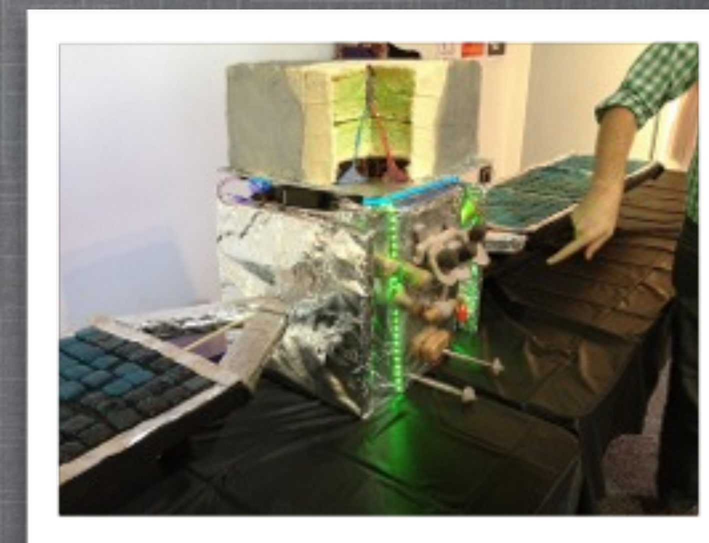
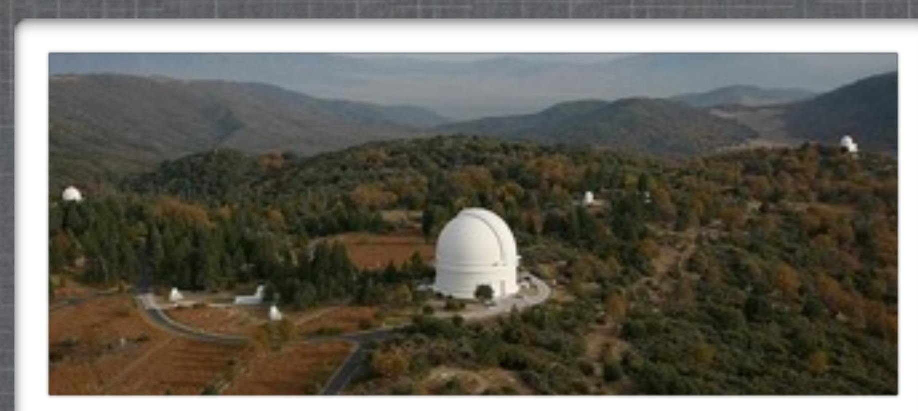
iPTF + *FERMI*: "BUY FOR A DOLLAR, SELL FOR TWO"

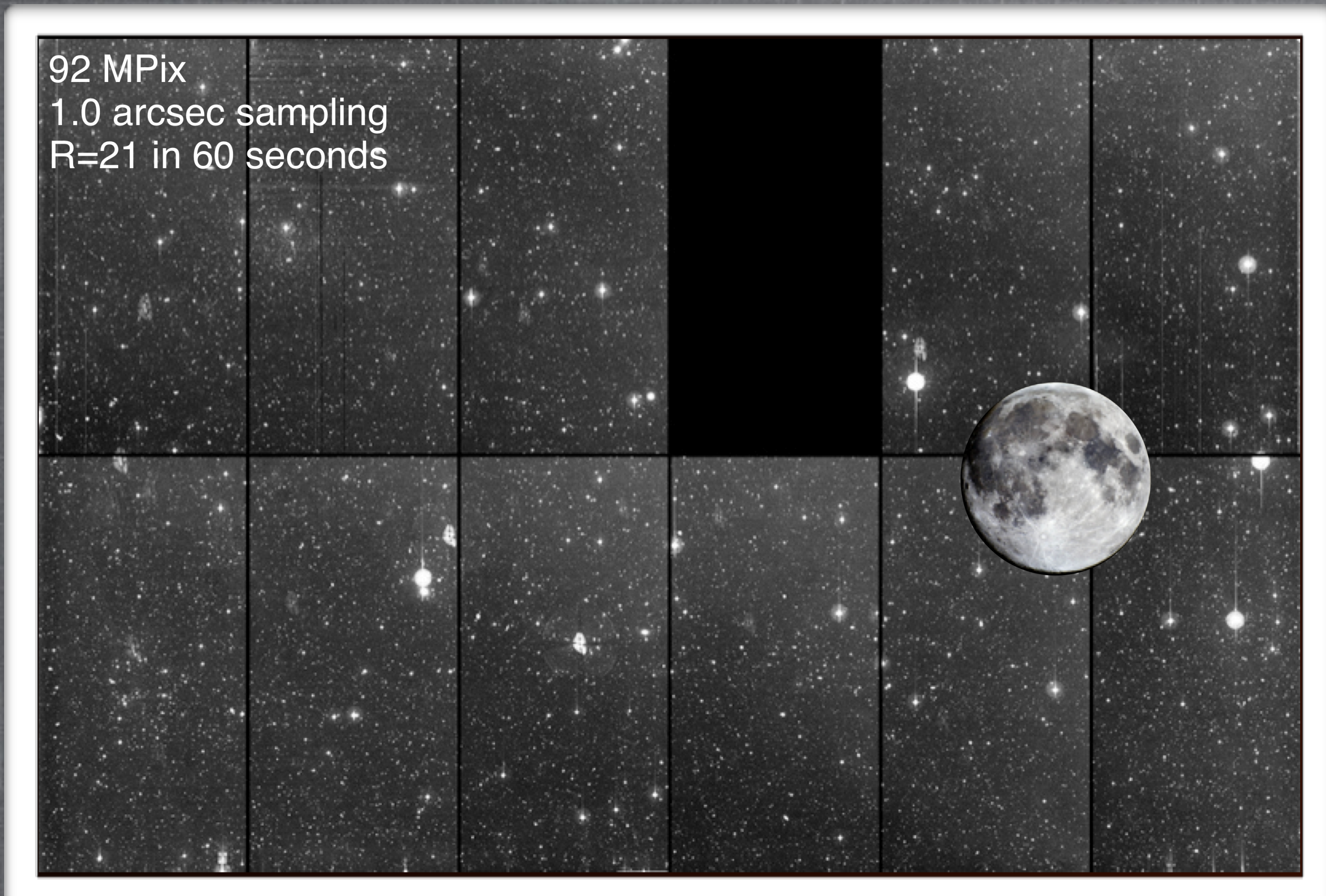


Gamma-Ray Bursts
Supernovae
Blazars
Pulsars
X-ray Binaries



NEW WIDE-FIELD CAPABILITIES

The Palomar Transient Factory (PTF), et al.



Over 2100 spectroscopically confirmed supernovae to date

- Palomar 48 inch Schmidt telescope + CFHT12k ⇒ 7.2 deg^2 field-of-view
- Supernova search (2-3 day cadence) + more regular monitoring of nearby galaxies
- Automated discovery + multi-color photometry (P60)
- Large spectroscopic follow-up programs (Keck, Gemini, P200, Lick, etc.)

PALOMAR TRANSIENT FACTORY

Wide-Field Discovery + Automated Multi-Color Follow-Up

Summit of Palomar Mountain

P48 = Discovery

P200+Keck+Lick+Gemini = Spectroscopy

P60+PAIRITEL = Filtered Photometry

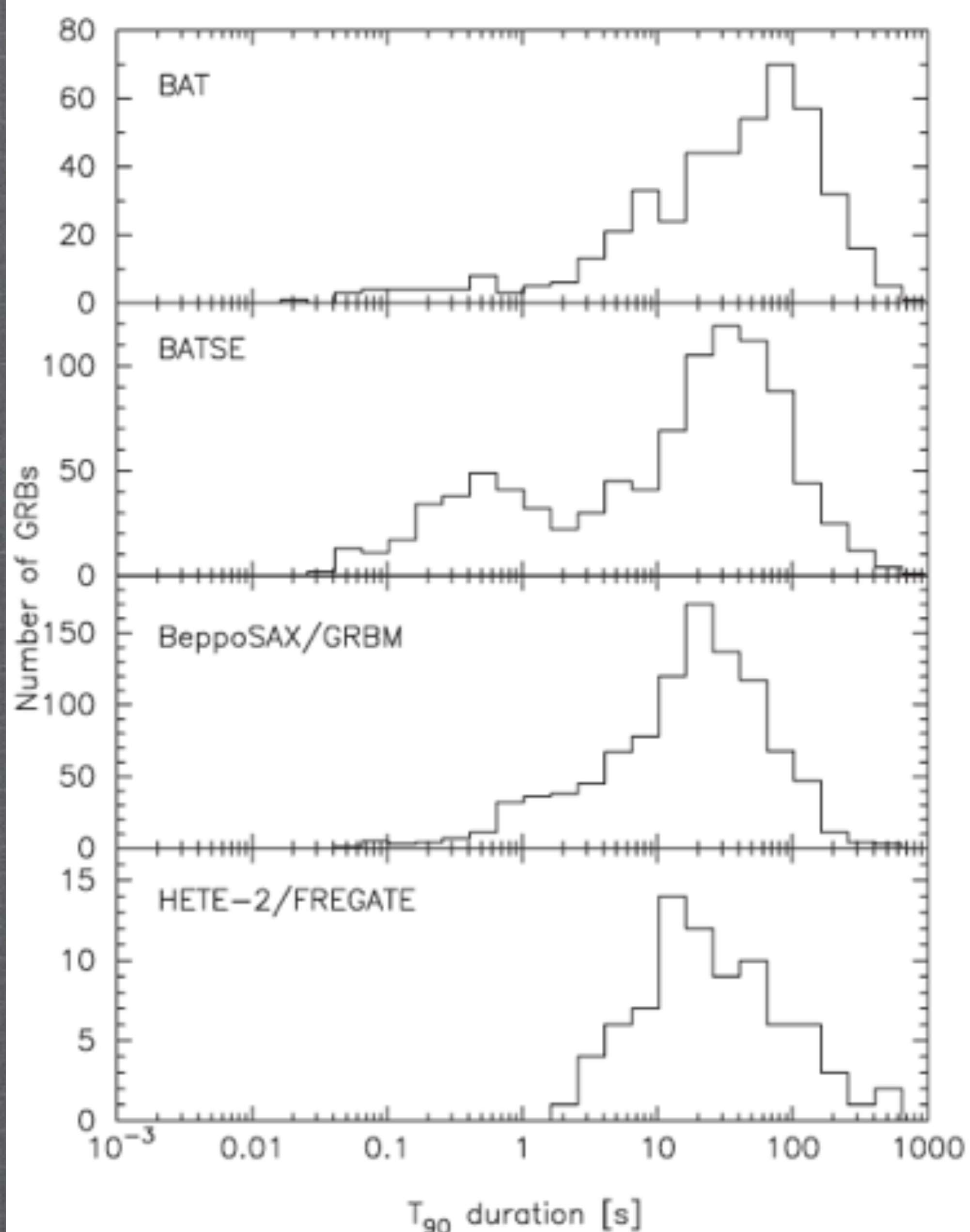
Factory = Fully automated, end-to-end discovery + follow-up

JOINT iPTF+*FERMI* INVESTIGATIONS

- GBM Afterglow Discovery
- Unidentified LAT Source identification (short-period pulsars)
- “New Relativistic Explosions”

GBM+PTF MOTIVATIONS

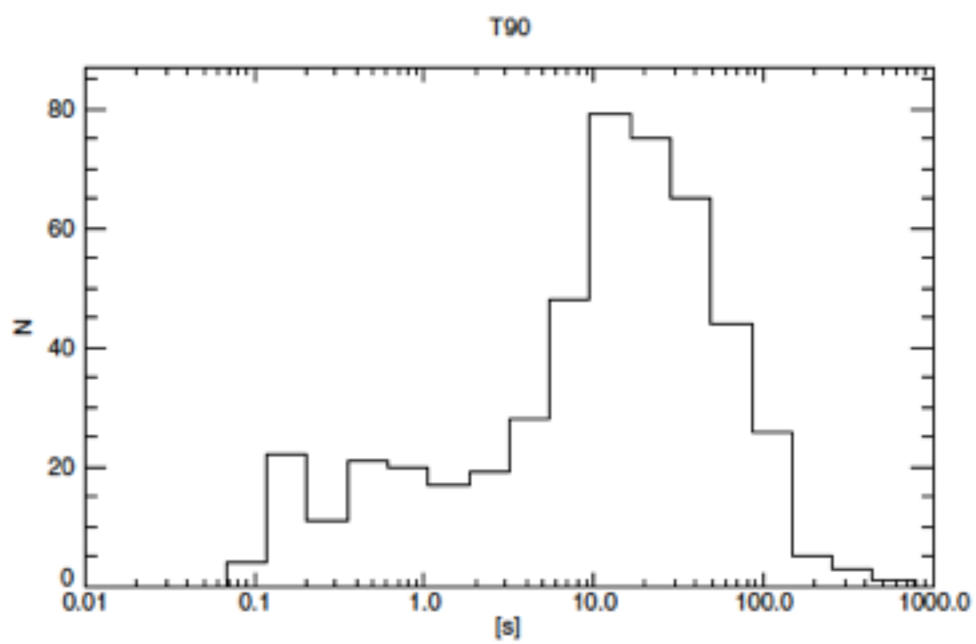
Swift BAT, 2004–2009, 476 GRBs



Sakamoto et al. (2011, ApJS 195:2)

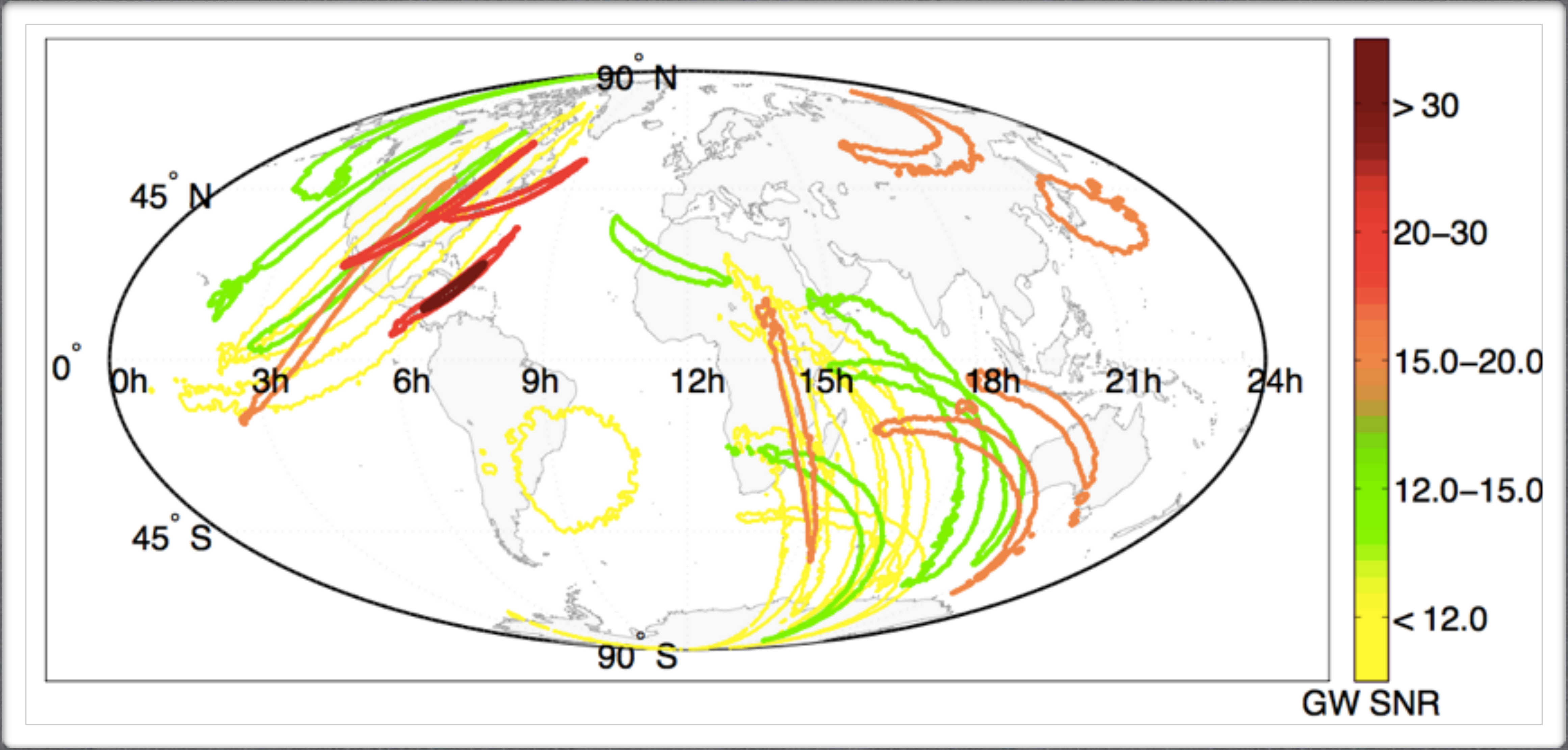
Fermi detects **more, shorter,** and **harder** GRBs than *Swift*.

Fermi GBM, 2008–2010, 491 GRBs



Paciesas et al. (2012, ApJS 199:18)

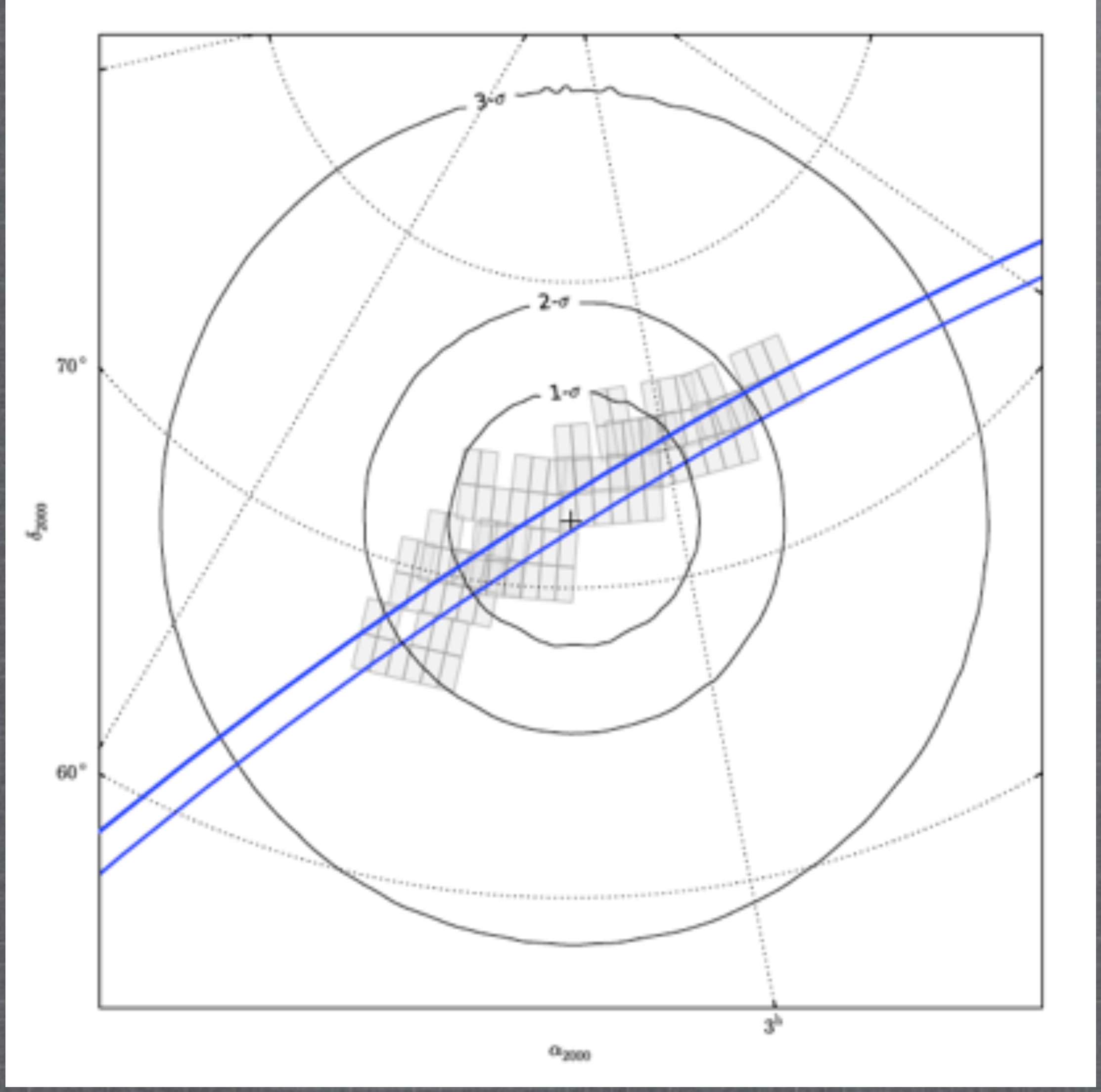
GBM+PTF MOTIVATIONS



Kasliwal & Nissanke, 2013

Predicted electromagnetic signatures are faint, rapidly fading, and these sources will be very poorly localized

GBM+PTF LOGISTICS



- Receive Human-in-the-loop (HITL) localizations (time delay ~ 1 hour)
- Scaled confidence intervals (now use refined localization contours)
- Limited to 10 fields (71 deg), ~ 1-2 triggers per month
- Focus on bright events (fluence, peak count rate) and short-hard GRBs
- Run through full iPTF machinery

GBM+PTF LOGISTICS

27,004 transient/variable candidates found by real-time iPTF analysis

26,960 not known minor planets

2740 sources without SDSS detections brighter than r'=21

43 sources detected in both P48 visits, presented to human scanners

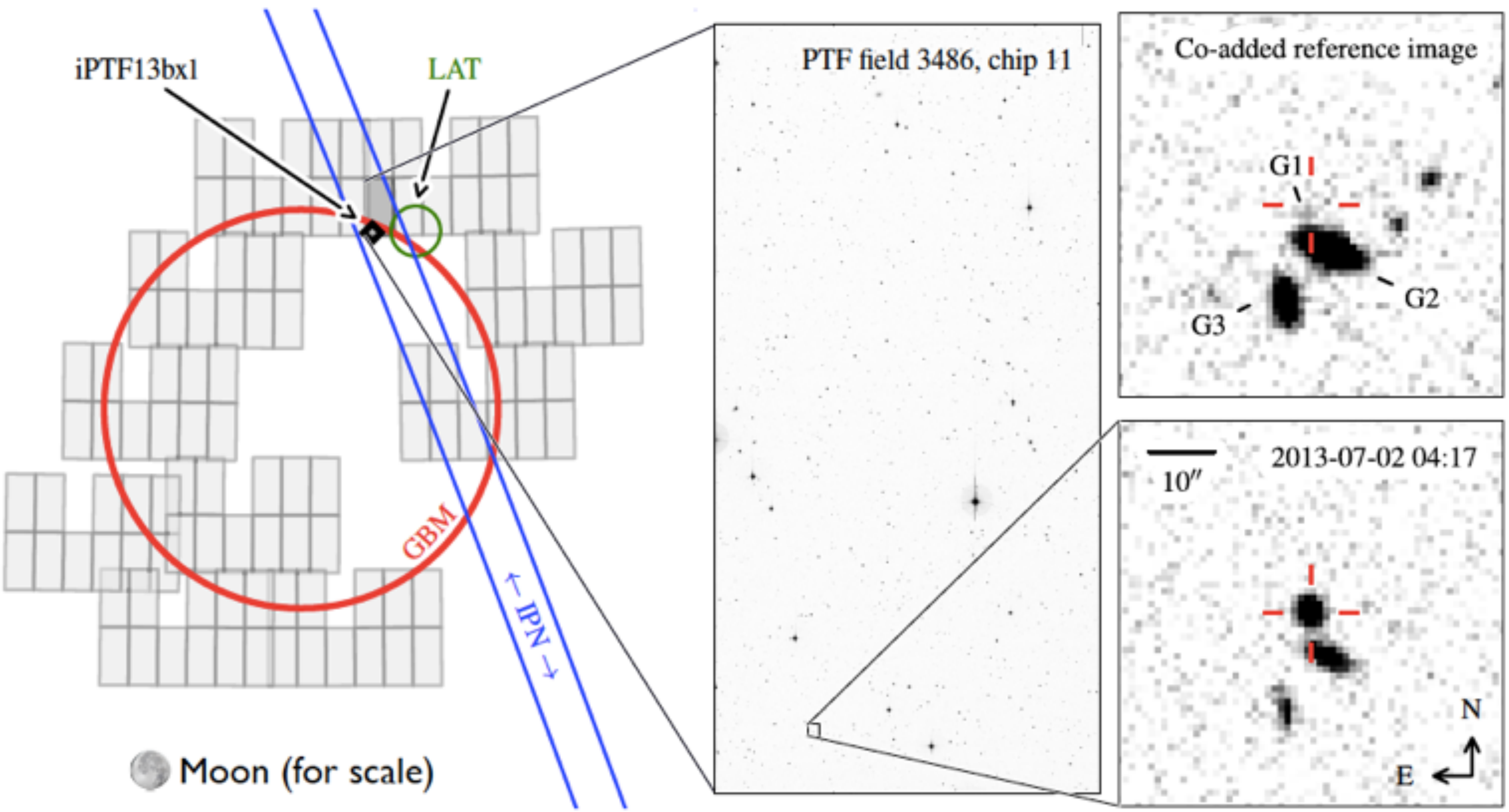
7 sources saved by humans

3 afterglow-like candidates scheduled for follow-up

GBM+PTF SUCCESSES

(Almost exactly) one year after IPN GRB:

Discovery & redshift of a GBM GRB in 71 deg²

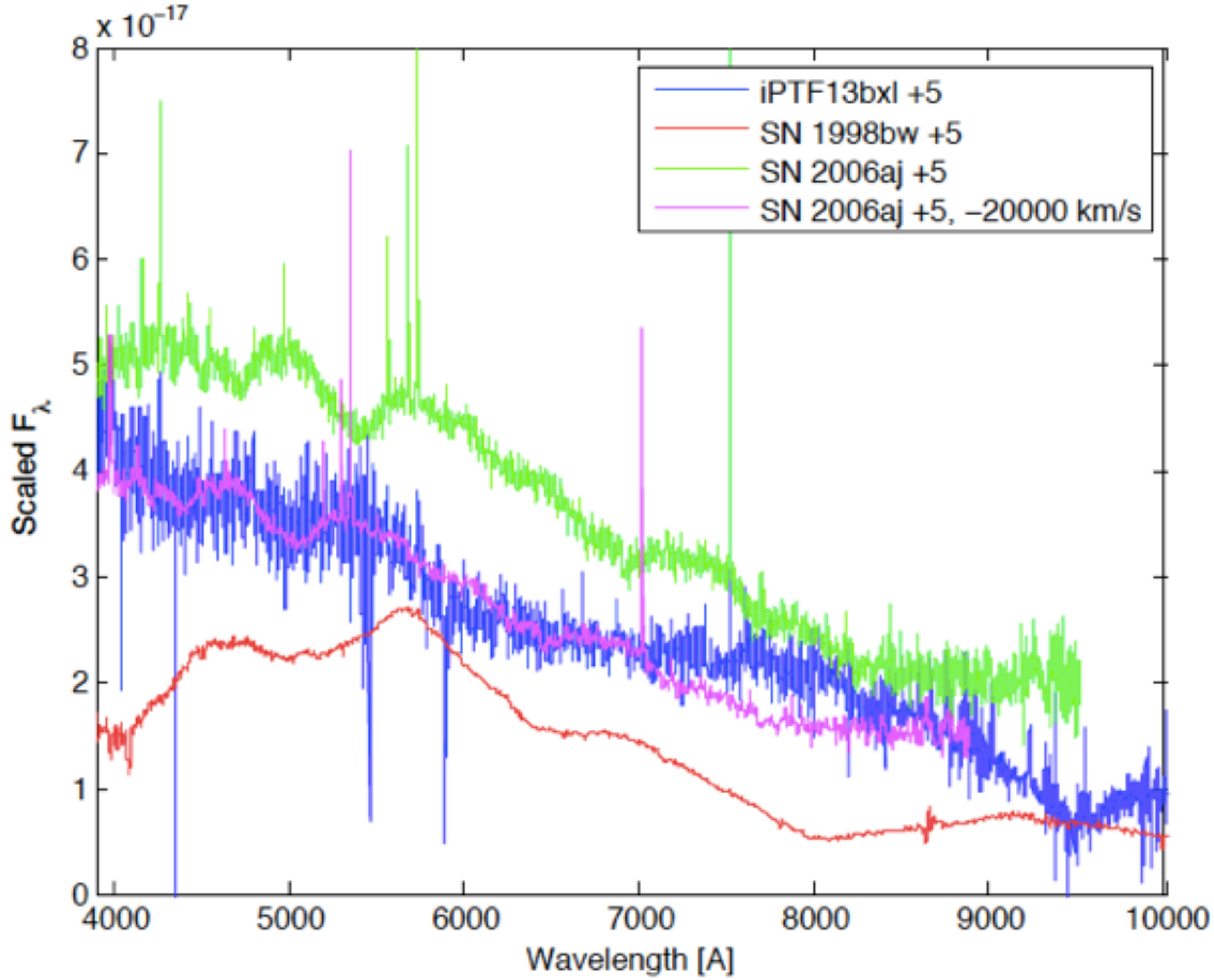


Singer et al.(2013, 2013, ApJL 776:34)

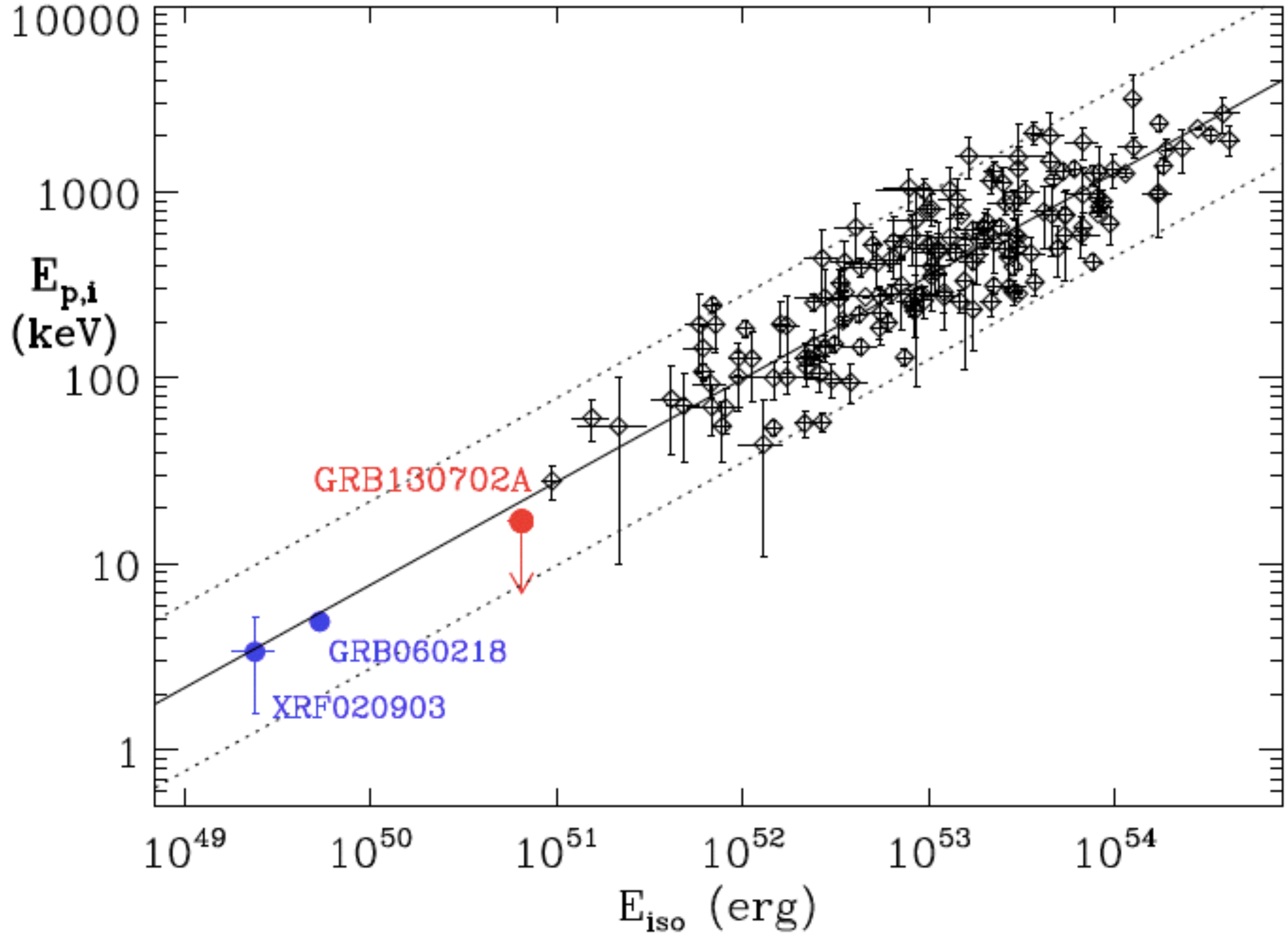
http://dx.doi.org/10.1088/2041-8205/776/2/L34

GBM+PTF SUCCESSES

GRB 130702A's supernova: comparison with SN 2006aj (Ic)

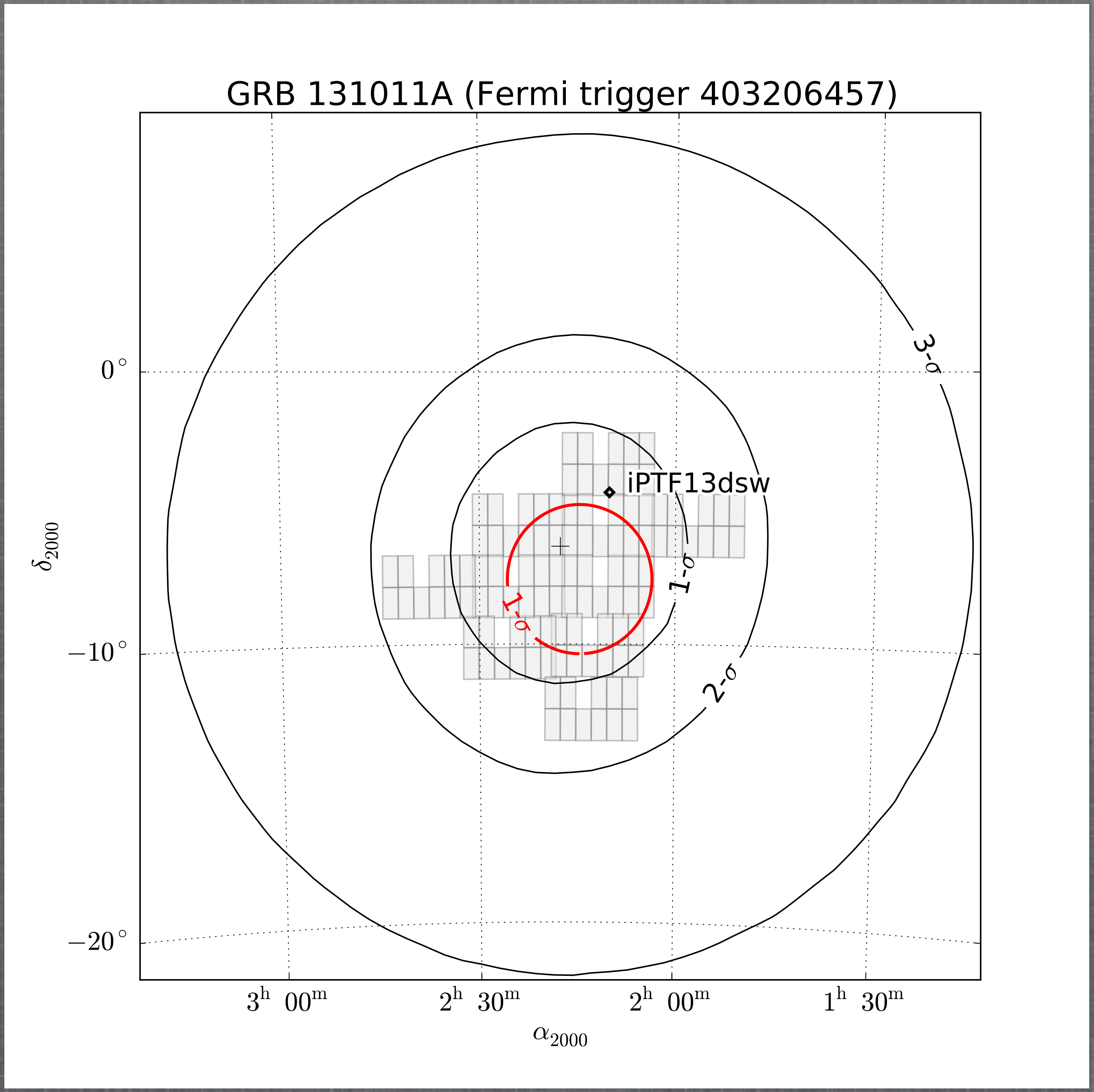


GBM+PTF SUCCESSES



Amati et al. (2013, GCN Circ. 15025)

GBM+PTF SUCCESSES

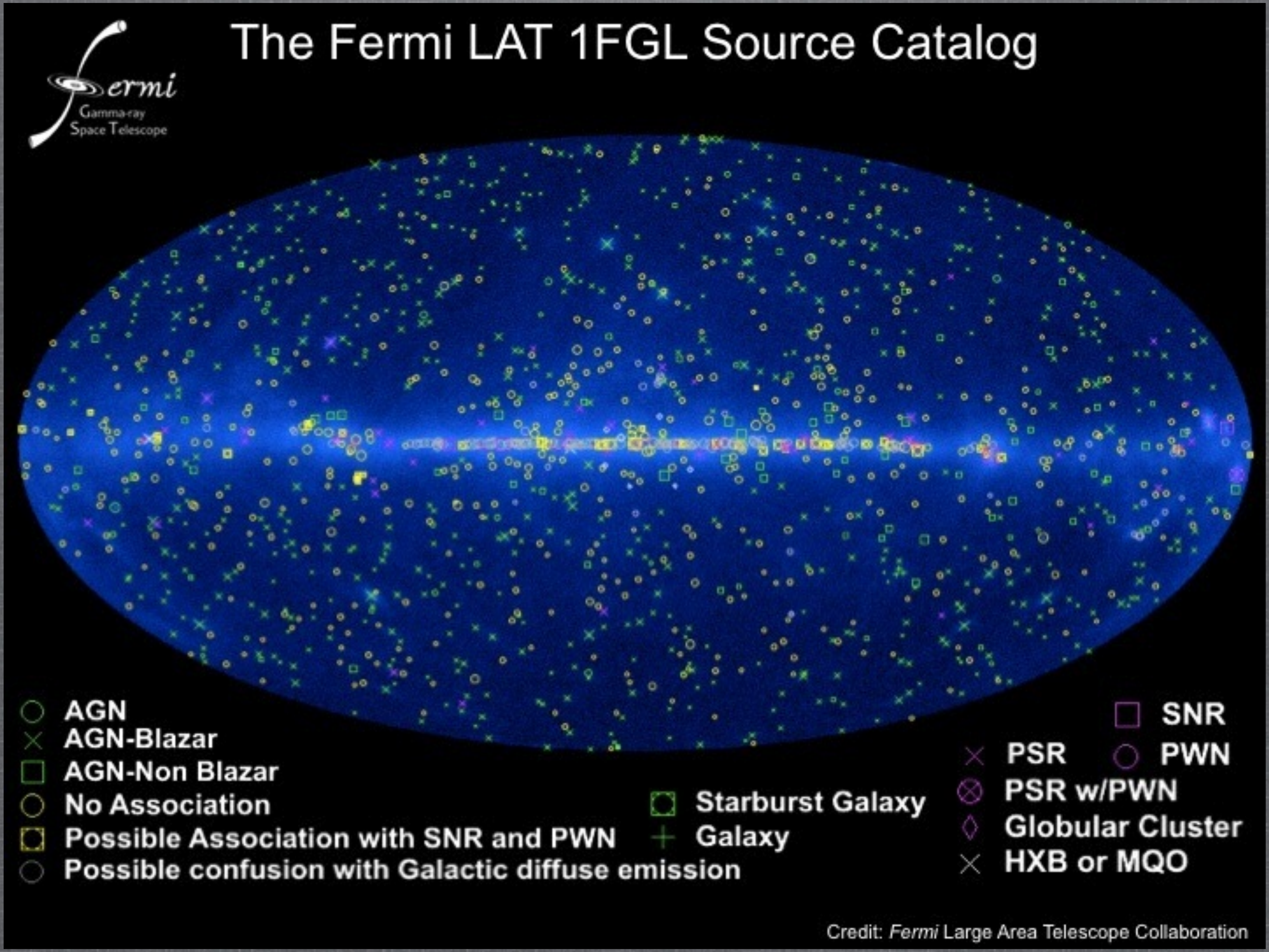


$z = 1.874$; limited broadband follow-up

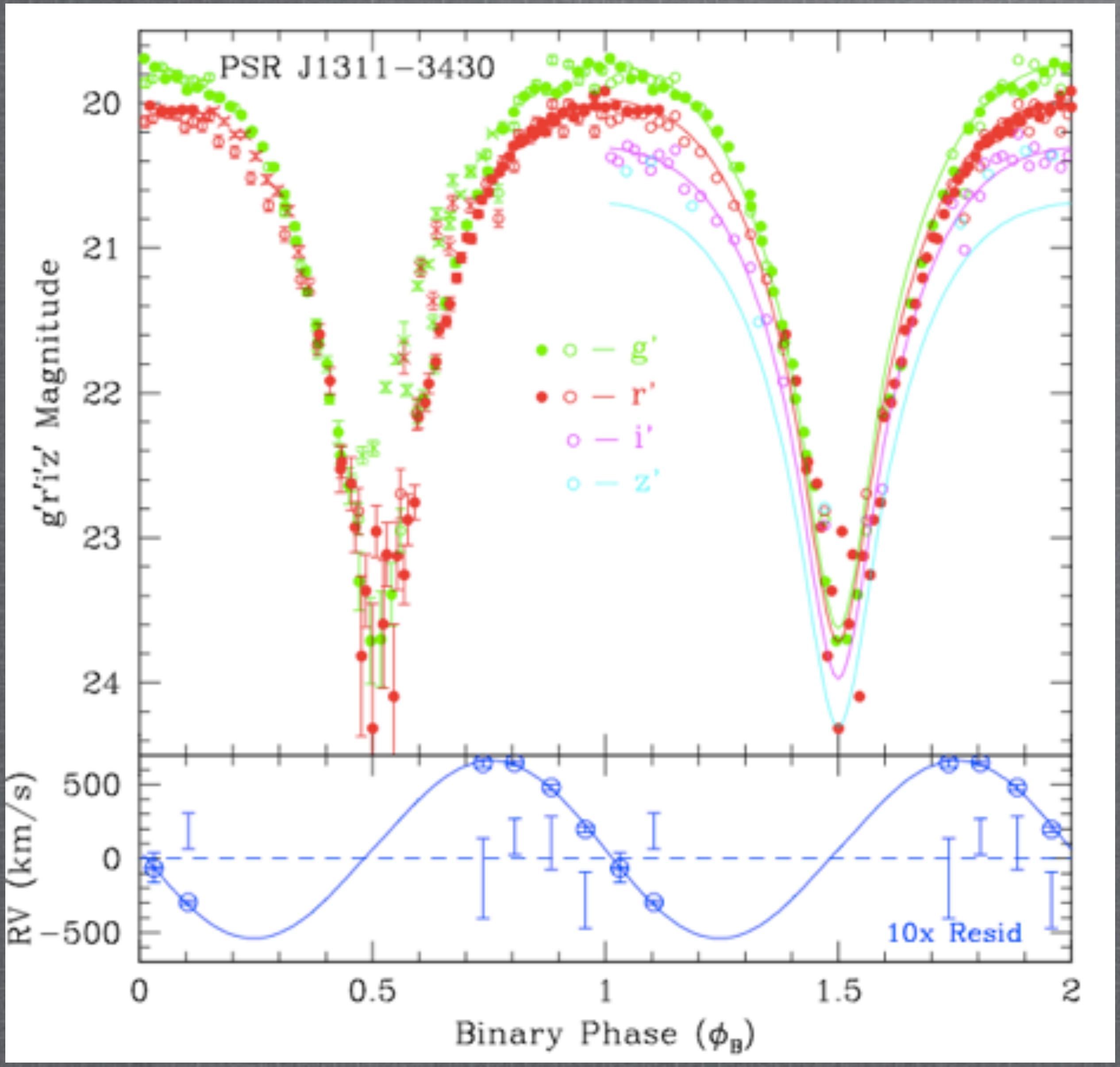
GBM FOLLOW-UP STATUS

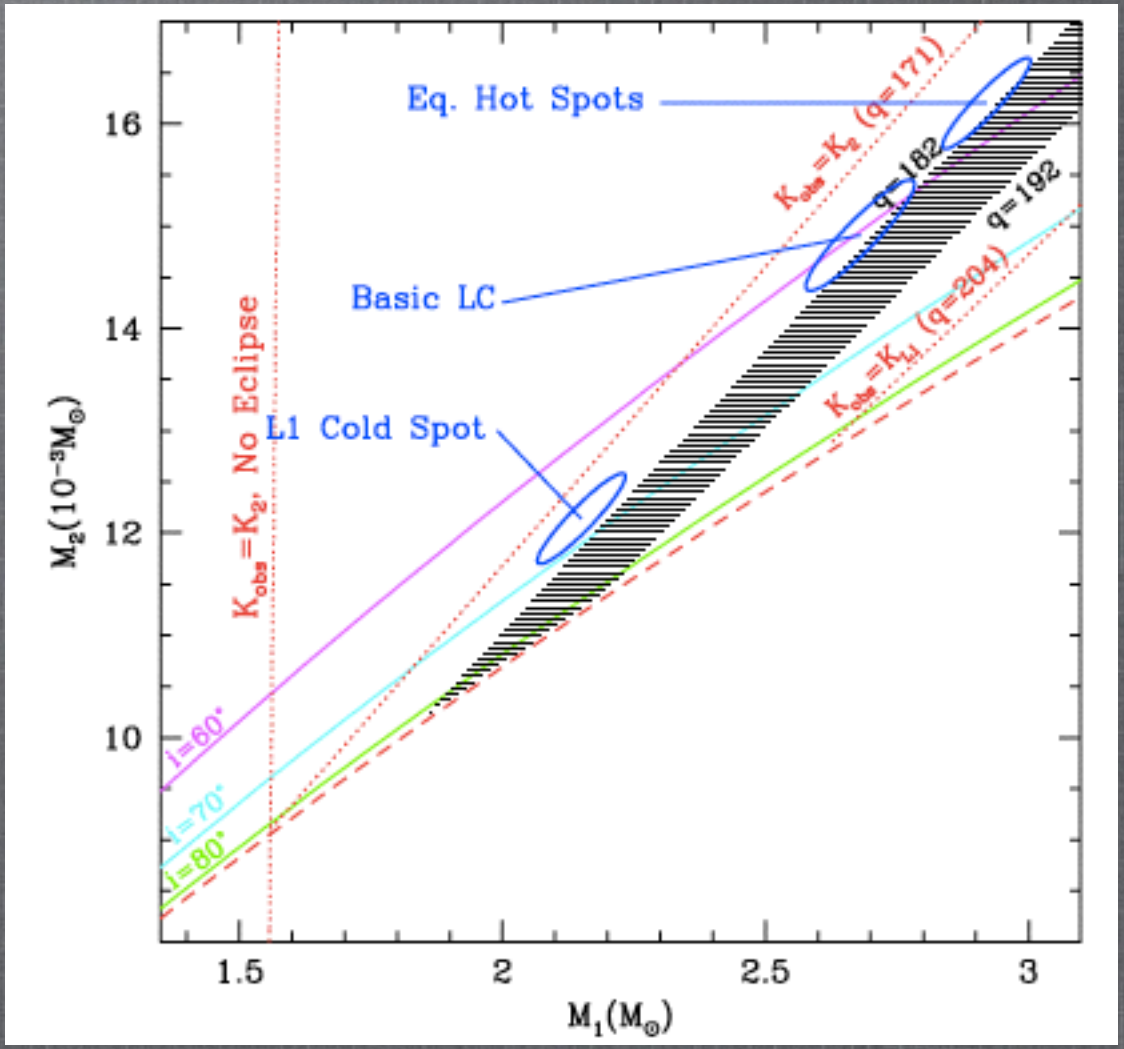
- ~ 12 GBM bursts followed-up to date (but only covered fraction of error circle for each, some later than others)
- 2 SHBs followed up (same night!) - no afterglows to ~ 20 mag at t ~ 7 hr. This is not really constraining, need to think about strategy
- Helping to consume and develop prompt localization contours (including systematic uncertainty)

UNIDENTIFIED LAT SOURCES



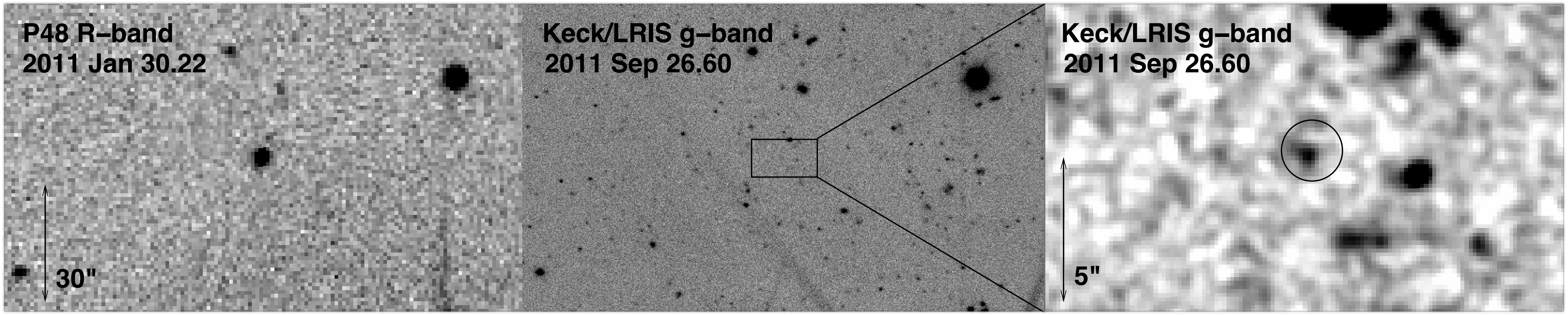
UNIDENTIFIED LAT SOURCES



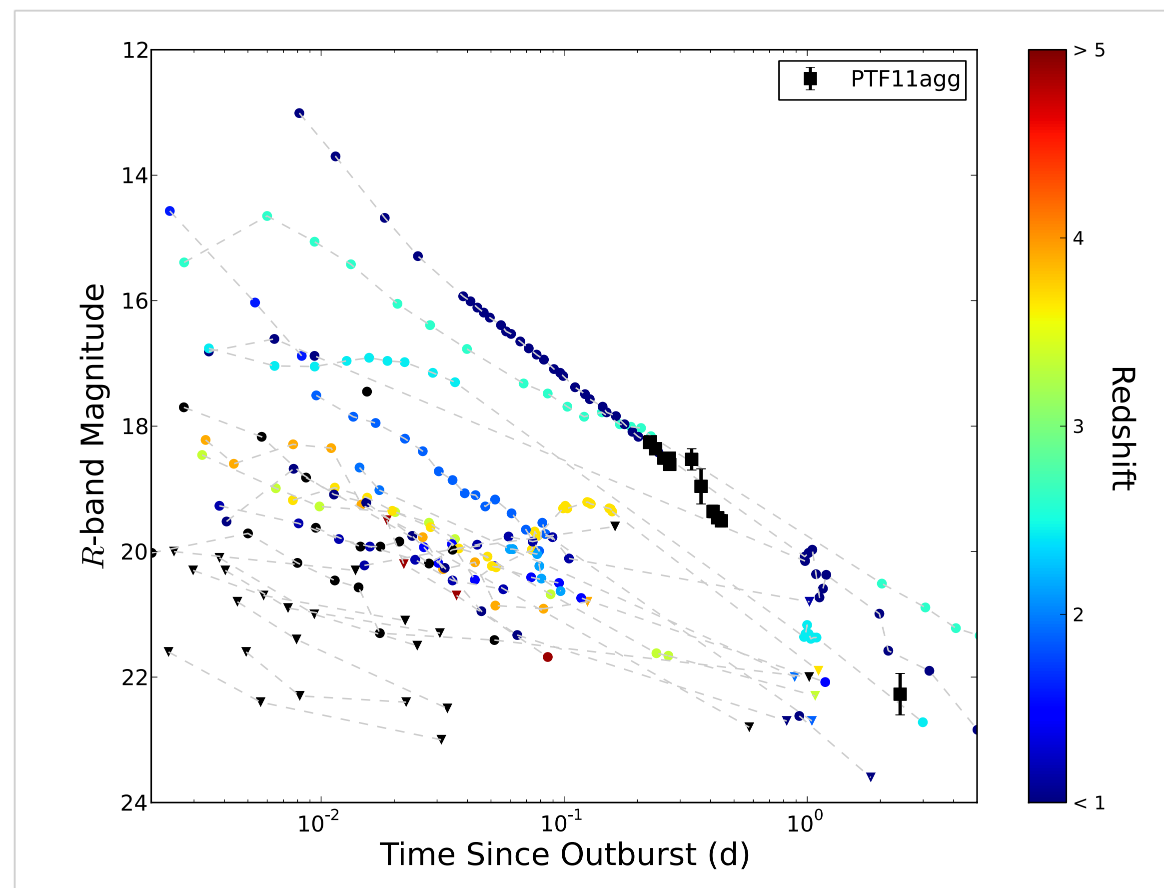


Searching for short (<~ few hours) period optical counterparts to find more candidate BW/redback pulsars

PTF11AGG: ORPHAN AFTERGLOW?

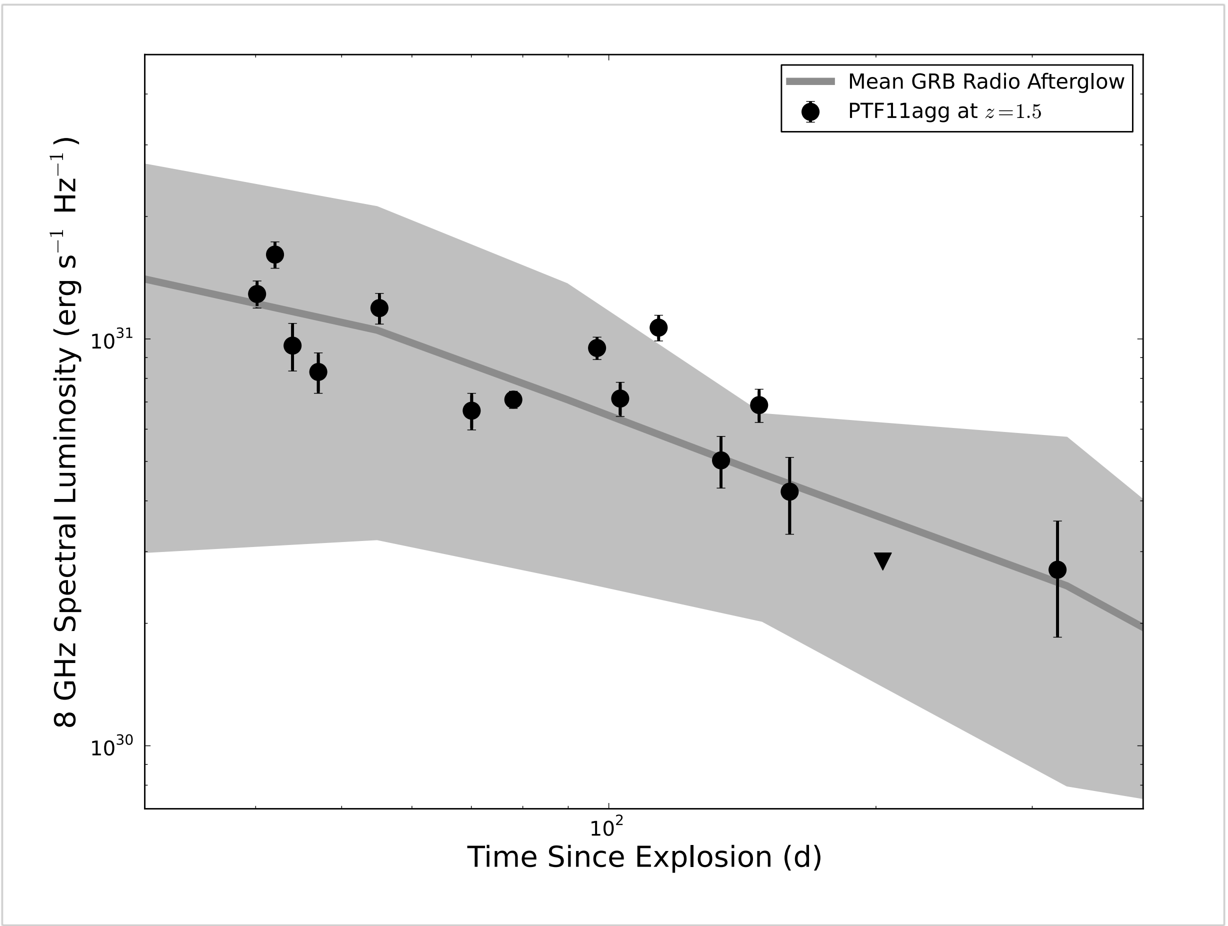


PTF11agg: discovered at R = 18.0 mag on Jan 30, faded by 1.5 mag in 5 hours, 4 mag in 2 days, 8 mag in 2 weeks. Quiescent counterpart with R = 26.0 mag, blue color.



SBC+, 2013

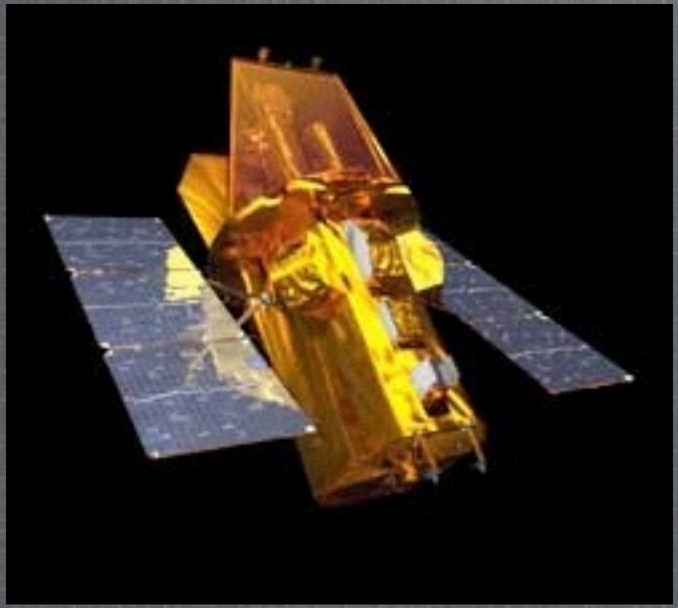
PTF11AGG: ORPHAN AFTERGLOW?



SBC+, 2013

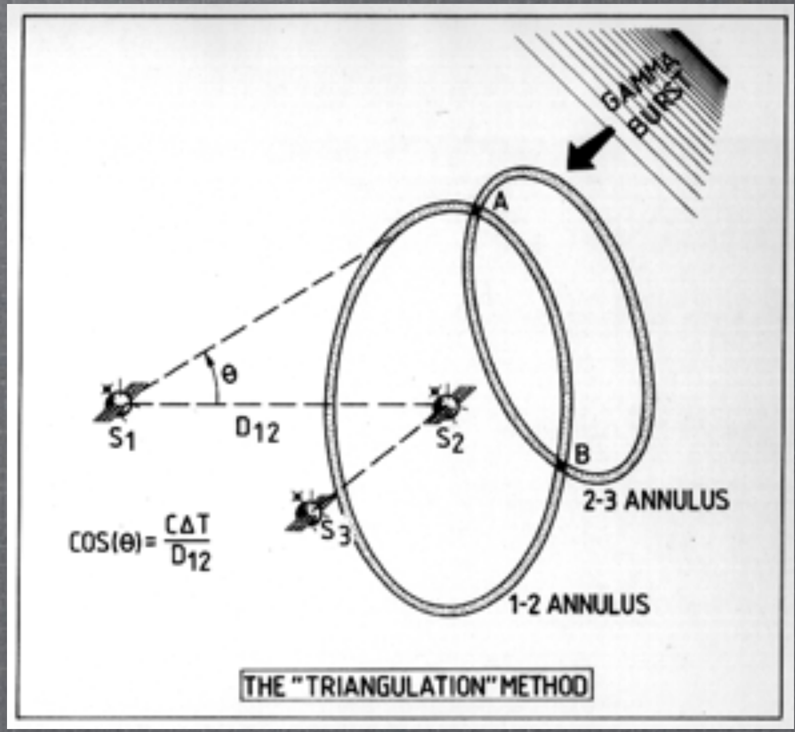
- Long-lived, scintillating radio counterpart ⇒ angular size ~ 20 mas at Δt ~ 40 d
- At cosmological distances, requires (modestly) relativistic ejecta (Γ > 1.5)
- No obvious high-energy counterpart, but not particularly constraining
- Likelihood of chance (on-axis) GRB detection by PTF is modest (~ few percent)
- Either very lucky or more common class of relativistic outbursts

“UNTRIGGERED” GRB?



Swift/BAT: 2 sr FOV,
f > 6 x 10^{-9} erg cm^{-2}

Fermi/GBM: 8 sr FOV,
f > 4 x 10^{-8} erg cm^{-2}

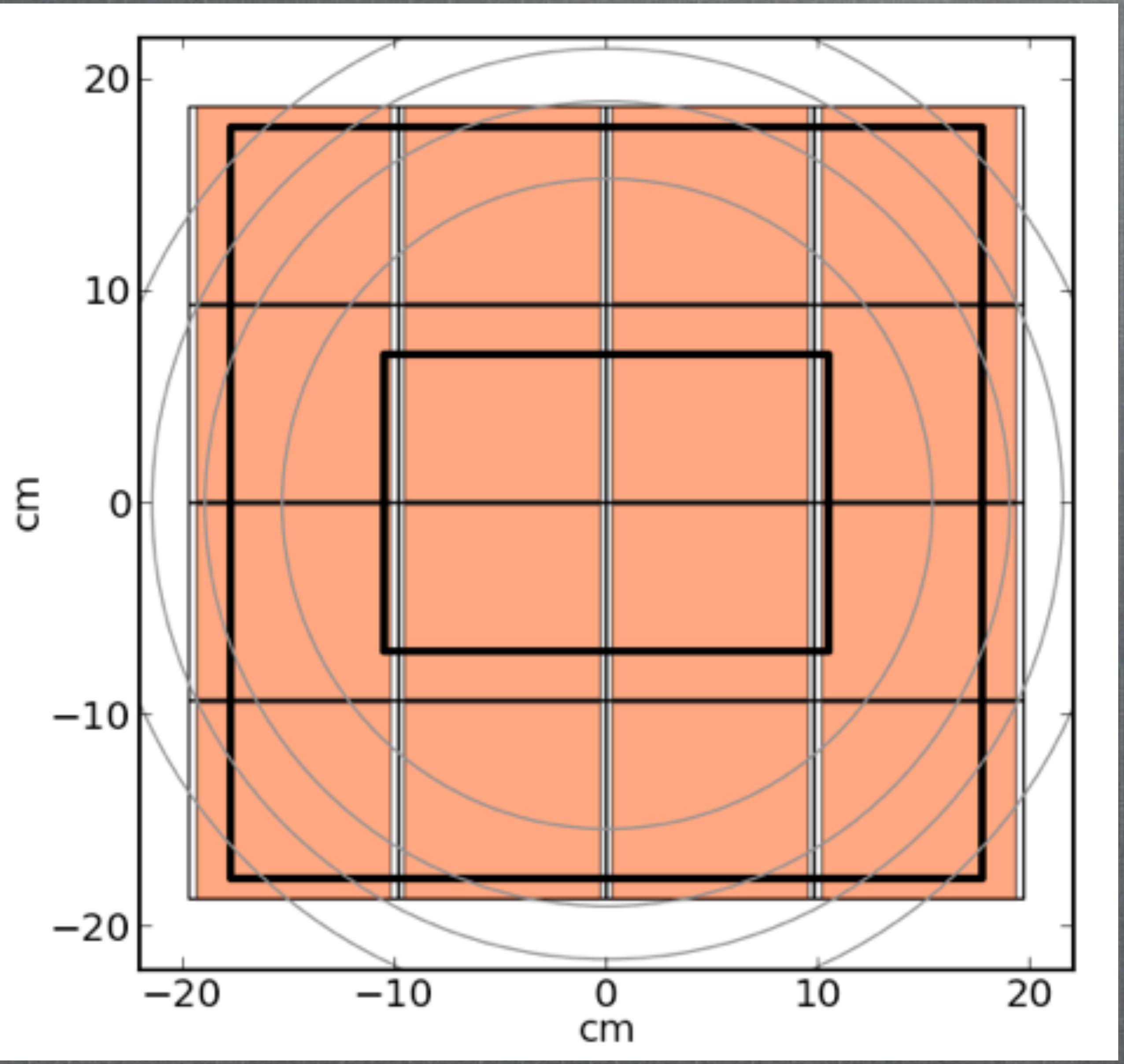


Inter-Planetary Network:
all-sky, f > 6 x 10^{-7} erg cm^{-2}

~ 40% of non-detection by both *Swift* and *Fermi* for events with fluence below IPN sensitivity

FUTURE I: ZTF

Zwicky Transient Facility (ZTF)



- New camera populating entire focal plane of P48, ~ 45 deg^2 (i.e., a factor of 6 larger area than current camera)

- With faster readout and shorter (30 s) exposures, survey volume increases by ~ 14x

- Expected Discoveries:
  - 1 young (< 24 hr) SN per night
  - 5 orphan afterglows per year
  - 20 11agg-like events per year
  - > 250 pointings of all Northern sky

FUTURE II: BROADER VIEW

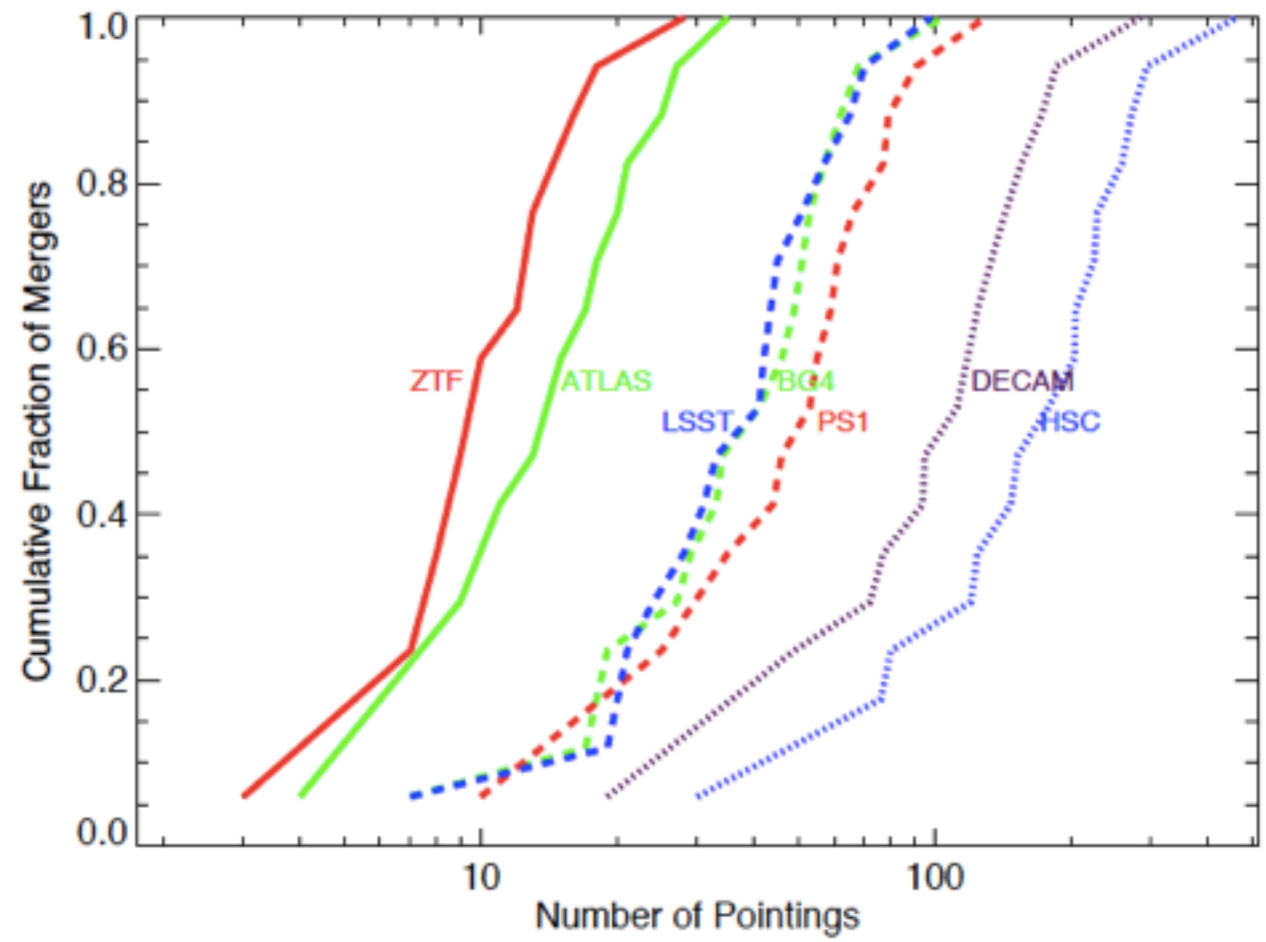


FIG. 3.— Cumulative distribution of number of pointings necessary to tile localization arcs at all sky positions by LIGO-H and LIGO-L. Color represents telescope diameter: 0.5m-class (green), 1m-class (red), 4m-class (purple) and 8m-class (blue). Line style represents camera angle: few tens of deg^2 (solid), several deg^2 (dashed) and few deg^2 (dotted).

TABLE 1

Facility	Aperture (m)	Field-of-View (deg^2)	Exposure (sec)	Overhead (sec)	Sensitivity (5σ, i-mag)	Detectable Fraction (−16; −14; −12 mag)	Lag (hr)
Palomar: Zwicky Transient Facility (ZTF)[a]	1.2	47	600	15	22.2	0.94; 0.35; 0.06	1 ± 2
BlackGEM-4 (BG4)[b]	4×0.6	4×2	600	15	22.2	0.65; 0.12; 0.06	12 ± 2
Pan-STARRS1 (PS1)[c]	1.8	7.0	180	10	21.9	0.76; 0.18; 0.06	3 ± 2
ATLAS[d]	0.5	30	600	5	21.0	0.53; 0.06; 0.06	3 ± 2
CTIO: Dark Energy Camera (DECAM)[e]	4.0	3.0	10	30	22.8	0.53; 0.47; 0.12	12 ± 2
Subaru: HyperSuprimeCam (HSC)[f]	8.2	1.77	1	20	22.4	0.47; 0.47; 0.18	3 ± 2
Large Synoptic Survey Telescope (LSST)[g]	8.4	9.6	1	2	22.4	1.00; 1.00; 0.65	12 ± 2