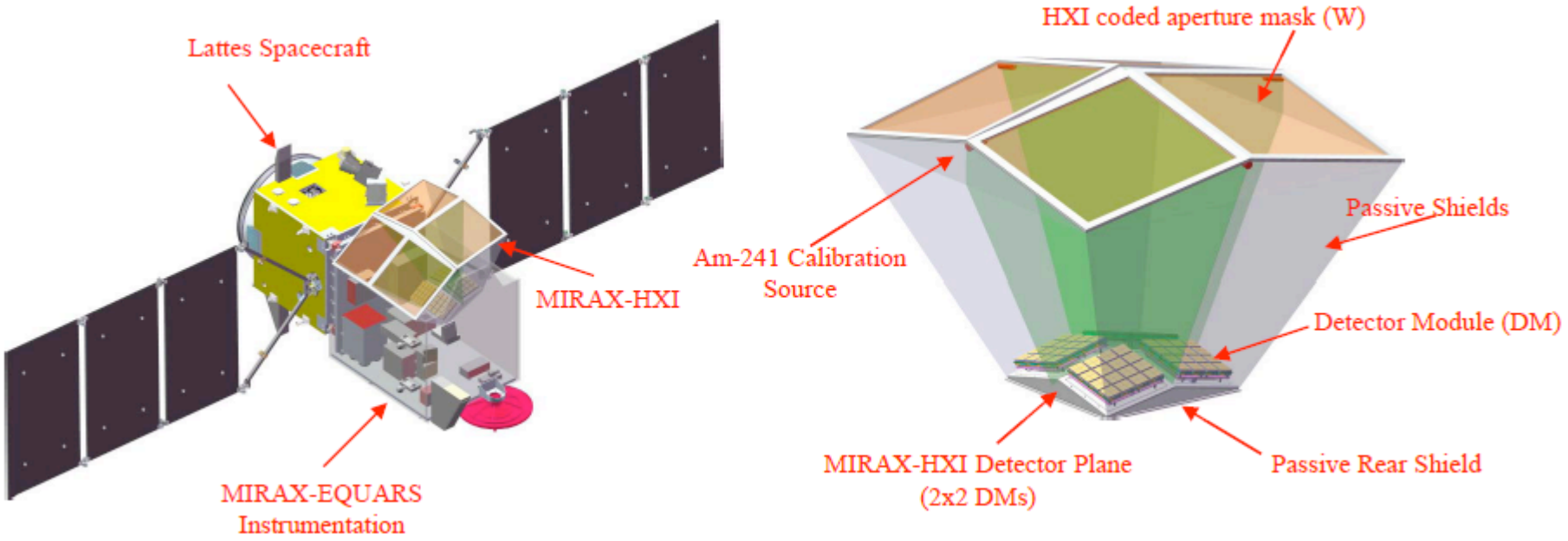
MIRAX-HXI **images full southern sky (δ < +20°) each 96 min orbit**



5σ sens. (mCrab/y):
(~2-3X BAT sens.)

Overview of *MIRAX-HXI* on *Lattes* Satellite

- Four wide-field, *Scanning-Coded aperture imaging* telescopes



- Four sub-telescopes, each with *HXI* imaging detector plane, image 50^{o} x 50^{o} *with full sensitivity* & out to 60^{o} x 60^{o} FWHM

Time Domain High Energy Astrophysics Survey

- *MIRAX-HXI* will provide the first *high-cadence* (~10-15 min exposure *every 97min*) *time variability survey* of the hard X-ray (5-200 keV) Universe

- *MIRAX-HXI provides continual southern sky coverage for LSST and Time Domain Astronomy* as one of the highest ranked science objectives of the Decadal Survey

- *MIRAX-HXI* will discover *disk-jet physics in flaring AGN* as well as *new classes of extreme blazars (resembling GRBs!)* – and jet-powered TDEs, like Sw J1644 and Sw J2058

Mission Requirements to achieve science objectives

- *Wide-field-scanning* coded aperture imaging over broad band (5-200 keV) with high angular resolution (~5') and precise source positions (r(90%) <40" for >5σ sources)

- *Southern sky "continual" visibility* to measure Galactic Center and Bulge/Plane soure populations and variability

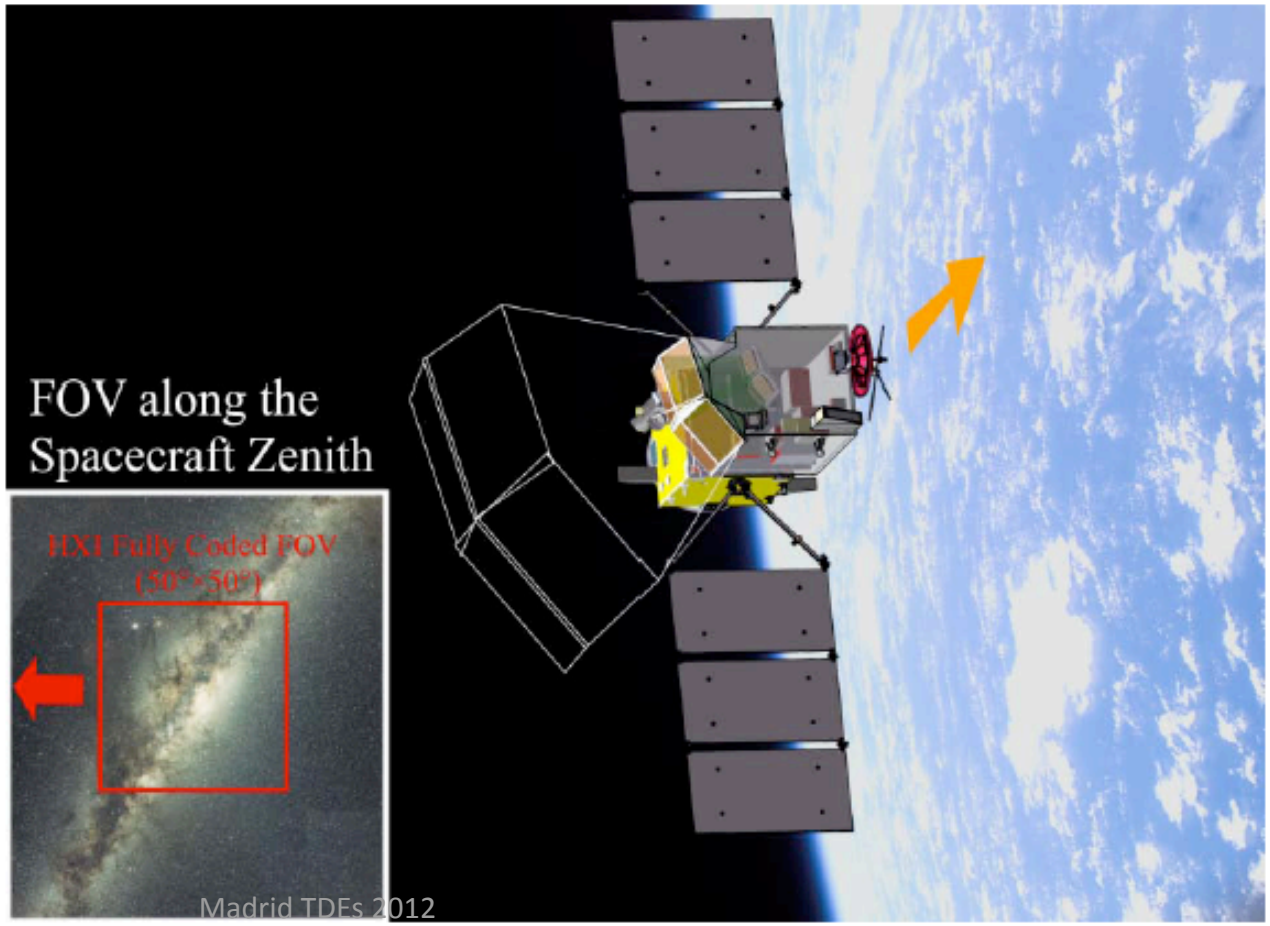
- *Continual scanning* to maximize exposure on every source observable per orbit, with photon counting and on board processing and high bandwidth "event mode" telemetry to ground for time-critical followup (e.g. GRBs)

And how does *HXI* image while *scanning?*

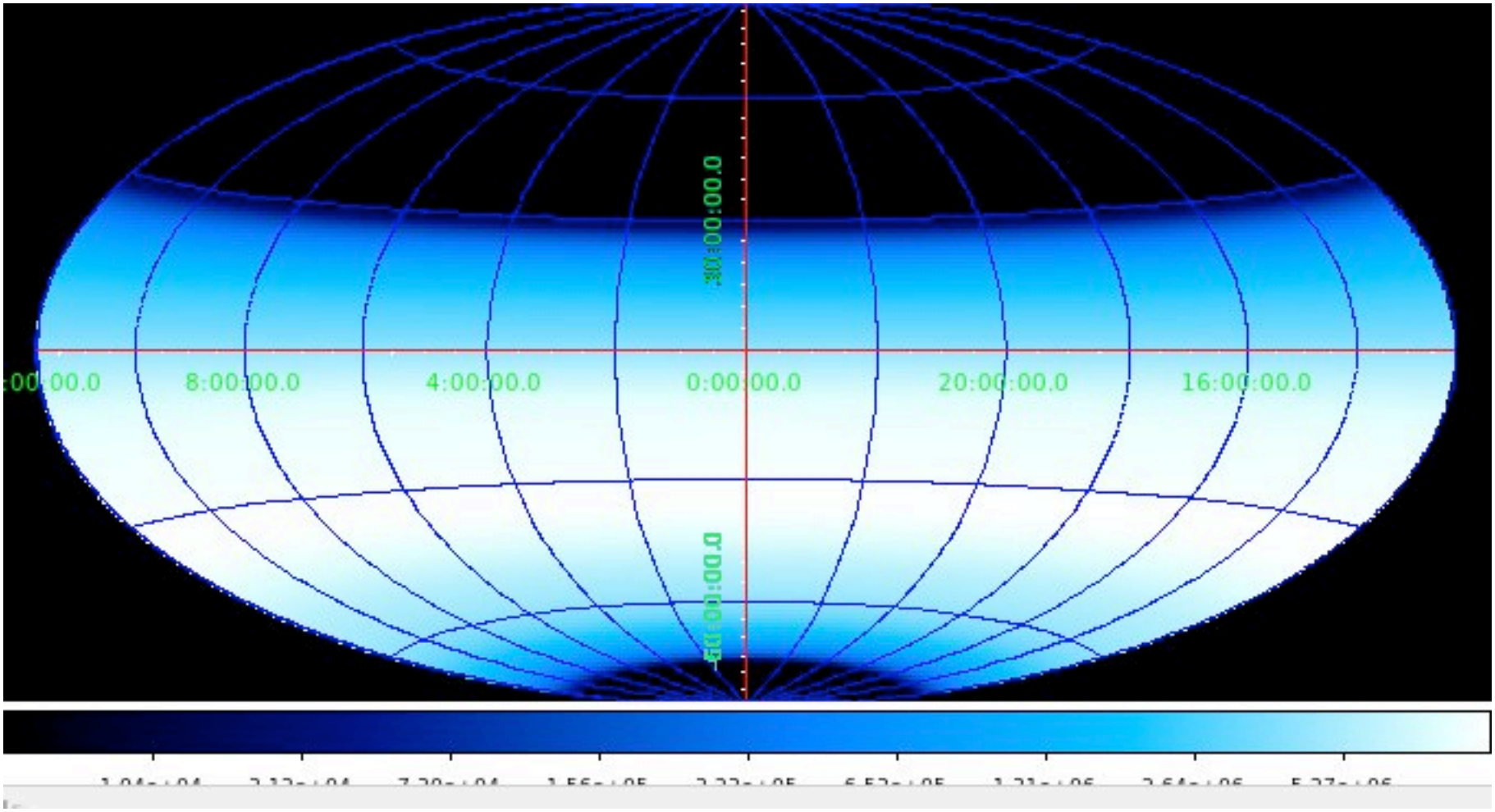
- *HXI images each X-ray photon* precisely in position and time so that with 10” aspect from *Lattes*, images are sharp

- *HXI* photons time-tagged to 0.1msec, or 0.024” of scan.

- For 10” aspect, must “image” every 40msec and do Fast FFTs onboard but only GRB rate triggers

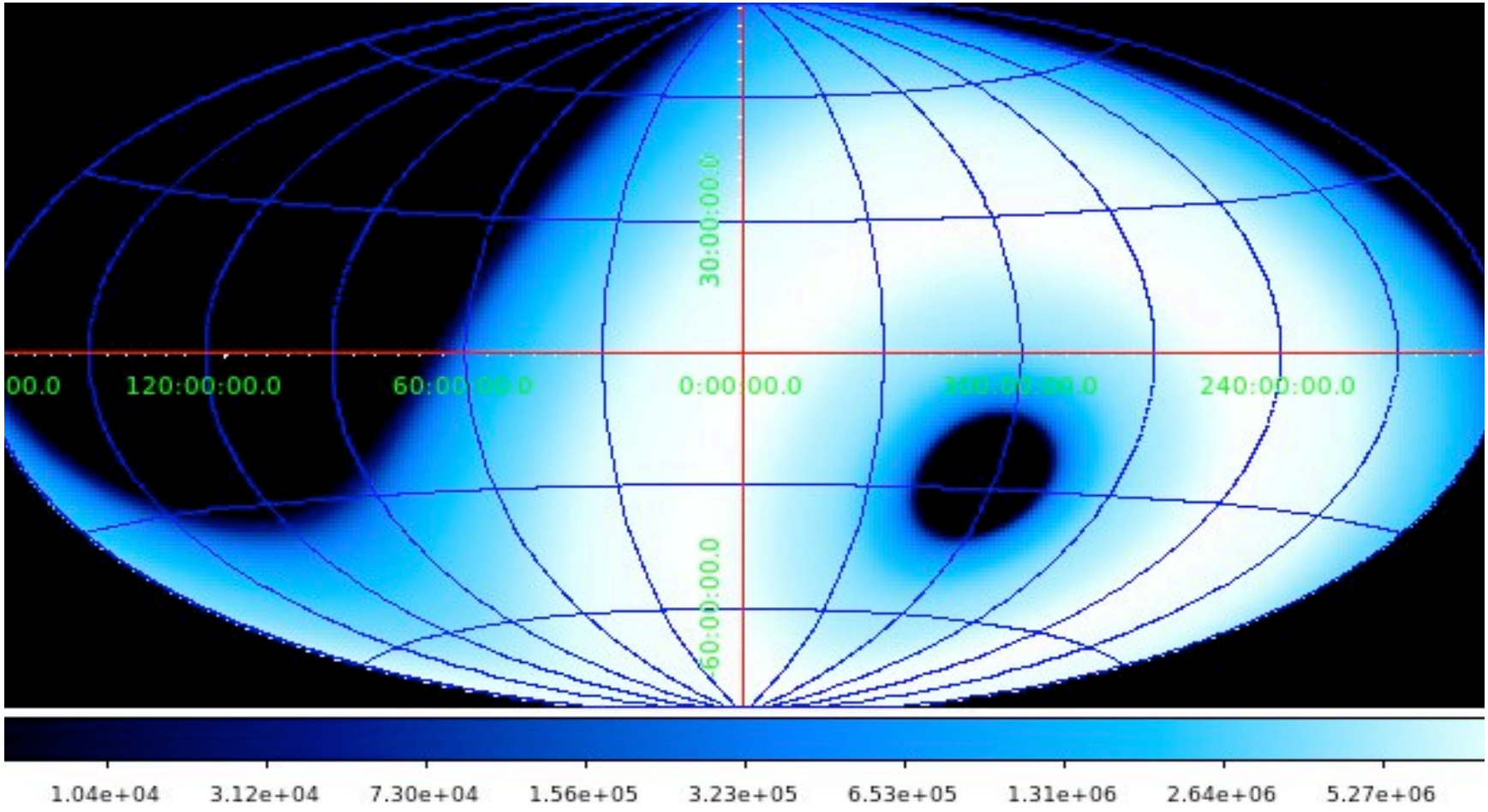


HXI sky coverage (equatorial coordinates)



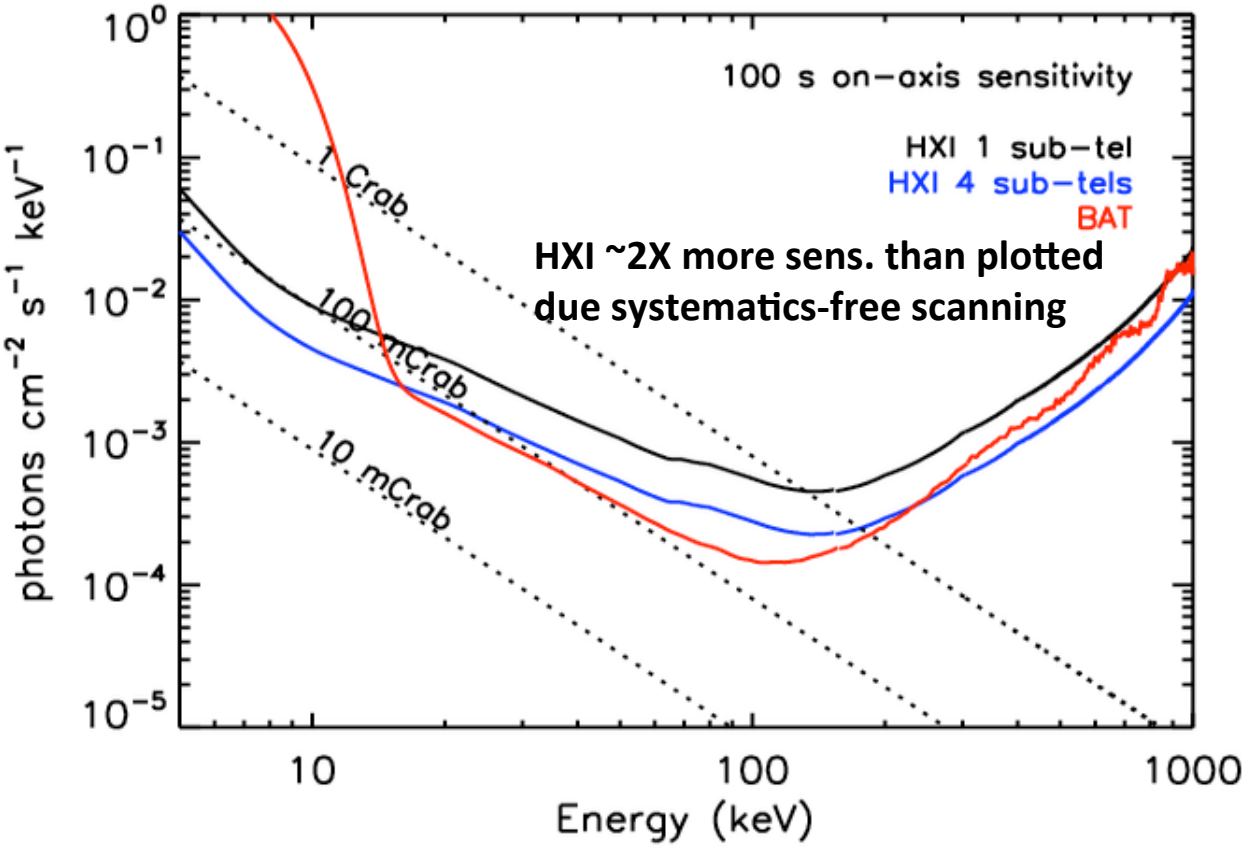
… *and in* galactic coordinates, both NGP and SGP!

(for good coverage of TDEs and AGN flares…)



HXI imaging exposure (sec/yr of mission)

HXI sensitivity



HXI sensitivity comparable to Swift/BAT over ~15-50 keV but >10X better below 15 keV (unique coverage to ~5keV) due to lower CXB and improved systematics from scanning. Sky exp./yr also **~3X larger**

Summary and Prospects

- The X-ray sky is highly variable, with unexpected bright transients from Algol binaries to flaring AGN – to be distinguished from TDEs

- Extreme flares from stars, accreting BH/NS, AGN *and TDEs* are best measured/identified with a *high-cadence, wide-field scanning survey*

- *MIRAX-HXI* gives *continual* TDA coverage/trigger for LSST & ALMA/MWA and provides stand-alone galaxy IDs (<10" positions) for A-LIGO SGRBs!

- Combination of *eROSITA and MIRAX-HXI* (if simultaneous, in 2017?) will enable TDE survey over full range of NH (heavily obscured nuclei to "clean" ellipticals…), and thermal vs. jet-powered TDEs