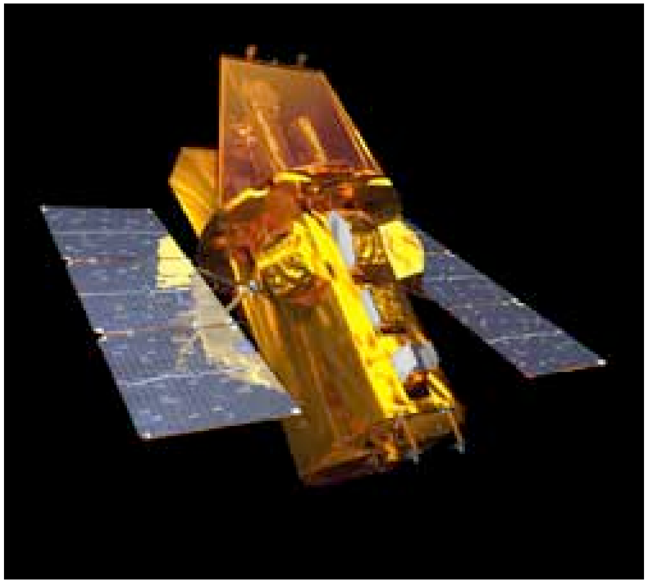
INTEGRAL and Swift



An Opportunity to Use Wisely: Coordination is the Key

Jack Tueller
SWIFT/BAT Survey Lead

INTEGRAL & SWIFT Together

- XRT/UVOT follow up of INTEGRAL sources
  - more accurate positions for counterpart ID
  - X-ray absorption and variability measurements
  - UV photometry
- BAT extended hard X-ray monitoring
- Coordination of Survey Activities

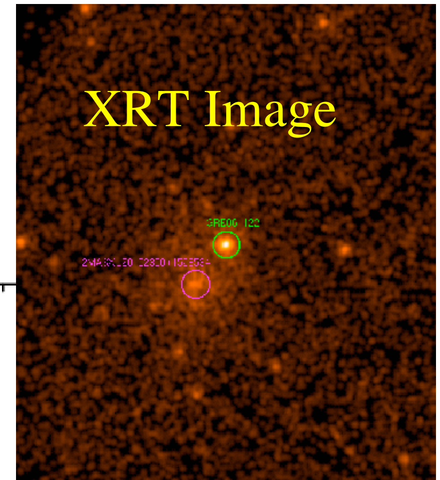
INTEGRAL GRBs Detected by XRT

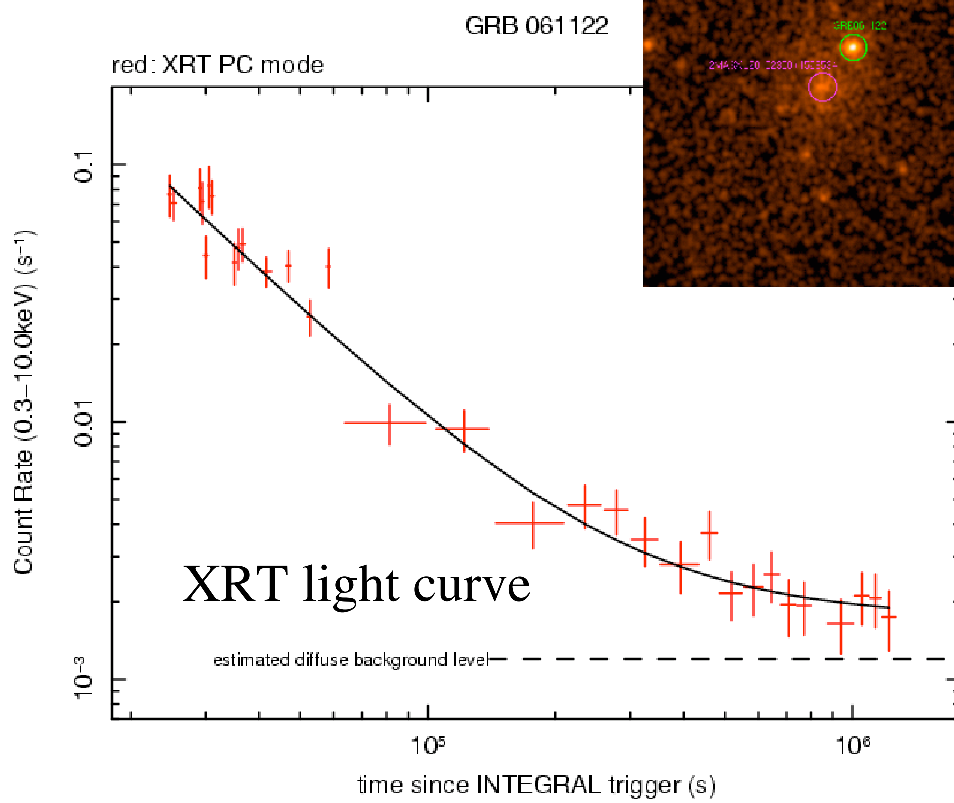
INTEGRAL can measure Epeak>100 keV

XRT gives position for optical spectroscopy

GRB 061122

- GRB 070615
- GRB 070311
- GRB 070309
- GRB 061122
- GRB 061025
- GRB 060901
- GRB 051211B
- GRB 050714A
- GRB 050522
- GRB 050520
- GRB 050504





INTEGRAL & Swift in the Abstract

ADS citations in 2006 and 2007 only:

- 123 citations with Swift and INTEGRAL in the abstract
  - 24 GRB
  - 99 other sources
- >431 different authors

INTEGRAL - Swift Collaborations

Bassani et al.	Swift observations of unidentified IBIS galactic sources
Soldi et al.	Swift observations of INTEGRAL superfast transients
Beckmann et al.	Joint work on IBIS and BAT AGN surveys

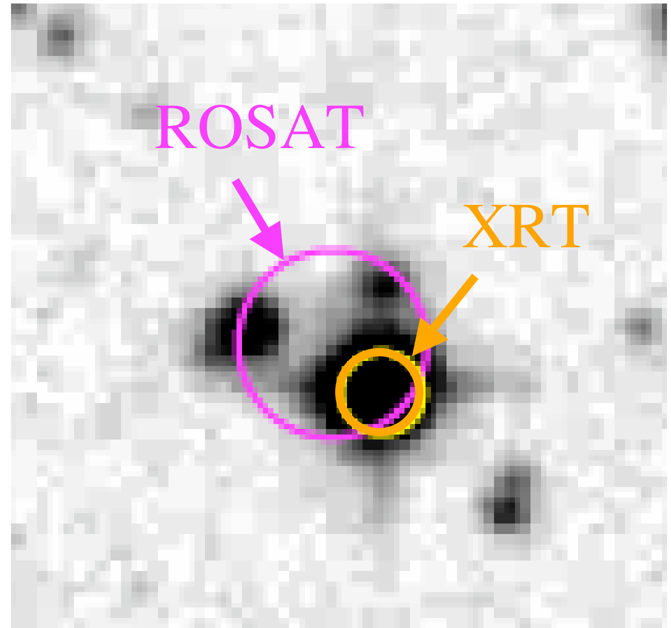
Aharonian, F.; Ajello, M.; Akerlof, Carl W.; Akhperjanian, A. G.; Akimov, V.; Albert, J.; Aliu, E.; Amoros, C.; Anderhub, H.; Antonelli, Angelo; Antonelli, L. A.; Antoranz, P.; Aoki, K.; Arefiev, V.; Armada, A.; Armus, Lee; Avila-Reese, V.; Bad'in, D.; Bailyn, C.; Baixeras, C.; Ballet, J.; Balman, S.; Band, David L.; Bardoux, A.; Bardoux, A.; Barlow, E. J.; Barres de Almeida, U.; Barret, D.; Barrio, J. A.; Barthelmy, S. D.; Bartko, H.; Bartolini, C.; Bassani, L.; Bastieri, D.; Bazer-Bachi, A. R.; Bazzano, A.; Beardmore, A. P.; Becker, J. K.; Beckmann, V.; Behera, B.; Beilicke, M.; Bélanger, G.; Belloni, T.; Benbow, W.; Berg, M. Van Den; Bernardini, M. G.; Bernlöhr, K.; Beskin, G.; Bianchin, V.; Bianco, C. L.; Bikmaev, I. F.; Bird, A. J.; Biryukov, A.; Blanton, Michael R.; Blecha, A.; Bloemen, H.; Bode, M. F.; Boisson, C.; Bolz, O.; Brandt, S.; Briggs, Michael S.; Brinkmann, J.; Buckley, D.; Budtz-Jorgensen, C.; Burenin, R. A.; Burrows, D. N.; Butler, N. R.; Bykov, A. M.; Caballero-Garcia, M. D.; Cabrera, J. I.; Caccianiga, A.; Cadolle Bel, M.; Caito, L.; Campana, R.; Campana, S.; Capitanio, F.; Caraveo, P. A.; Carrier, F.; Carruba, V.; Carter, D.; Castillo Carrión, S.; Castro-Tirado, A. J.; Cellone, S. A.; Chardonnet, P.; Charles, P. A.; Charmandaris, Vassilis; Chaty, S.; Chen, Y.; Chen, Yan-Mei; Chenevez, J.; Cherix, M.; Chester, M.; Chincarini, G.; Churazov, E.; Clark, D. J.; Clarke, Fraser; Cohn, H.; Comastri, A.; Cominsky, L.; Cool, Richard J.; Corbel, S.; Courvoisier, T. J.-L.; Covino, S.; Crampton, D.; Cucchiara, A.; Cucchira, A.; Cummings, J.; Cunniffe, R.; Cusumano, G.; Dainotti, M. G.; D'Avanzo, P.; Davies, R. L.; de Luca, A.; de Martino, Domitilla; de Rosa, A.; de Ugarte Postigo, A.; Dean, A. J.; Debaes, C.; Decourchelle, A.; Degenaar, N.; Della Ceca, R.; Della Valle, M.; den Hartog, P. R.; Dermer, Charles D.; Desmet, L.; Devost, Daniel; Di Cocco, G.; Diaz Trigo, M.; Dib, R.; Domingo, A.; Dubner, G. M.; Durant, M.; Ebisawa, K.; Eckert, Dominique; Ehanno, M.; Eisenstein, Daniel J.; Esposito, P.; Evans, P. A.; Falanga, M.; Falcone, A. D.; Farinelli, R.; Ferrigno, C.; Filliatre, P.; Fiocchi, M. T.; Fiore, F.; Firmani, C.; Foley, S.; Forrest, Bill; Foschini, L.; Fraschetti, F.; Fraser, S. N.; Freeman, David; Frontera, F.; Fuchs, Y.; Furusawa, H.; Gehrels, N.; Gevin, O.; Ghirlanda, G.; Ghisellini, G.; Giacani, E. B.; Gianotti, F.; Gilfanov, M.; Gilli, R.; Gillies, Kim; Giommi, P.; Giovanna Dainotti, M.; Giroletti, M.; Gliozzi, M.; Godet, O.; Goldoni, P.; Goldwurm, A.; Gomboc, A.; Gomez, V.; Goodsall, Timothy; Gorosabel, J.; Gotthelf, E. V.; Gotz, D.; Gotz, D.; Gotz, D.; Götz, D.; Götz, D.; Grazia Bernardini, M.; Grebenev, S. A.; Greco, G.; Greiner, J.; Grindlay, J.; Grindlay, J.; Guarnieri, A.; Guida, R.; Guida, Roberto; Guidorzi, C.; Hanlon, L.; Hannikainen, D. C.; Hasinger, G.; Hasinger, Guenther; Hasuike, K.; Hermsen, W.; Hill, A. B.; Hogg, David W.; Holland, S. T.; Hong, J.; Hong., J. ; Horns, D.; Hu, Chen; Hurley, Kevin C.; Immler, S.; Ishii, Y.; Ishioka, R.; Israel, G. L.; Jelínek, M.; Jiang, L. H.; Jiang, P.; Kaastra, J.; Kallman, Tim; Kanbach, G.; Kaneko, Yuki; Karpov, S.; Kaspi, V. M.; Kawai, N.; Kennea, J. A.; King, A. R.; Klein-Wolt, M.; Klochkov, D.; Koenig, X.; Krajewski, R.; Krassilchtchikov, A. M.; Kretschmar, P.; Kreykenbohm, I.; Kubánek, P.; Kuiper, L.; Kumakhov, M.; Kuulkers, E.; La Barbera, A.; Lacombe, K.; Landi, R.; Lapshov, I.; Laurent, P.; Laycock, S; Lazos, M.; Lazzaro, D.; Le Floc'h, Emeric; Lebrun, F.; Levan, A. J.; Levin, V.; Leyder, J.-C.; Li, T. P.; Limousin, O.; Lu, F. J.; Lubinski, P.; Lugger, P.; Lugiez, F.; Lugiez, F.; Lund, N.; Lutovinov, A. A.; Lynn, J.; Lyons, N.; Maitra, D.; Malaguti, P.; Malesani, D.; Malizia, A.; Malzac, J.; Mangano, V.; Mangano, V.; Maraschi, L.; Markwardt, C. B.; Masetti, N.; Mateo Sanguino, T. J.; Mattana, F.; McBreen, B.; McGlynn, S.; Meegan, C. A.; Mereghetti, S.; Mescheryakov, A.; Michtchenko, T. A.; Miller, J. M.; Mineo, T.; Minniti, D.; Mirabel, Felix; Molina, M.; Molkov, S. V.; Monfardini, A.; Moretti, A.; Morris, D.; Mottram, C. J.; Mowlavi, N.; Mueller, Andreas; Mukai, Koji; Mundell, C. G.; Mushotzky, R.; Nava, L.; Nousek, J.; O'Brien, P. T.; Ohta, K.; Osborne, J.; Ottevaere, H.; Oxborrow, C. A.; Paciesas, William S.; Page, K. L.; Paizis, A.; Palazzi, E.; Paltani, S.; Pandey, S. B.; Panessa, F.; Pavlinsky, M.; Pavlov, G. G.; Penquer, A.; Pereira, D.; Perri, M.; Petry, D.; Pian, E.; Piccioni, A.; Piconcelli, E.; Plait, P.; Pons, R.; Potter, S.; Preece, R.; Pretorius, M. L.; Produit, N.; Racusin, J.; Rau, A.; Rea, N.; Renaud, M.; Revnivtsev, M. G.; Ribo, M.; Rich, R. M.; Risquez, D.; Riva, A.; Rodriguez, J.; Romano, P.; Romero, G. E.; Roming, P.; Roth, Katherine; Rouaix, G.; Ruffini, R.; Sala, G.; Salvato, M.; Sambruna, R. M.; Sanchez-Fernandez, C.; Santangelo, A.; Santo, M. Del; Sato, G.; Saz Parkinson, P. M.; Sazonov, S. Yu.; Schanne, S.; Schiavone, F.; Schlegel, David J.; Schlegel, E. M.; Schneider, Donald P.; Segreto, A.; Sekiguchi, K.; Semena, N.; Senziani, F.; Severgnini, P.; Sguera, V.; Shaw, S. E.; Silva, S.; Simard, L.; Smith, R. J..; Soldi, S.; Song, L. M.; Stamatikos, M.; Stappers, B.; Starling, R.; Staubert, R.; Steele, I. A.; Stella, L.; Stephen, J. B.; Still, M.; Strong, A. W.; Sunyaev, R. A.; Swan, H. F.; Swank, J. H.; Symeonidis, Myrto; Tagliaferri, G.; Tarana, A.; Tavecchio, F.; Tecza, Matthias; Terrier, R.; Thatte, Niranjan; Tiengo, A.; Torii, K.; Tramacere, A.; Treister, E.; Trudolyubov, S.; Tsunemi, H.; Tueller, J.; Turolla, R.; Turolla, R.; Ubertini, P.; Ueda, Yoshihiro; Urry, C. M.; Uvarov, Yu. A.; van den Berg, M.; Van Erps, J.; Vanden Berk, Daniel E.; Vercellone, S.; Vergani, S. D.; Vervaeke, M.; Vignali, C.; Virani, S.; Vitek, S.; Volckaerts, B.; von Kienlin, A.; Vynck, P.; Walker, S.; Walter, R.; Wang, H. Y.; Wang, J. M.; Wang, J. X.; Westergaard, N. J.; Wijnands, R.; Williams, D. A.; Williams, O. R.; Willis, D.; Wu, B. B.; Wu, M.; Xue, S.-S.; Yamada, T.; Yang, Fang; Zane, S.; Zhang, S. N.; Zhao, P.; Zurita, J.

Swift TOOs for INTEGRAL Sources

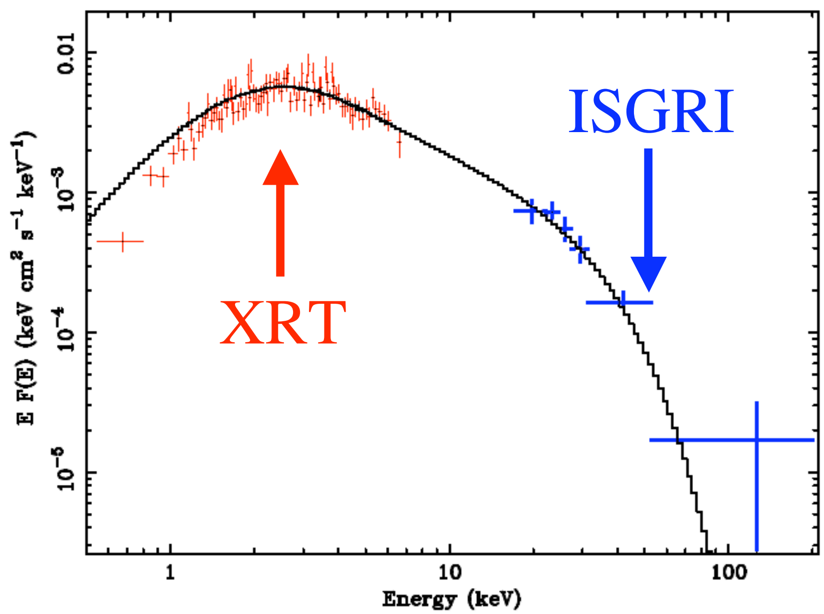
342	IGR 17098-3628 (BH candidate transient)	Capitanio	Jul 19, 2007
308	IGR J11215-5952 (supergiant XR tran.)	Soldi	Jun 1, 2007
280	IGR J17191-2821 (gal transient)	Klein-Walt	Apr 25, 2007
276	IGR J175585-2409 (HESS cntrpart?)	Kennea	Apr 23, 2007
244	IGR J17191-2821	Swank	Mar 6, 2007
227	IGR J17453-2853	Wijnands	Feb 16, 2007
197	IGRJ11215-5952 (Be tran, 330d per.)	Sidoli	Jan 4, 2007
117	IGR J20286+2544 (starburst of AGN?)	Basani	May 30, 2006
102	IGR J19140+0951 (HMXB, campaign)	Rodriguez	Apr. 20, 2006
096	IGR 2018+4043	Kennea	Mar. 23, 2006
095	IGR 1121.5-5956 (HMXB outburst)	Torres	Mar. 20, 2006
090	IGR J16403-4348	Kuiper	Mar. 9, 2006
083	IGR J14515-5542, J14493-5534	Kuiper	Feb. 28, 2006
071	IGR 1010.1-	Kuiper	Jan. 10, 2006
066	IGR J01583+6713 (transient)	Kennea	Dec. 12, 2005
047	IGR J1741.9-2802	Kennea	Oct. 3, 2005
028	IGR J12349-6434	Sokoloski	July 13, 2005
023	IGR17204-3554 (mol cloud)	Bazzano	July 4, 2005
007	IGR J17098-3628	Grebenev	April 12, 2005
006	IGR IJ16283-4838	Soldi	April 11, 2005

XRT/UVOT follow-up (IGR J16194-2810 SWIFT J1619.6-2807)

Masetti et al "Using the accurate X-ray position allowed by Swift/XRT data, we pinpointed the optical counterpart"



"the combined use of the spectral information afforded by XRT and INTEGRAL/IBIS shows that this source can be described with an absorbed Comptonization model"

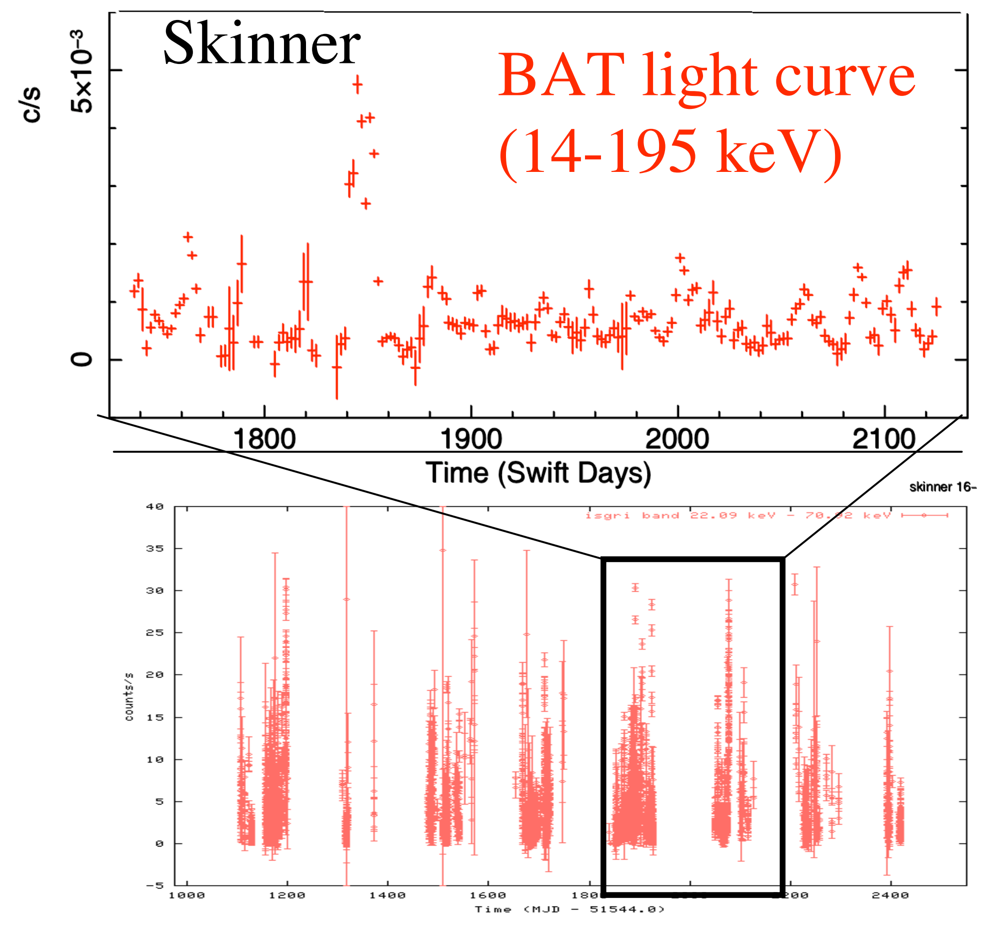


"a [rare] new symbiotic X-ray binary"

Swift for Monitoring Campaigns

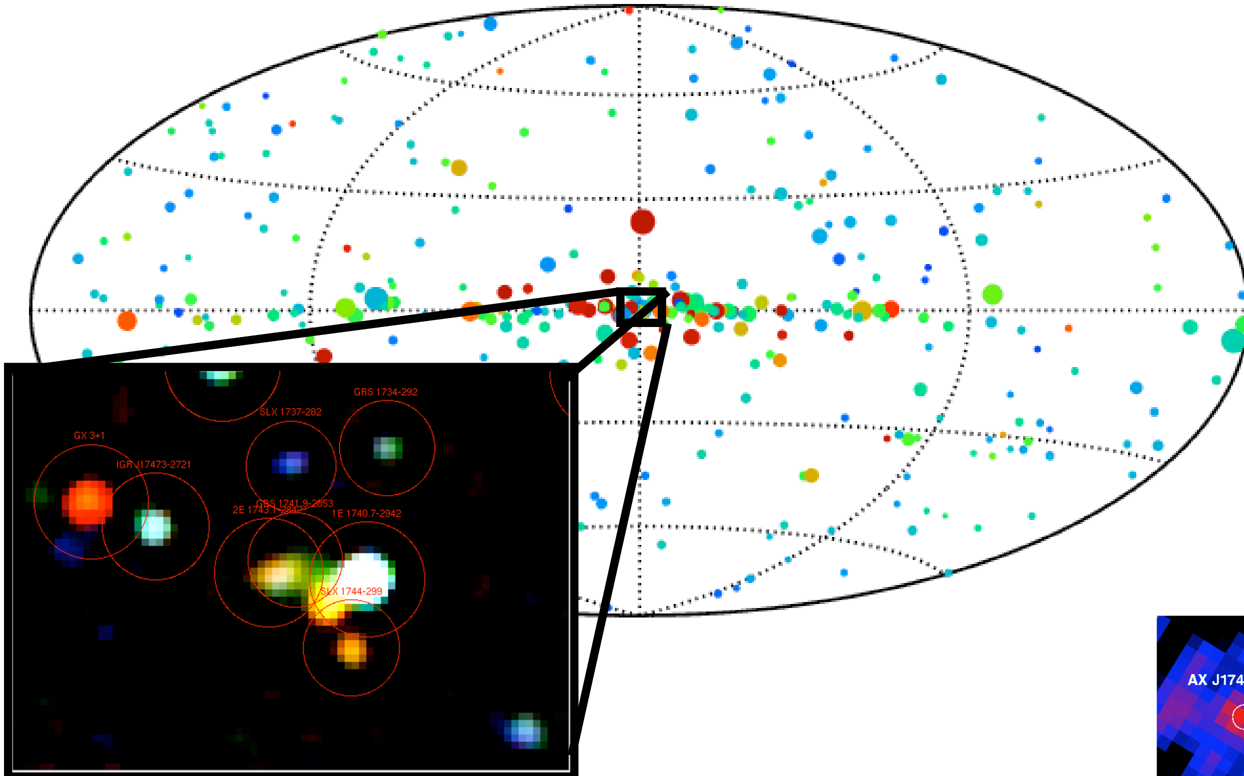
IGR J16318-4848 INTEGRAL highly absorbed source

- BAT can detect sources to ~8° from the Sun
- BAT can detect sources anywhere in the anti-Sun hemisphere
- BAT covers ~60% of the sky each day, so monitoring is free
- BAT automatically provides hard X-ray light curves with minimal gaps

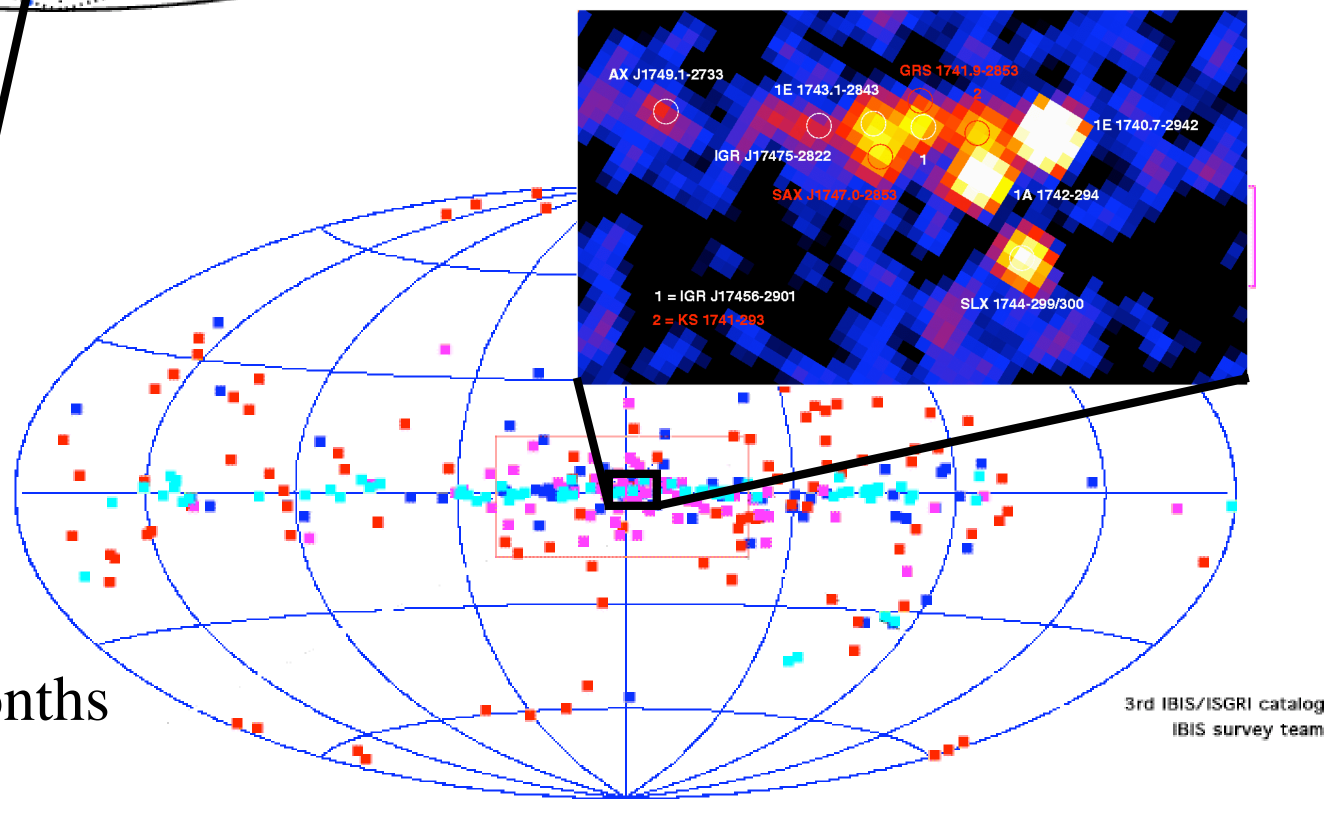


Walter et al, Matt&Guainazzi, Filliatre&Chaty, Lutovinov et al, Ibarra et al

Swift and INTEGRAL Surveys



SWIFT at 9 Months
~150 AGN and
~150 Galactic
Markwardt et al,
Tueller et al

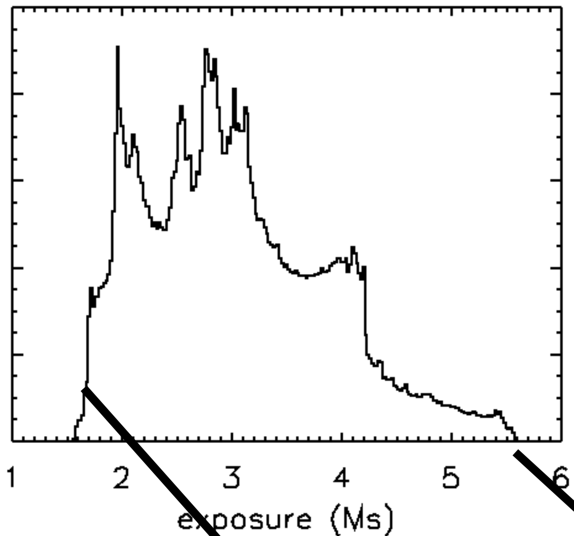


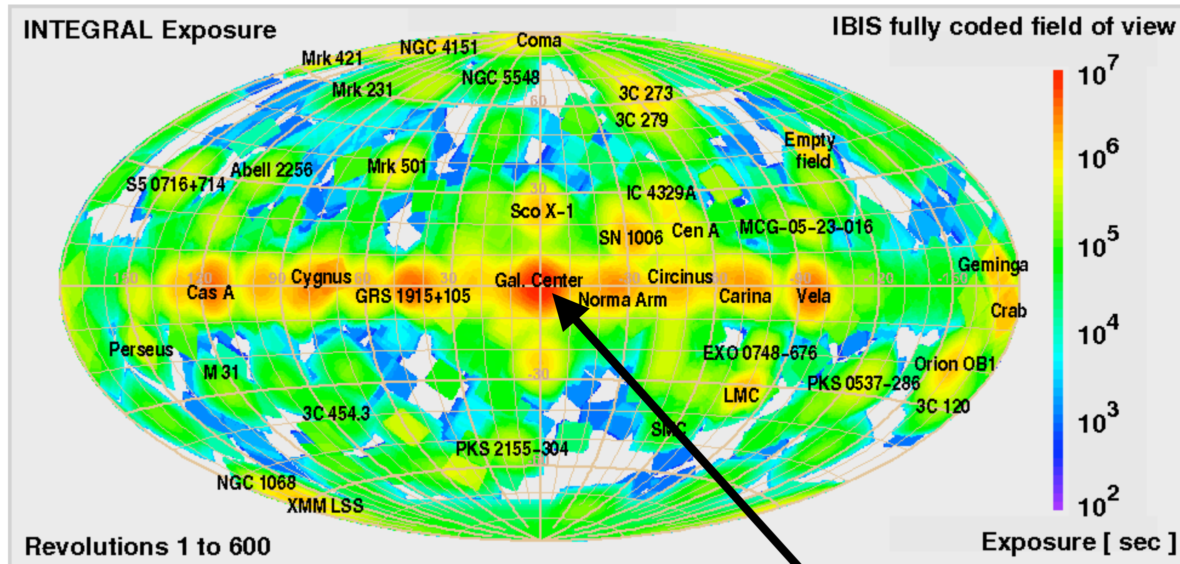
INTEGRAL at 42 months
421 sources Bird et al

BAT and ISGRI Surveys

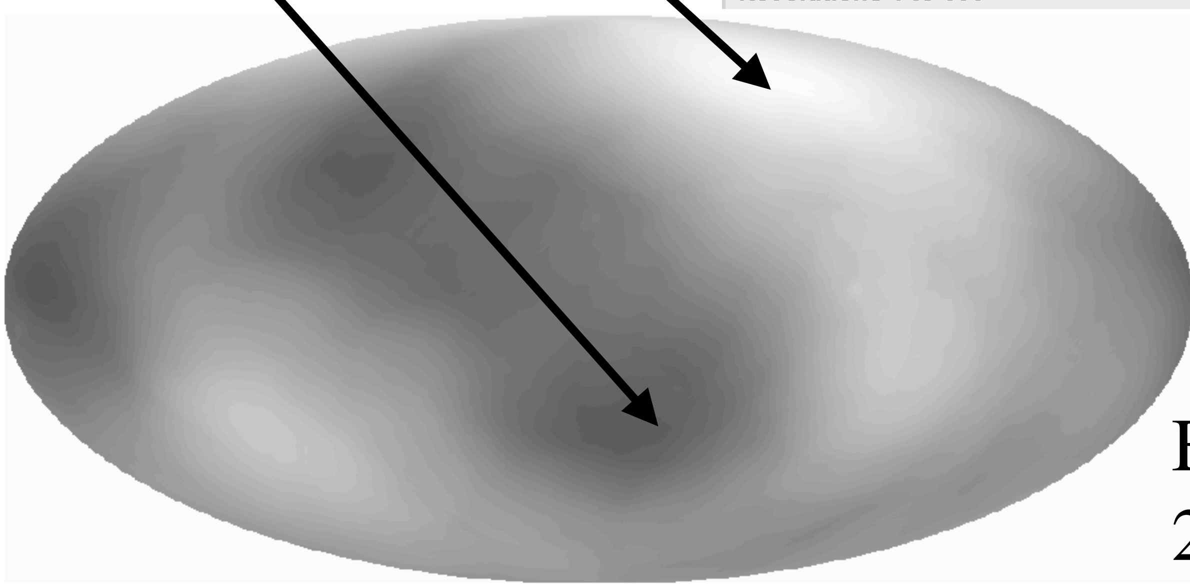
	Swift/BAT	Integral/ISGRI
Energy Range	14 - 195 keV	15 keV - 10 MeV
Area	5200 cm^2	2600 cm^2
Field of View	2 Steradian Partially Coded	0.24 Steradian Partially coded
Equivalent Fully Coded Exposure	~1-2 Ms/year (all sky)	>10Ms for selected fields
Background	~7000 count/s	~700 counts/s
Sensitivity	few X 10^{-11} ergs cm^{-2} at 9 months	few X 10^{-12} ergs cm^{-2}
Observing Strategy	Random following GRB's	Selected Pointings

Swift/BAT and INTEGRAL Exposure



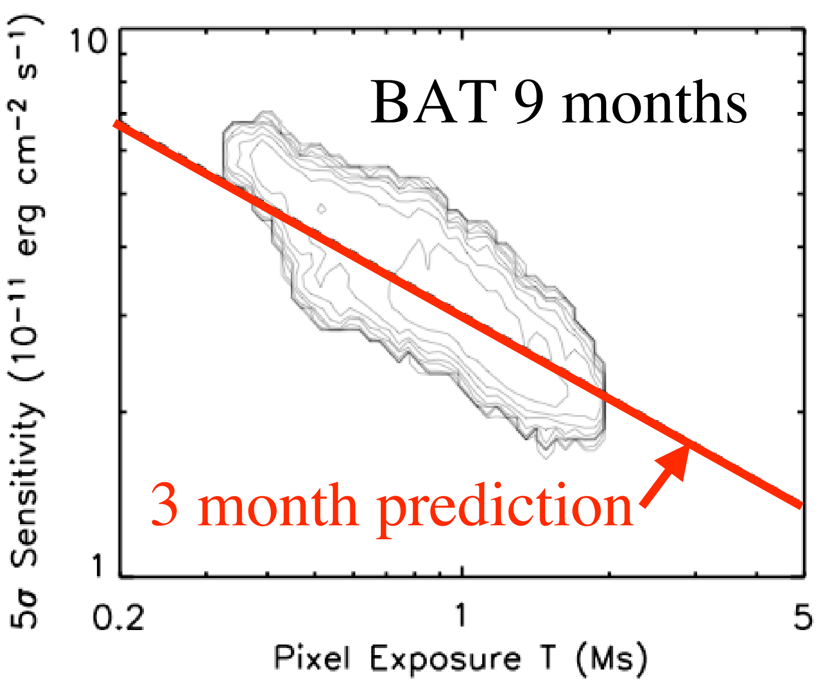


Integral exposures to $>10^7$ s

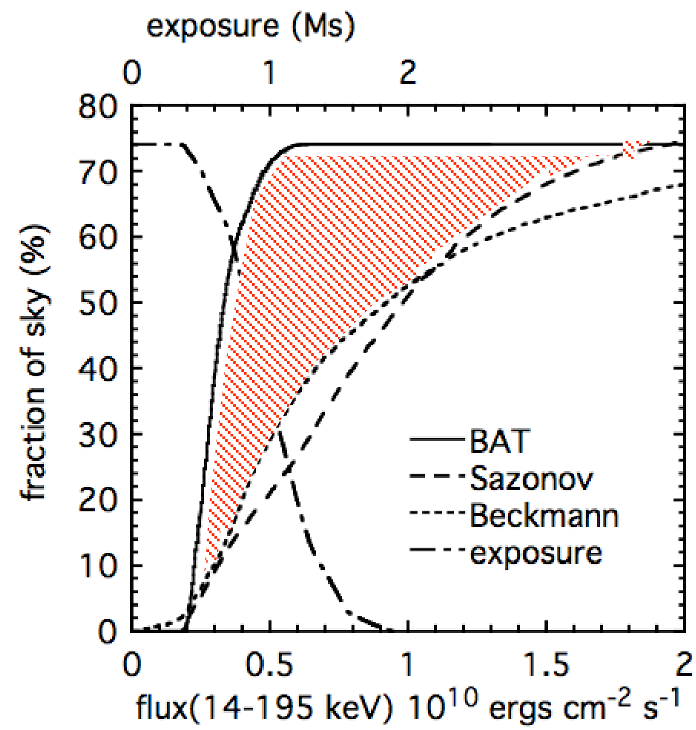


BAT Exposure (all sky)
2-4 10^6 s/22 months

Swift/BAT Exposure & Sensitivity

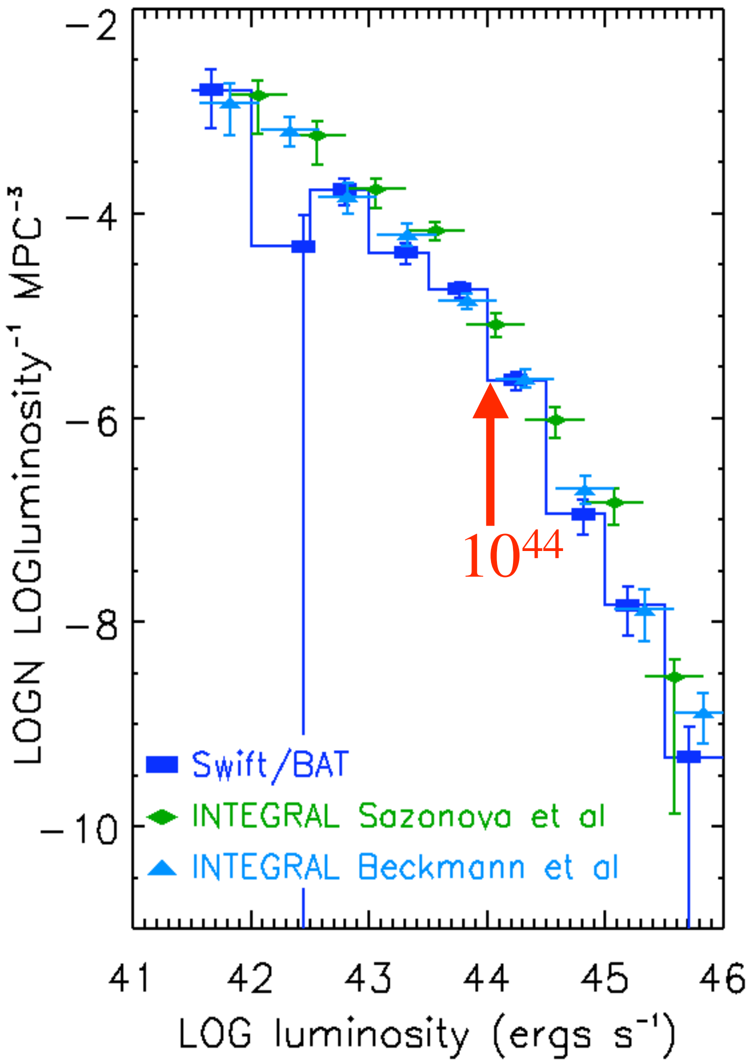


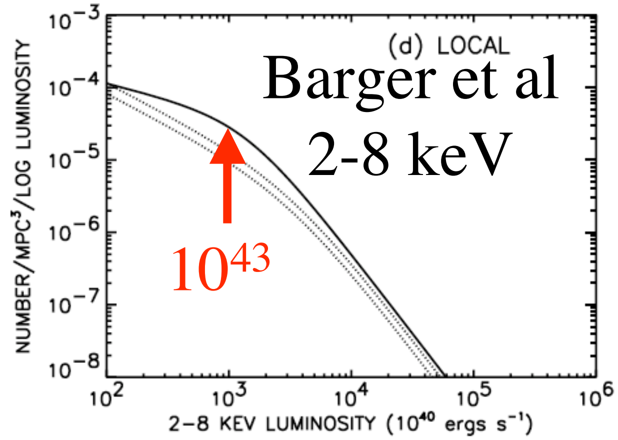
BAT sensitivity improves as $t^{1/2}$



BAT at 9 months vs INTEGRAL at 36

Swift/BAT and INTEGRAL Luminosity Functions



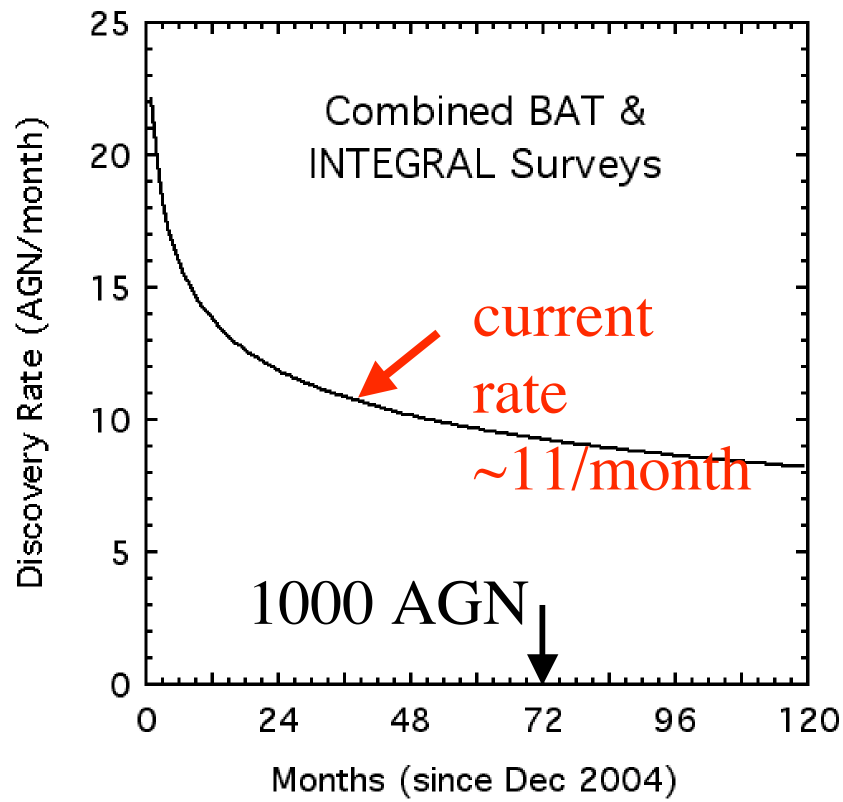


Chandra X-ray Luminosity Function

- Swift/BAT and INTEGRAL (Beckmann et al and Sazanov et al) luminosity functions are in good agreement (scaled to 14-200 keV)
- The break luminosity is 5X higher than in X–ray luminosity function (scaled to 14-200 keV)
- Confirmed by BAT and INTEGRAL

AGN in the BAT and ISGRI Surveys

- Similar in design and performance
- ISGRI ~2 X faster than BAT
- BAT has more sky coverage
- BAT AGN discovery rate is ~4X ISGRI
- ISGRI exposures of a few X 10^7s should be 6X more sensitive than BAT and detect ~45 AGN with no evolution or ~90 AGN with evolution



Evolution of $(1+z)^4$ and median redshift of 0.125 yields 1.6 X more luminous

Evolution in BAT and INTEGRAL

Swift/BAT at 3 years >15° from the plane (74%)

	w/o evolution	with evolution	Significance (σ)
mean counts	389.57±20.56	565.83±22.78	5.74
mean redshift	0.038±0.002	0.089±0.007	7.47
log mean luminosity	44.71± 0.06	46.44± 0.10	15.07

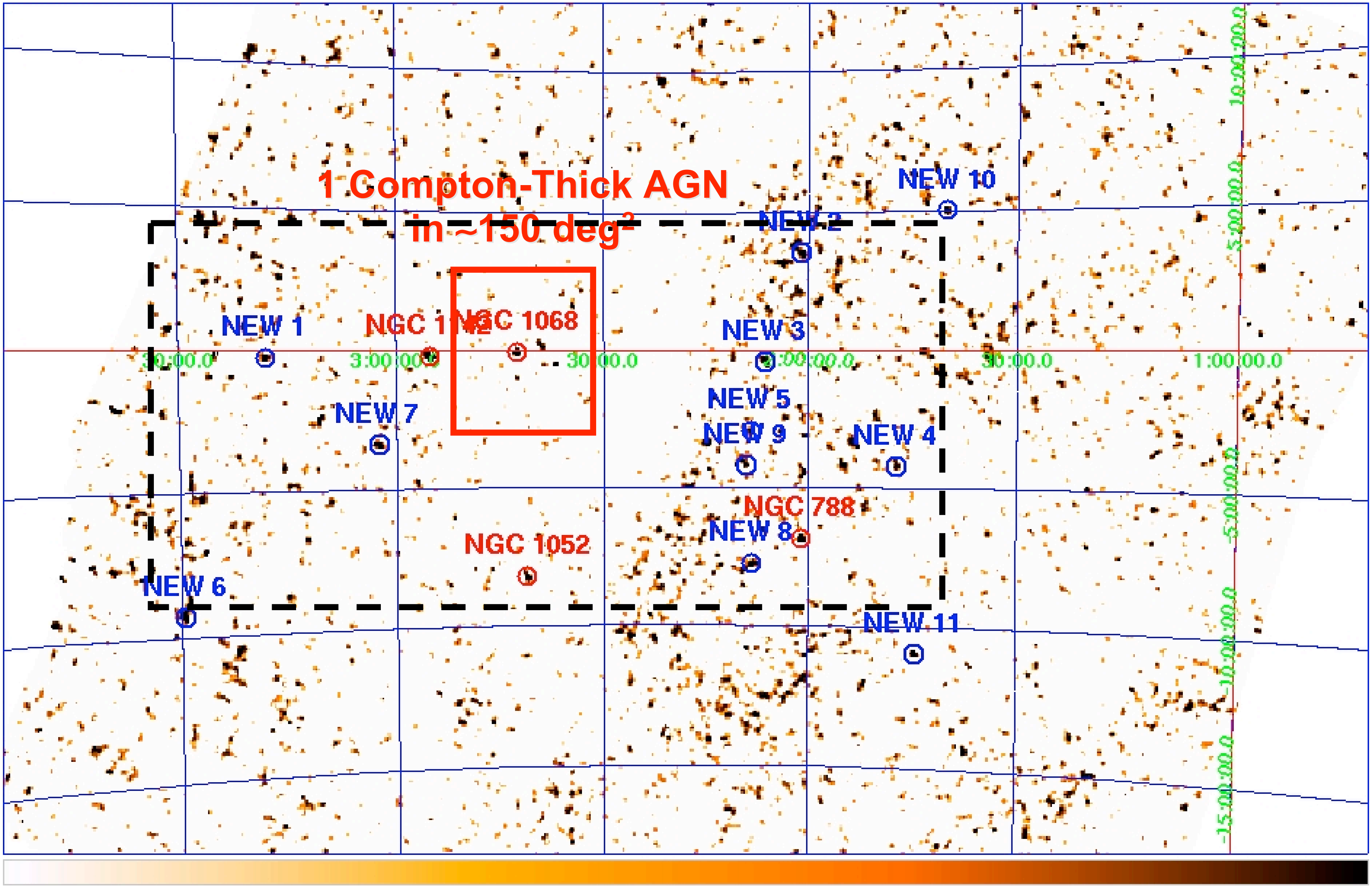
Only wide field hard X-ray surveys can detect the final stages of evolution.

Evolution Detected!

	w/o evolution	with evolution	Significance (σ)
mean counts	48.80± 6.38	111.51±10.47	5.11
mean redshift	0.071±0.010	0.207±0.022	5.68
log mean luminosity	45.14± 0.12	46.92± 0.12	10.40

Luminosity evolution $(1+z)^4$ Barger et al Chandra deep field
RMS errors calculated from Monte Carlo simulations.

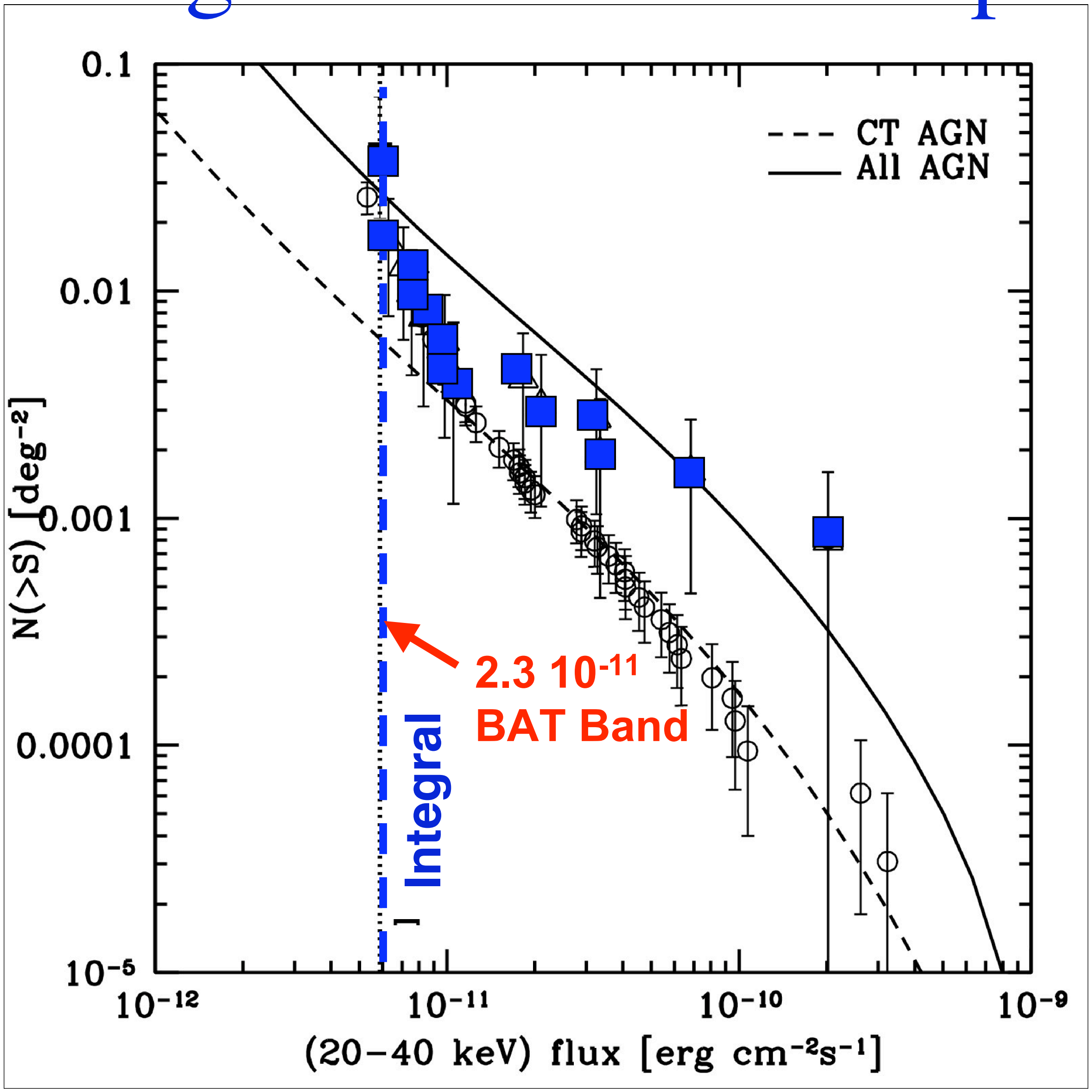
Deep Integral Survey of the Greater XMM-LSS region



1 Msec Integral (300 ksec of our 2 Msec)

www.stsci.edu/.../streaming/archive/SpringSymposium2007/ Meg**Urry**042407Hi_supporting/Meg**Urry**042407.ppt

LogN LogS INTEGRAL deep field



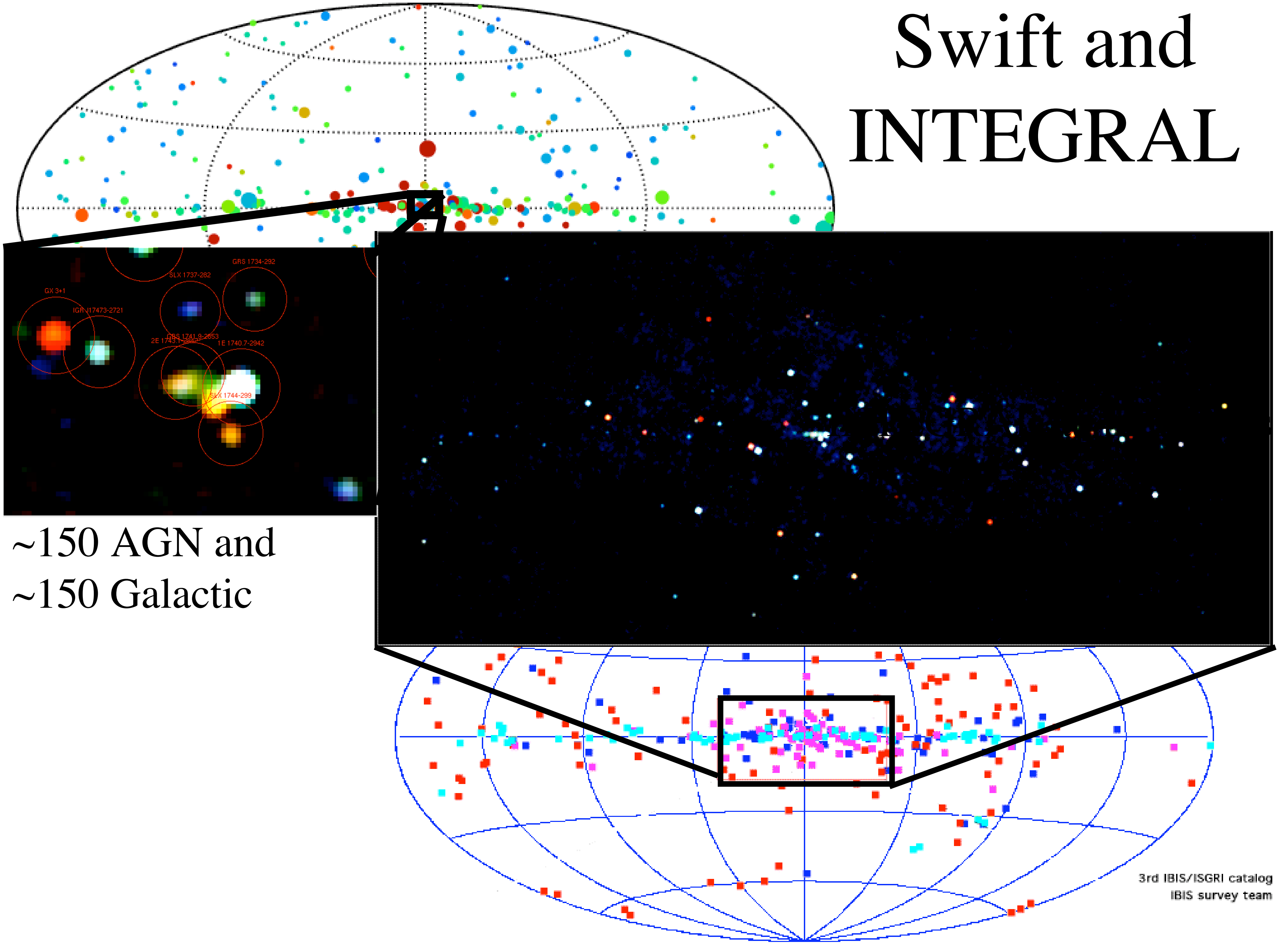
Treister et al. (2007)

www.stsci.edu/.../streaming/archive/SpringSymposium2007/ Meg**Urry**042407Hi_supporting/Meg**Urry**042407.ppt

Conclusions

- Continued follow up of IGR sources with XRT will yield more great science.
- Observations should take advantage of the strengths of each mission
  - Very deep fields for INTEGRAL AGN can detect AGN evolution!
  - Shallow all-sky survey is best done with BAT.
  - Monitoring Campaigns should make full use of BAT and XRT.
- Coming soon GLAST, NuSTAR, NEXT, SIMBOL-X
- INTEGRAL and Swift have a bright future of cooperation.

Swift and INTEGRAL



~150 AGN and
~150 Galactic