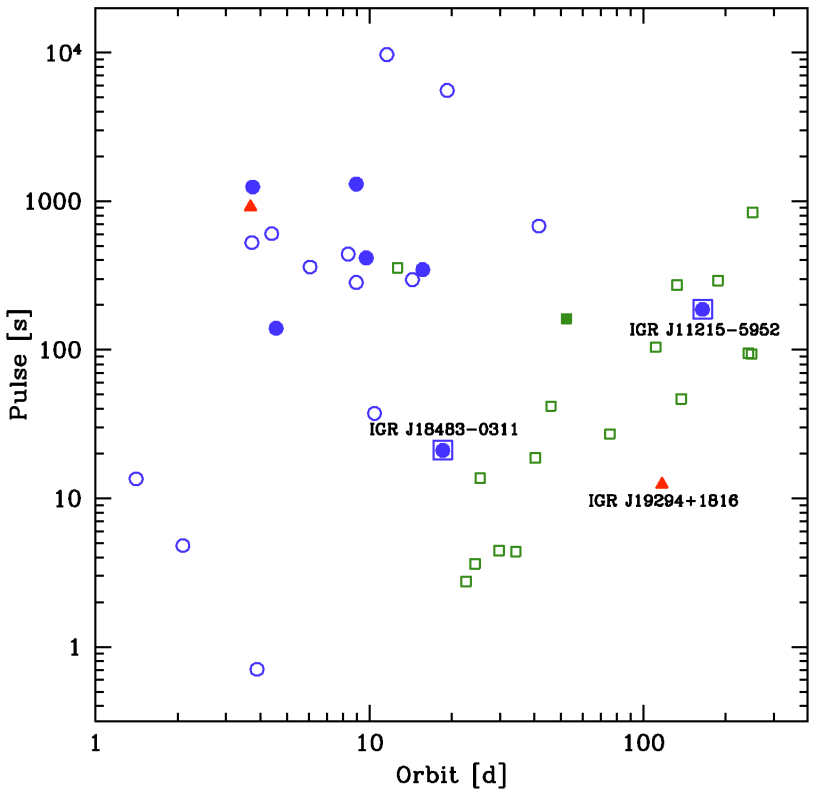
Obscured Sources

- From list of publications (2008-2009):
  - Tomsick et al., Chandra cycle 8 (US first author)
  - Tomsick et al., Chandra cycle 9 (US first author)
  - Rodriguez et al., Swift paper #1 (US co-author)
  - Rodriguez et al., Swift paper #2 (US co-author)
  - Butler et al., optical follow-up (US first author)
  - Chaty et al., optical/IR follow-up (US co-author)
  - Masetti et al., optical follow-up (US co-authors)
  - Masetti et al., optical/IR follow-up (US co-authors)
  - Cuadra et al., stellar winds in the Gal. Center region (US first author)
  - Morris et al., Suzaku follow-up (US first author)
  - Reig et al., 4U 2206+54 (US co-author)
  - Tomsick et al., IGR J16207-5129 (US first author) ... not in Excel file

Key Science Topics

- HMXBs
  - Stellar winds/equatorial outflow
  - Slow rotation periods and possibly binary magnetars
  - Soft excess
  - Possibility of finding good sources for neutron star mass measurements (EXO 1722-363)
  - Finding good sources for cyclotron line studies
- HMXB evolution
  - Be X-ray binaries vs. supergiant HMXBs
  - HMXBs with black holes?
  - NS-BH progenitors for gravitational wave studies (Phinney)
- Hard X-ray source populations (e.g., fraction of HMXBs)

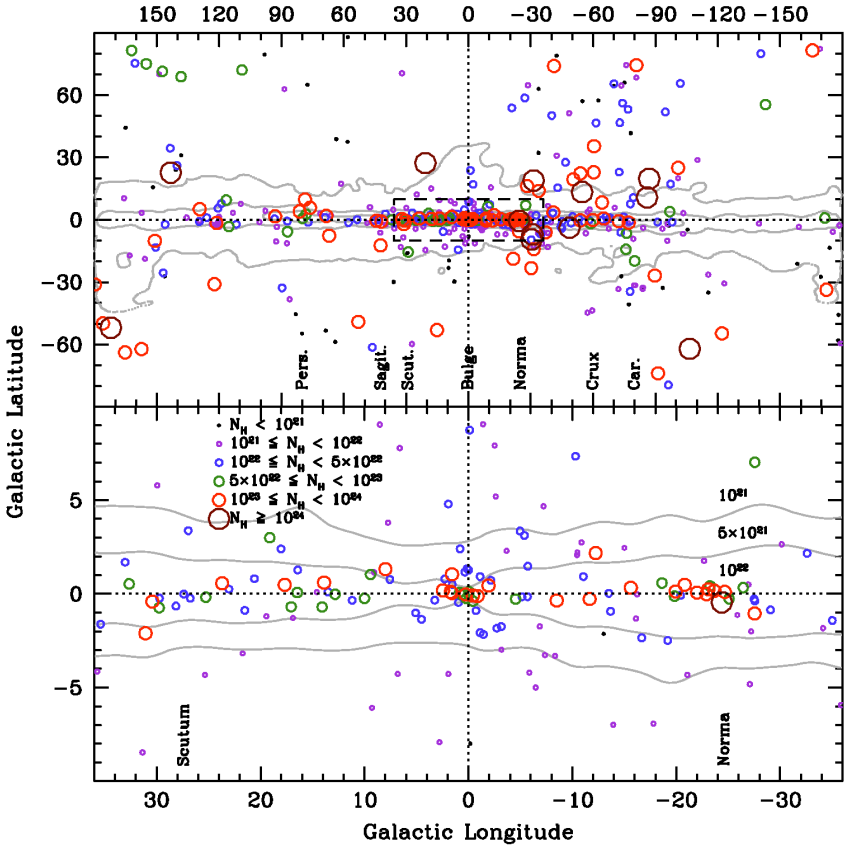
HMXB Populations



From Rodriguez et al. paper on IGR J19294+1816

- Corbet diagram divides sources into:
  - Be X-ray binaries
  - Wind-fed supergiants
  - Roche lobe overflow sources
- Filled symbols in plot are sources discovered by INTEGRAL

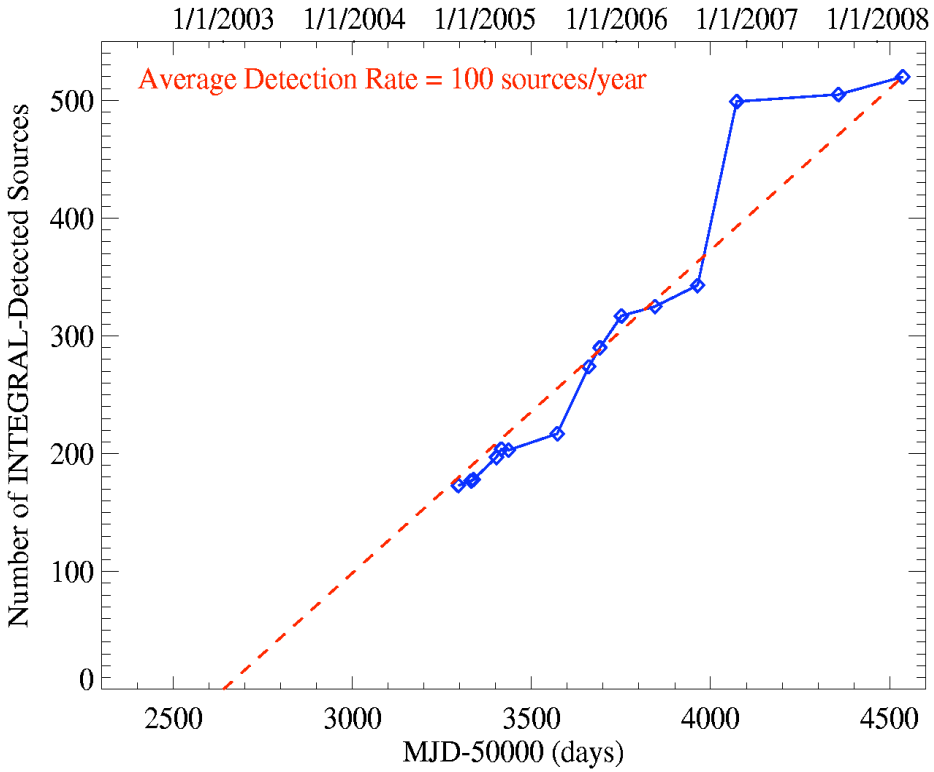
Galactic Distribution/HMXB Stats



Bodaghee et al. 2009, in prep. (updated version of 2007 May INTEGRAL Picture of the Month)

Quantity	SR08	SR10
Number of Sources detected by INTEGRAL	500 (Bodaghee et al. 2007)	723 (Bird et al. 2009)
Number of IGR HMXBs	32	41
IGR HMXBs with N_H>5e22 cm^{-2}	18	23
Supergiant IGR HMXBs	"more than half"	19
IGR HMXBs with pulsations detected	11	17

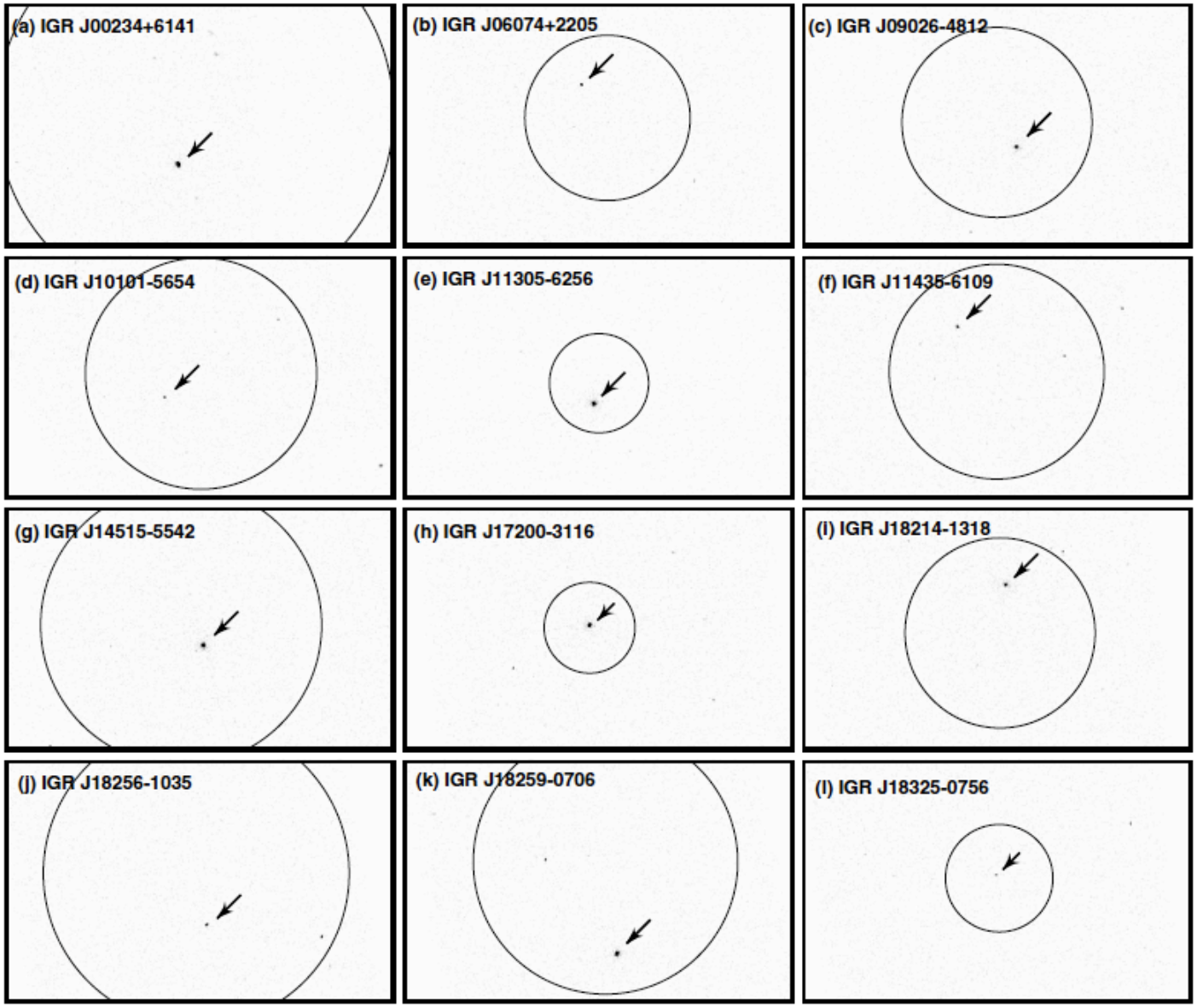
INTEGRAL Discovery Rate



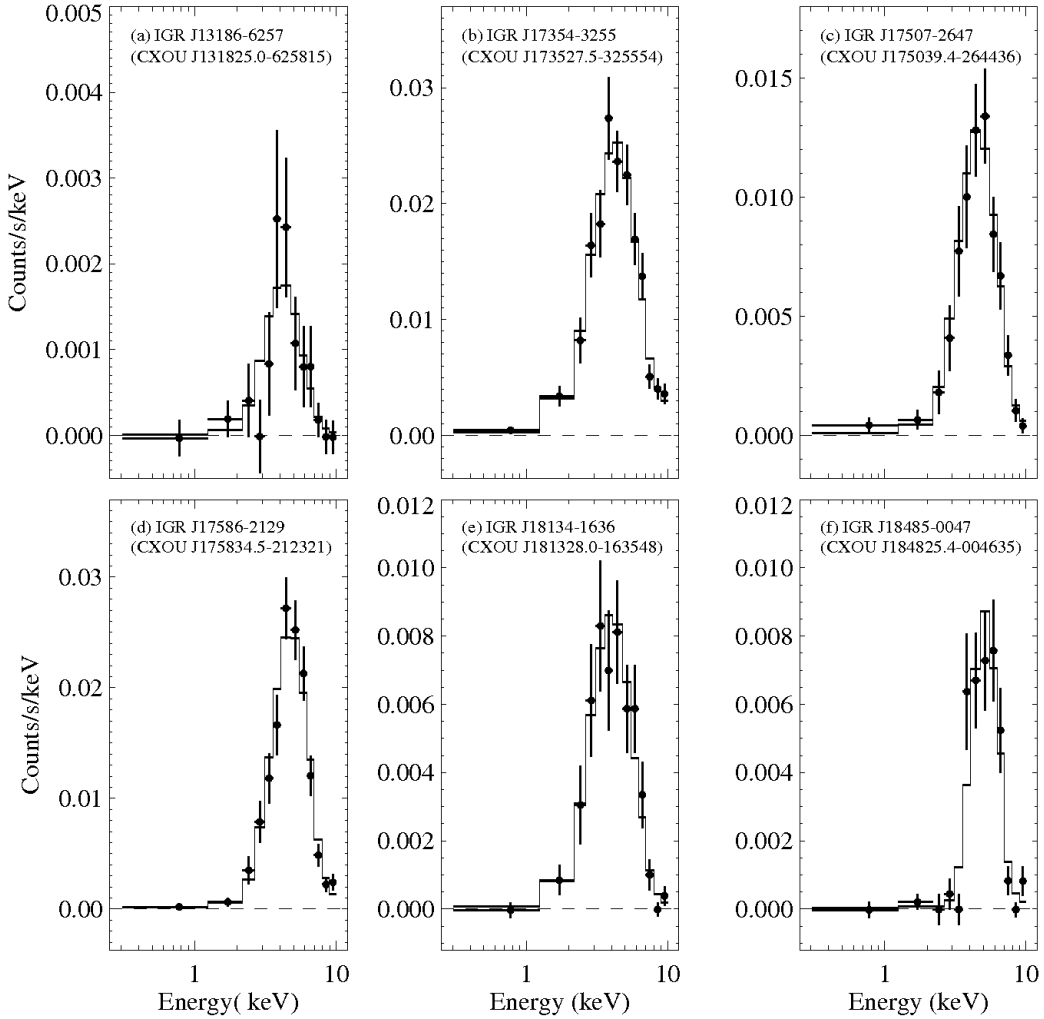
Tomsick et al. (2008 HEAD meeting)

- Needs to be updated...
- Trend will continue with the 723 sources in the 4th IBIS/ISGRI catalog (Bird et al. 2009)

Chandra cycle 8 program



Chandra cycle 9 program



- Main results:
  - Soft X-ray identifications for 18 of 22 targets
  - Six highly absorbed sources
  - 7 confirmed or likely X-ray binaries
  - 3 or 4 CVs
  - 1 to 3 AGN
  - Two extended sources

… and what about SR10?

- What is a compelling argument for continuing to fund INTEGRAL activities in the US?
  - Discovery of many new IGR sources.
  - Many follow-up programs are in place with successful track records.
  - Getting large enough numbers of sources that population studies are starting to get interesting (correlations between P_{orb}, P_{spin}, N_H, stellar wind properties, spectral type, eventually masses of binary components, perhaps B_{NS})

Black Hole Transients and State Transitions

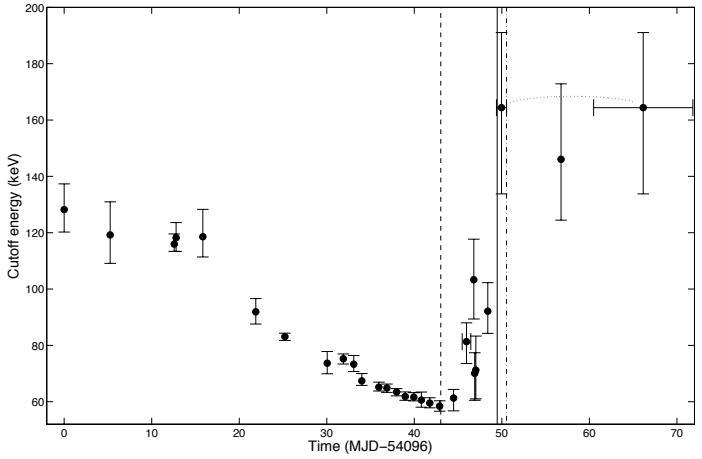
- From list of publications:
  - Caballero-Garcia et al., GX 339-4 (US co-authors)
  - Del Santo et al., GX 339-4 (US co-authors)
  - Motta et al., GX 339-4 (US co-author)
  - Prat et al., H 1743-322 (US co-author)
  - Capitanio et al., IGR J17091-3624 and IGR J17098-3628 (US co-author)
  - Hjalmarsdotter et al., Cyg X-3 (US co-author)
  - Malzac et al., Cyg X-1 (US co-author?)
  - BHs for other papers: GRS 1915+105, SS 433, XTE J1818-245, 1E 1740.7-2942

Comparison to SR08

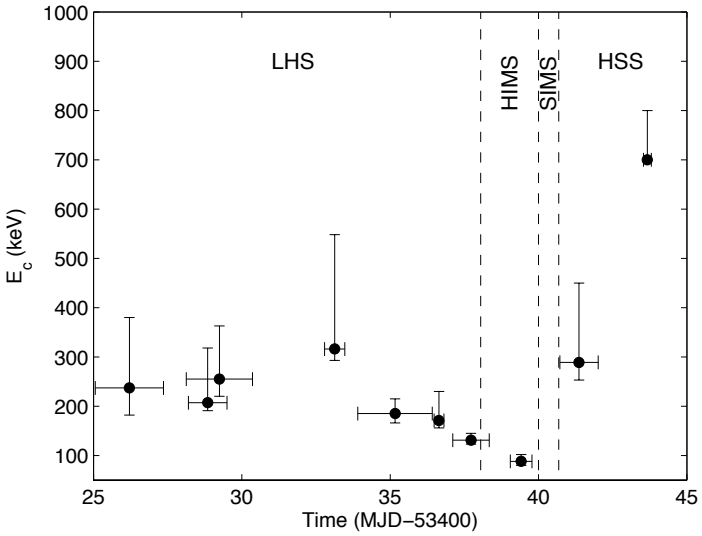
- SR08: "Since late-2005 INTEGRAL has carried out dedicated observations of 8 systems with stellar mass BHs."
- SR10 (not as many dedicated observations):
  - Only 1 BH TOO since late-2007: H1743-322
  - GX 339-4 was observed as a TOO in 2007 Jan-Mar
  - Also, SS 433, Cyg X-1, GRS 1915+105
- Science: SR08 emphasized the two high-energy (possibly thermal and non-thermal) components.

SR10 Results

- New results are consistent with 2 high-energy components:
  - GX 339-4: Caballero-Garcia et al.
  - 1E 1740.7-2942: Bouchet et al., "Unveiling the High Energy Tail ..."
- Also, for GX 339-4 and GRO J1655-40, Motta, Belloni, & Homan (2009) constrain the cutoff evolution



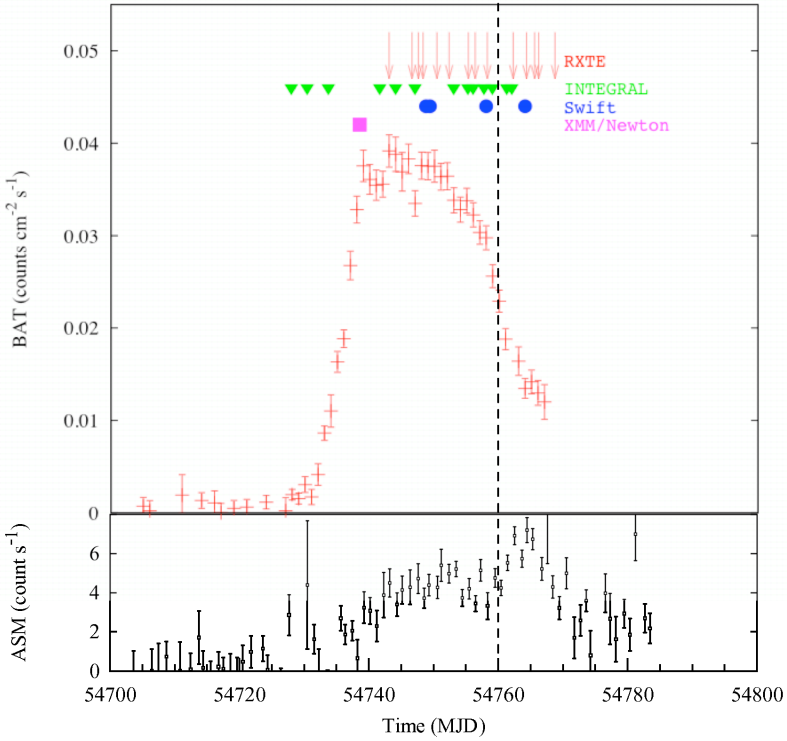
RXTE Obs. of GX 339-4



INTEGRAL Obs. of GRO J1655-40 (from 2005)

The Black Hole Transient H 1743-322

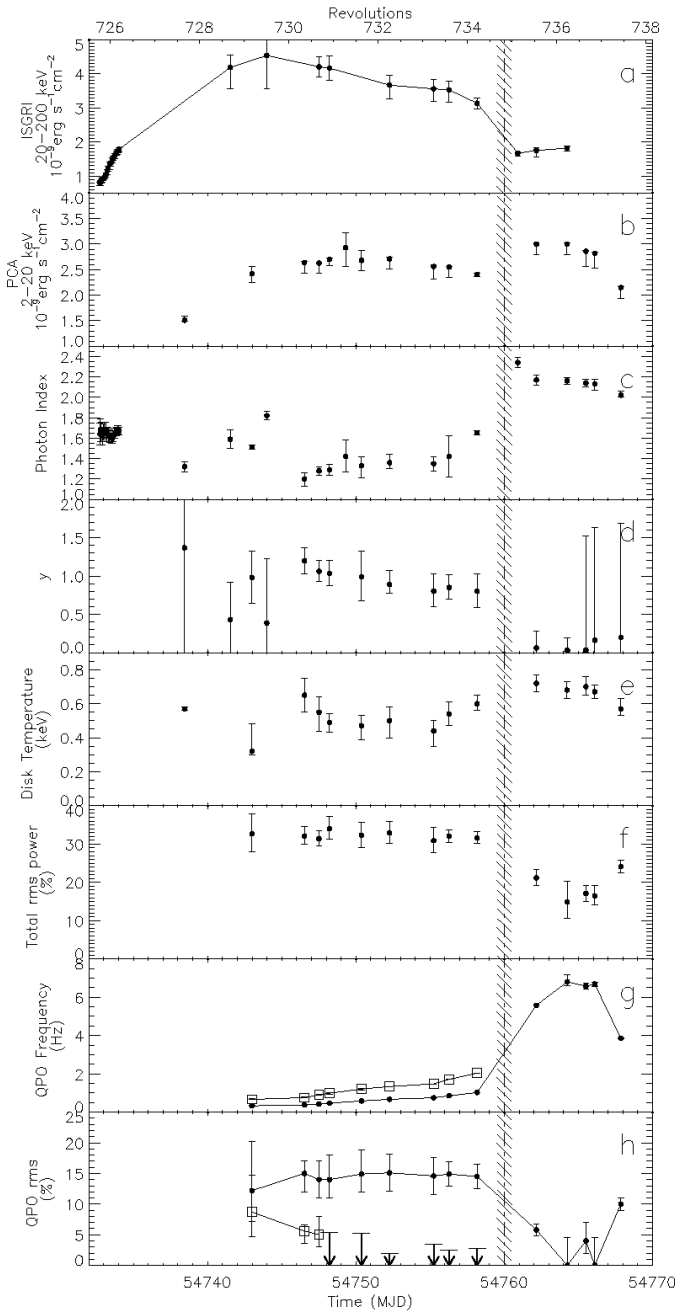
- INTEGRAL data come from the Galactic Center Key Program
- New aspect of this study is that we obtained coverage at the very earliest stage of the outburst (serendipitously)



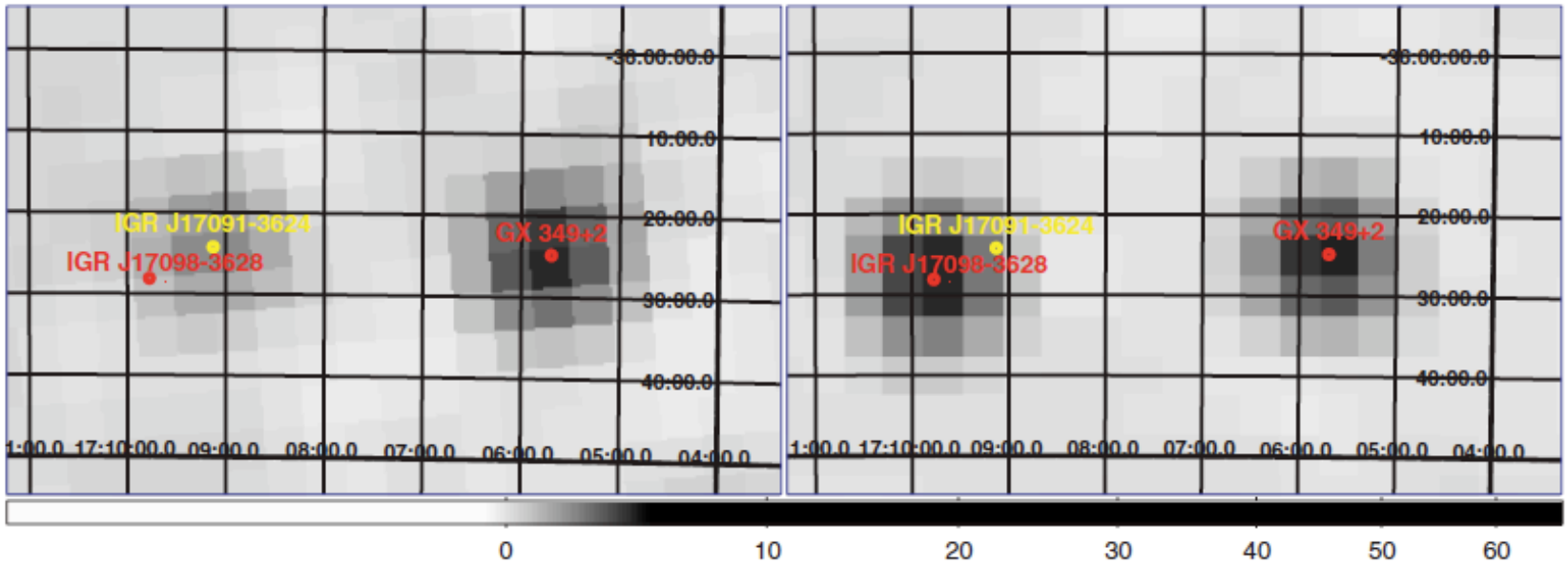
Light curves and summary of observations of H 1743 used in the Prat et al. paper

H1743-322 Study - 2

- Early detection by INTEGRAL allowed for a detailed study of spectral and timing properties during the rise.
- Fairly usual evolution from the Hard State to the Intermediate State, but such detailed studies are more often possible during outburst decay.
- Also, INTEGRAL triggered a radio observation on MJD 54744, and radio emission was detected at 2 mJy (jet).

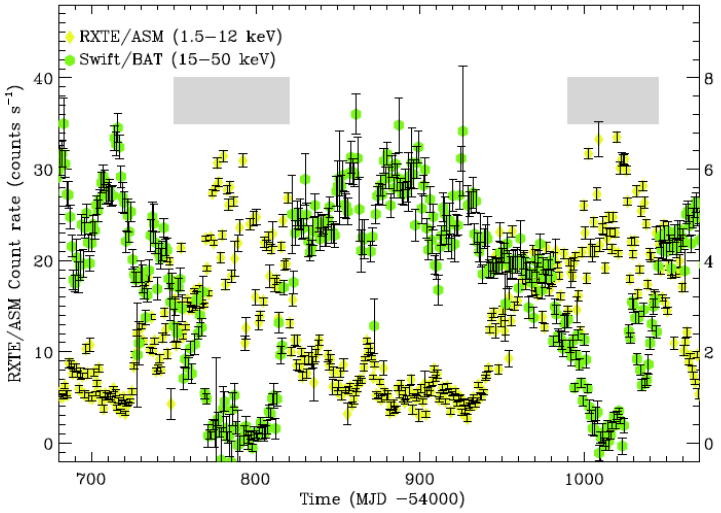


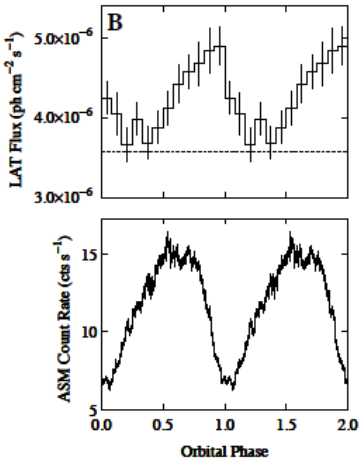
IGR J17091-3624 and IGR J17098-3628



- A lot of this paper is about Swift results (Jamie Kennea is the US co-author), but this figure shows off the INTEGRAL imaging capabilities.

Cyg X-3 Developments

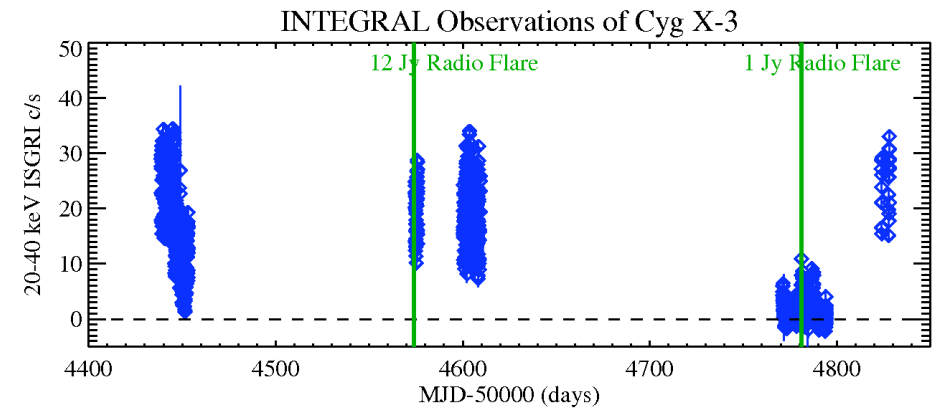


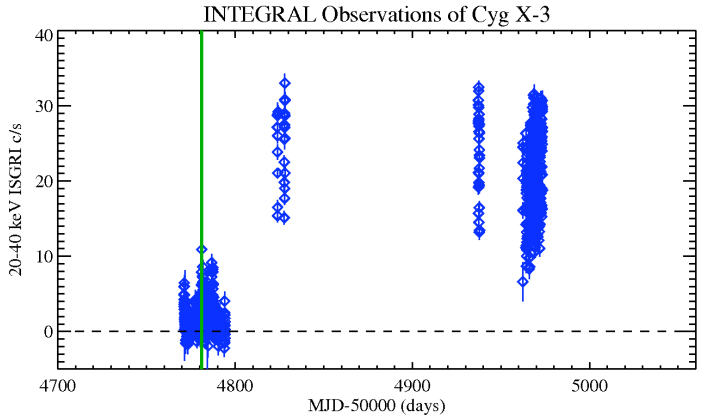


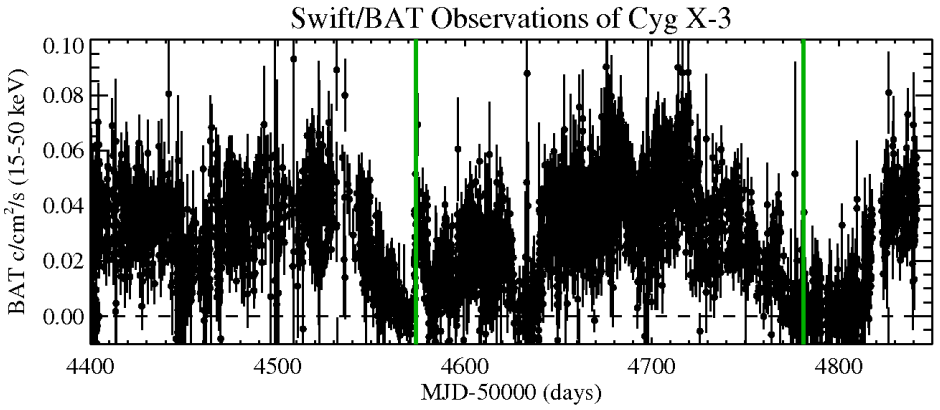
Both figures from Abdo et al., accepted in Science

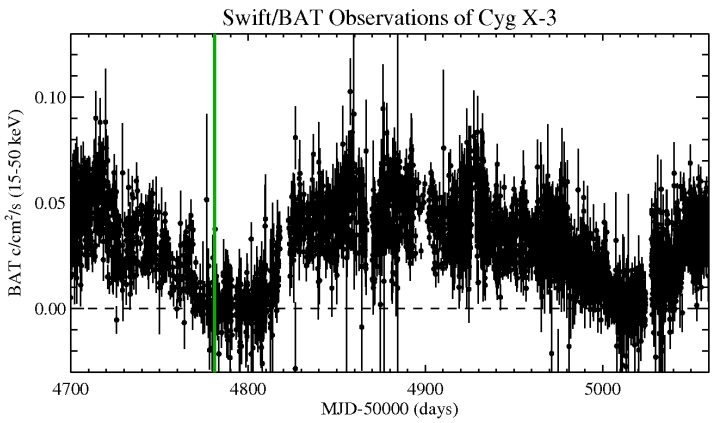
- AGILE and Fermi papers coming out in Nature and Science
- Also, gamma-ray flares appear to lead radio flares
- My analysis of the INTEGRAL data was considered for the Fermi Science paper

Cyg X-3 as seen by INTEGRAL - 1

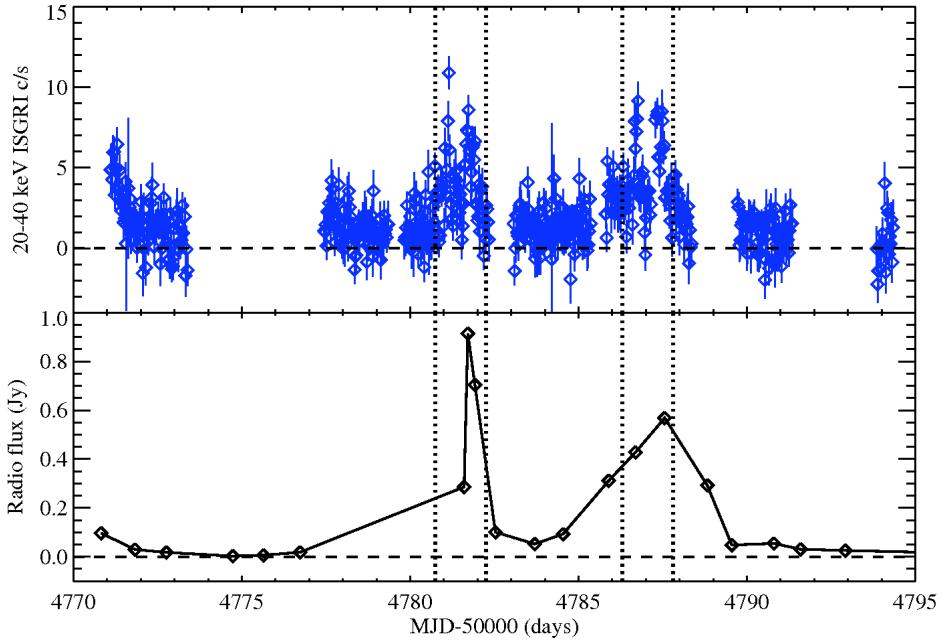


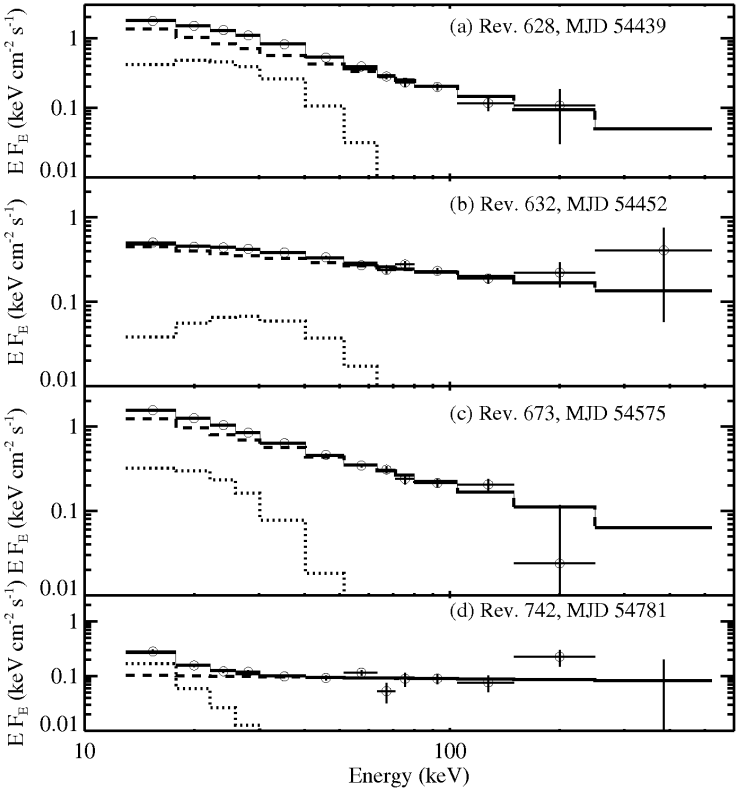






Cyg X-3 as seen by INTEGRAL - 2





Young Supernova Remnants

- Tian et al., HESS J1731-347 (US co-author)
- Gotthelf & Halpern, HESS J1837-069 (US first author)
- de Jager et al., Vela X (US co-author)
- Butt et al., TeV J2032+4130 (US first author)
- Gotthelf & Halpern, HESS J1813-178 (US first author)
- Tomsick et al., Chandra cycle 9 (US first author)
- Renaud et al., IGR J14003 (US co-authors)

Chandra cycle 9 program

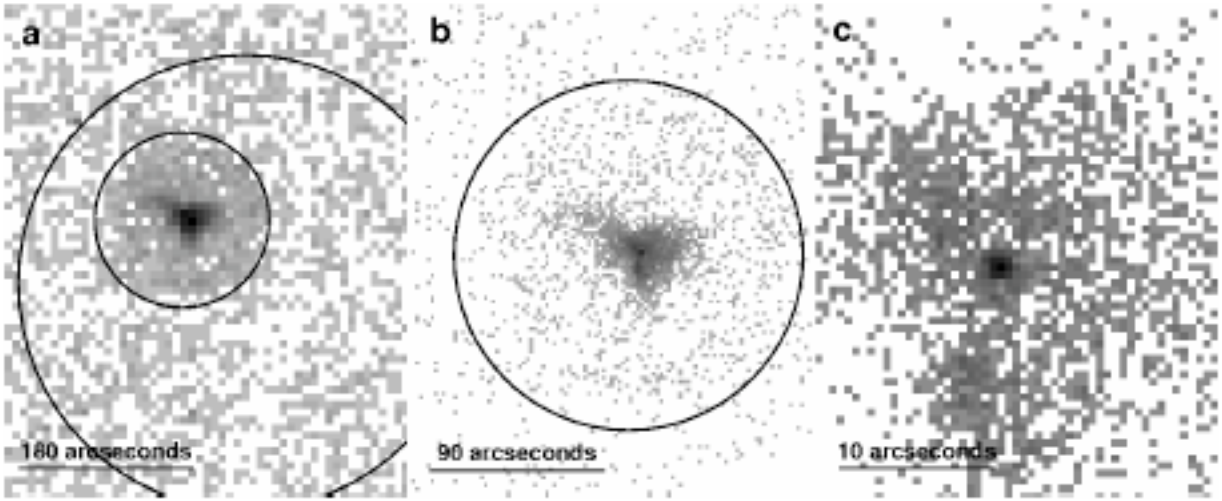
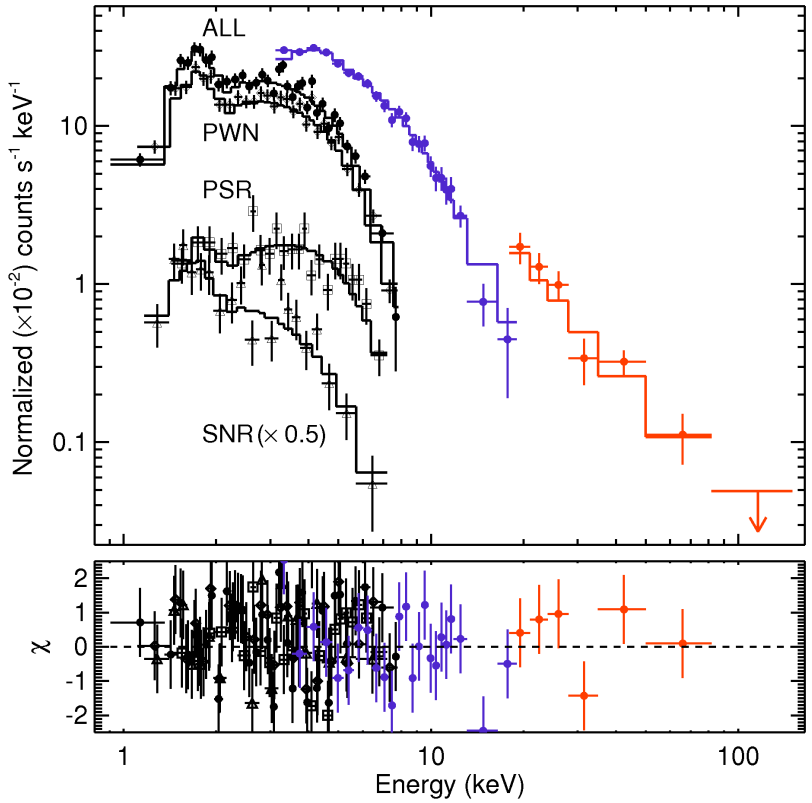


Fig. 4.— *Chandra* 0.3–10 keV images for IGR J14003–6326. *(a)* The pixel size in this image is 7″.9. The larger circle shows the 90% confidence *INTEGRAL* error circle, which has a radius of 3′.9. The smaller circle has a radius of 1′.5, and marks the approximate extent of the supernova remnant (SNR). *(b)* The pixel size in this image is 1″.97, and the image is meant to highlight the putative pulsar wind nebula. The 1′.5 radius circle is shown. *(c)* The pixel size in this unbinned image is 0″.492, and the image is meant to highlight the point-like source near the center of the SNR. In all 3 images, North is up and East is to the left.

- l = 310.57 deg, b = -1.61 deg (near Crux spiral arm region)
- 4075 counts in the 3 arcminute diameter region
- 0.3-10 keV unabsorbed flux = 3.6e-11 ergs/cm2/s, Gamma = 1.83+/-0.13

IGR J14003-6326: Renaud et al.



- P_{spin} = 31.18 ms (fastest unrecycled pulsar in the Galaxy)
- dE/dt = 5.1e37 ergs/s (one of the most energetic rotation-powered pulsars in the Galaxy)
- Age < 1000 yrs

HESS J1813-178/IGR J18135-1751

- Gotthelf & Halpern 2009
- ... but there has been quite a bit on this TeV source. It was previously, the only IGR source associated with a SNR.

Table 2
Multi-waveband Luminosity Measurements of PSR J1813−1749

Mission	Energy Band	Source	Luminosity[a] ($erg\ s^{-1}$)	ϵ[b] (%)	Reference
Chandra	2–10 keV	AX J1813–178	1.9×10^{34}	0.03	Helfand et al. (2007)
INTEGRAL	20–100 keV	IGR J18135−1751	7.3×10^{34}	0.1	Dean & Hill (2008)
Fermi[c]	0.1–1 GeV	0FGL J1814.3−1739	5.4×10^{35}	0.8	Abdo et al. (2009)
HESS	> 200 GeV	HESS J1813−178	4.8×10^{34}	0.07	Aharonian et al. (2006a)

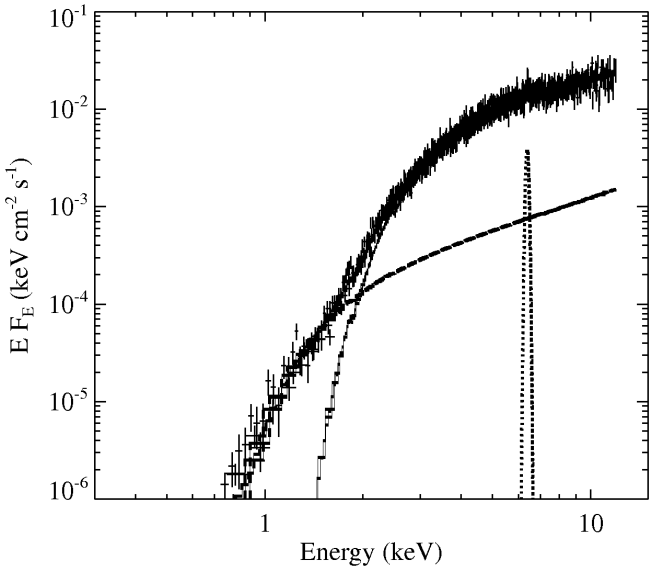
Notes.
[a] Total luminosity in the band assuming $d = 4.7$ kpc.
[b] Efficiency in the band assuming spin-down power $\dot{E} = 6.8 \times 10^{37}$ erg s^{-1}.
[c] Conversion from *Fermi* photon flux assumes a power-law photon index $\Gamma = 2$. However, association of the *Fermi* source with G12.82−0.02/PSR J1813−1749 is not yet established (see Section 3.2).

INTEGRAL-Related Activities

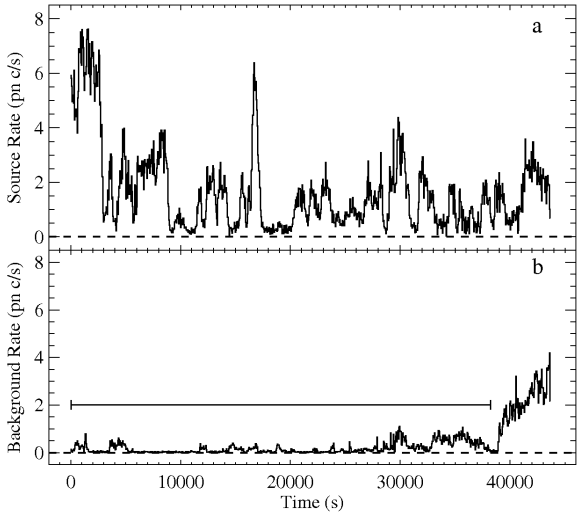
- *An XMM-Newton Spectral and Timing Study of IGR J16207-5129: An Obscured and Non-Pulsating HMXB*, Tomsick, Chaty, Rodriguez, Walter, Kaaret, & Tovmassian, accepted by ApJ
- *The Early Phase of a H1743-322 Outburst Observed by INTEGRAL, RXTE, Swift, and XMM-Newton*, Prat et al., accepted by A&A Letters
- Key Program observations of Cyg X-3 (cycle 5-6 program ... work in progress)
- Chandra localizations and soft X-ray spectra of IGR sources in the Galactic Plane
  - 4 Chandra observations in cycle 6 (Tomsick et al. 2006 mentioned in 2008 Senior Review proposal)
  - 20 Chandra observations in cycle 8 (Tomsick et al. 2008, ApJ, 685, 1143)
  - 22 Chandra observations in cycle 9 (work in progress: Tomsick & grad. student: S. Butler)
- Co-I on multi-wavelength study of GRS 1915+105 (PI: Rodriguez)
- Also at SSL: Wunderer work on using GRBs to constrain quantum gravity (presentation at INTEGRAL workshop)

IGR J16207-5129 XMM Study - 1

- Science Background: Many IGR sources are obscured HMXBs
  - 18 with N_H > 5e22 cm^{-2}
  - 11 with pulsations (typically 1000s up to 6000s)



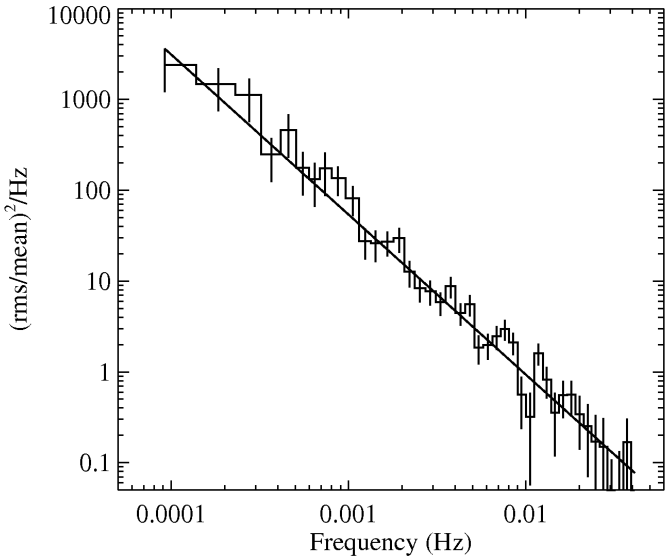
XMM light curve (0.4-15 keV) of J16207

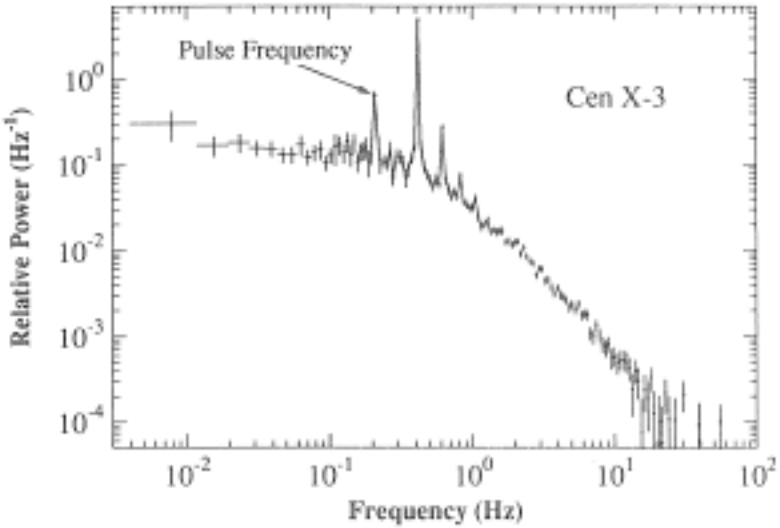


Results from XMM spectrum of J16207:

- Primary power-law is obscured (Gamma = 1.15, N_H = 1.2e23 cm^{-2})
- Soft excess
- 6.4 keV iron line with EW = 42 eV
- Consistent with neutron star (?) embedded in a spherical and "clumpy" wind

IGR J16207-5129 XMM Study - 2





Timing results for J16207:

- 2% rms upper limit on pulsations in the 10^{-4} – 88 Hz frequency range
- Power spectrum dominated by a steep power-law (index = 1.76, rms = 64%)
- Similar to two other apparently non-pulsating HMXBs: 4U1700-377 and 4U2206+54

- So, too bad there are no pulsations for J16207, but we noticed that the power spectra for J16207, 4U1700, and 4U2206 all look like the upper parts of the power spectra of pulsating HMXBs

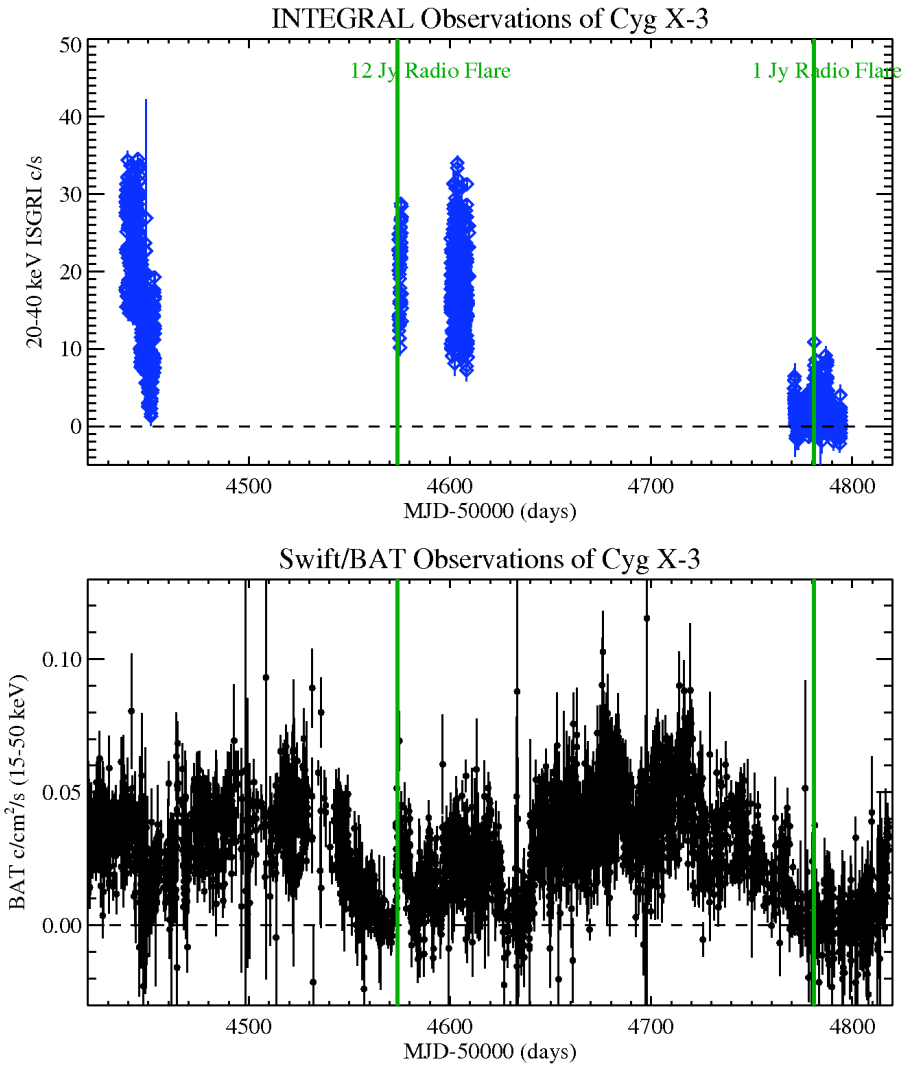
- Suggestion: Maybe J16207 and other apparently non-pulsating HMXBs are very slow rotators.

IGR J16207-5129 XMM Study - 3

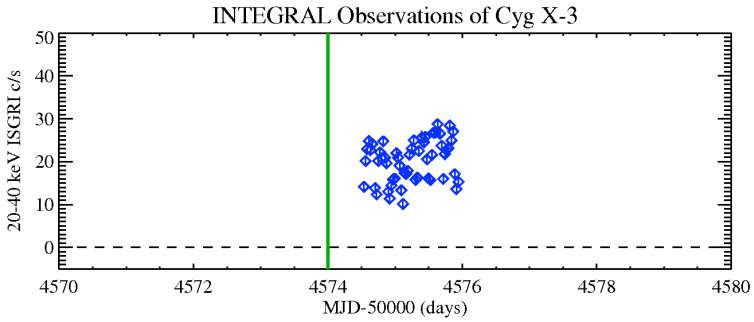
- Then, a new paper on one of our comparison sources appeared on astro-ph:
- "Discovery of slow X-ray pulsations in the HMXB 4U 2206+54" by Reig et al. (2008)
  - 5560 s pulsations from 4U 2206+54
- Implications of slowly rotating neutron stars: The magnetic fields at birth were likely very high ... perhaps in the magnetar (>10^{14} G) range (Li & van den Heuvel 1999).
- Currently working on XMM observations of IGR J00370+6122

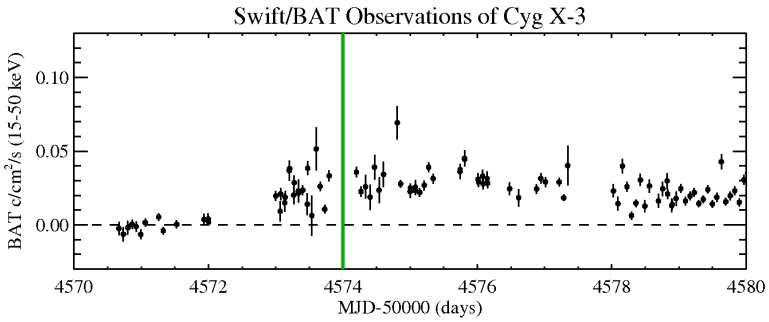
Key Program Observations of Cyg X-3

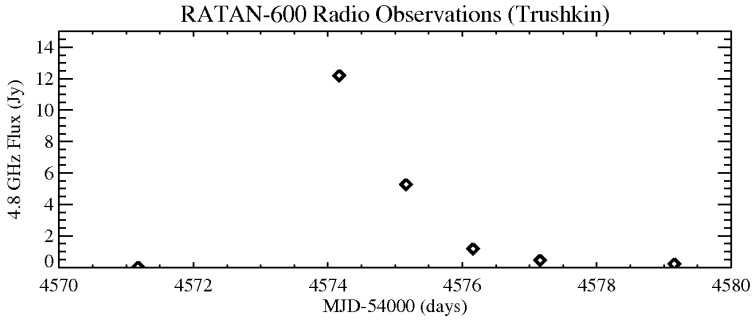
- Cygnus X-3:
  - Wolf-Rayet/BHC in a 4.8 hour binary orbit
  - Capable of producing very strong radio emission (extended jet)
  - Soft X-ray flux is very highly modulated by the orbit
  - Is the hard X-ray flux (>20 keV) correlated with the radio? How is the "corona" related to the jet?

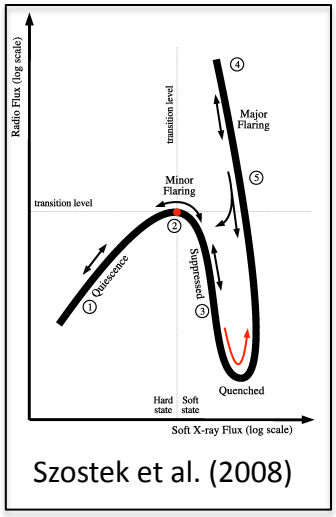


Key Program Observations of Cyg X-3

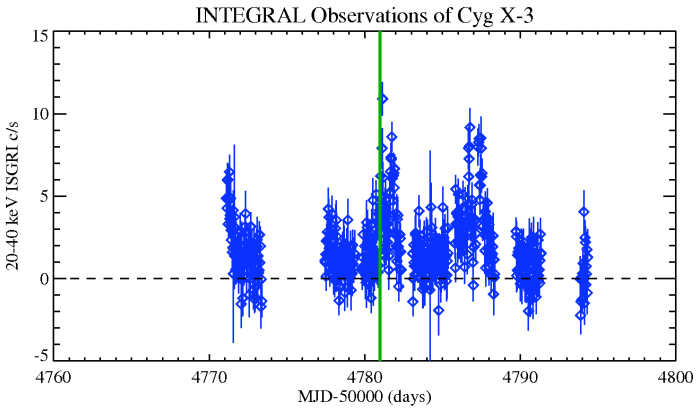


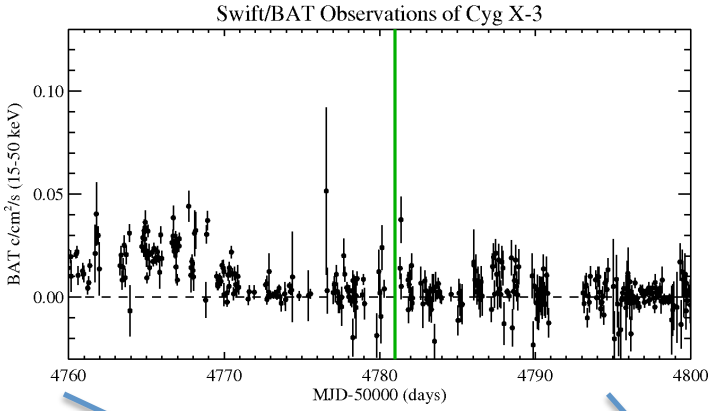


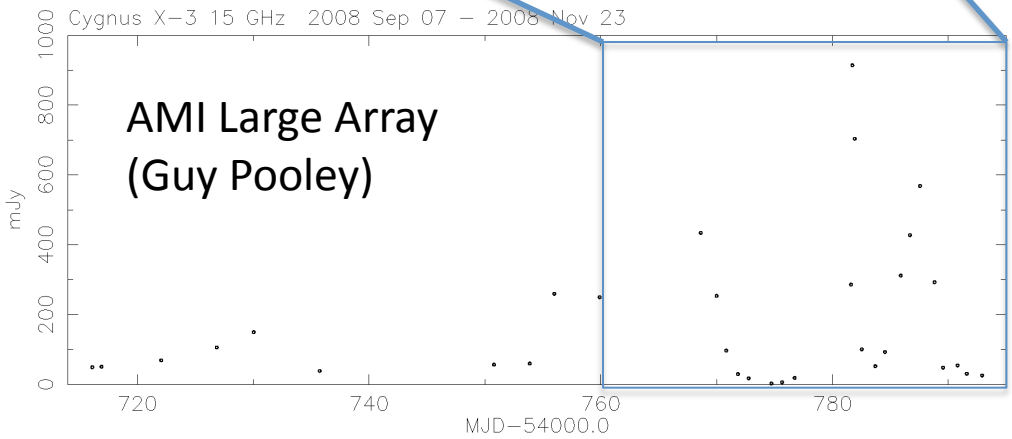




Szostek et al. (2008)







AMI Large Array
(Guy Pooley)

Summary: Role of INTEGRAL

- IGR J16207-5129: Discovery of new, extreme populations
- H 1743-322: Improving temporal coverage of black hole outbursts
- Cyg X-3: Extending X-ray/radio correlation studies to higher energy