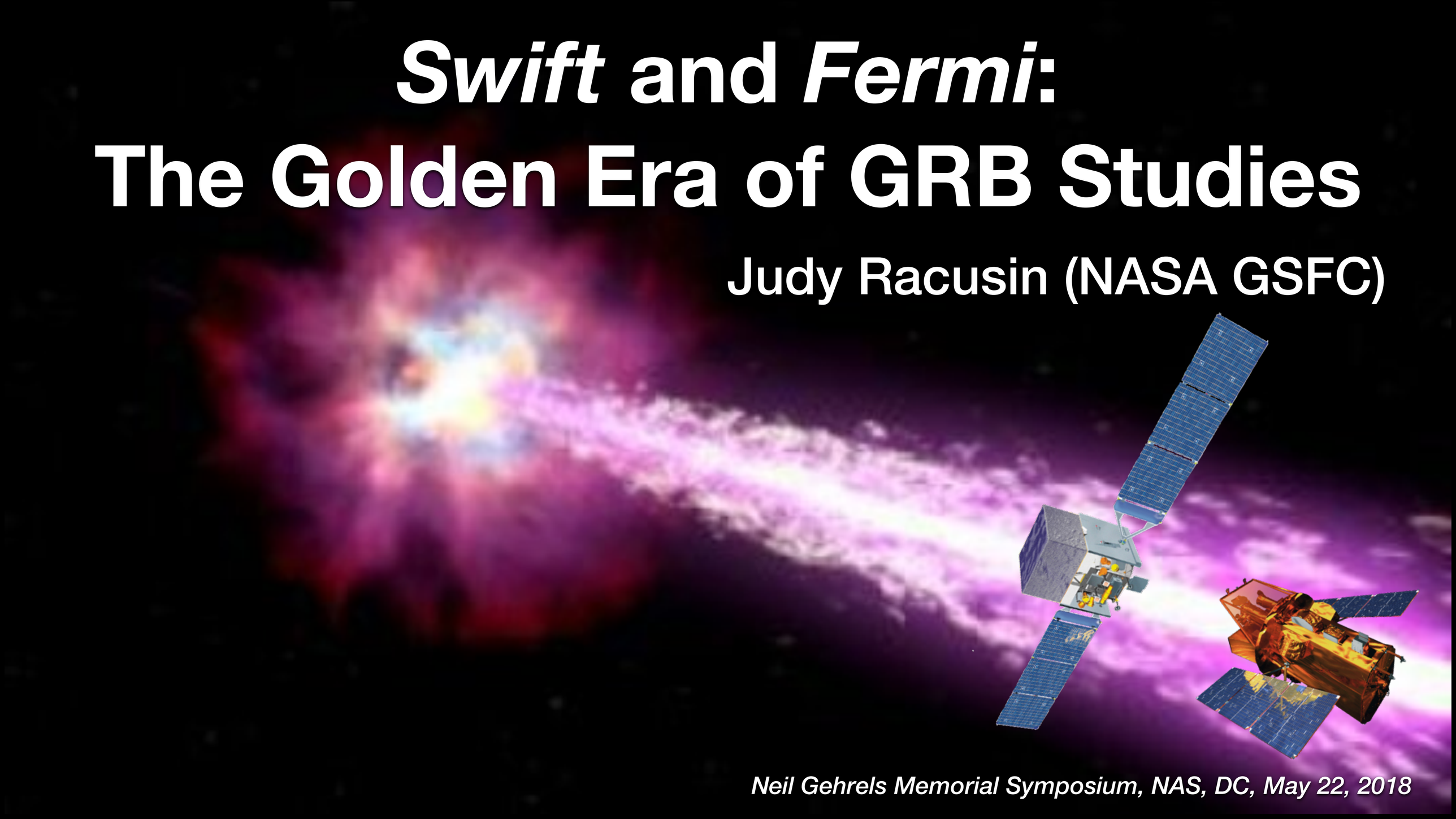
Swift and *Fermi*: The Golden Era of GRB Studies

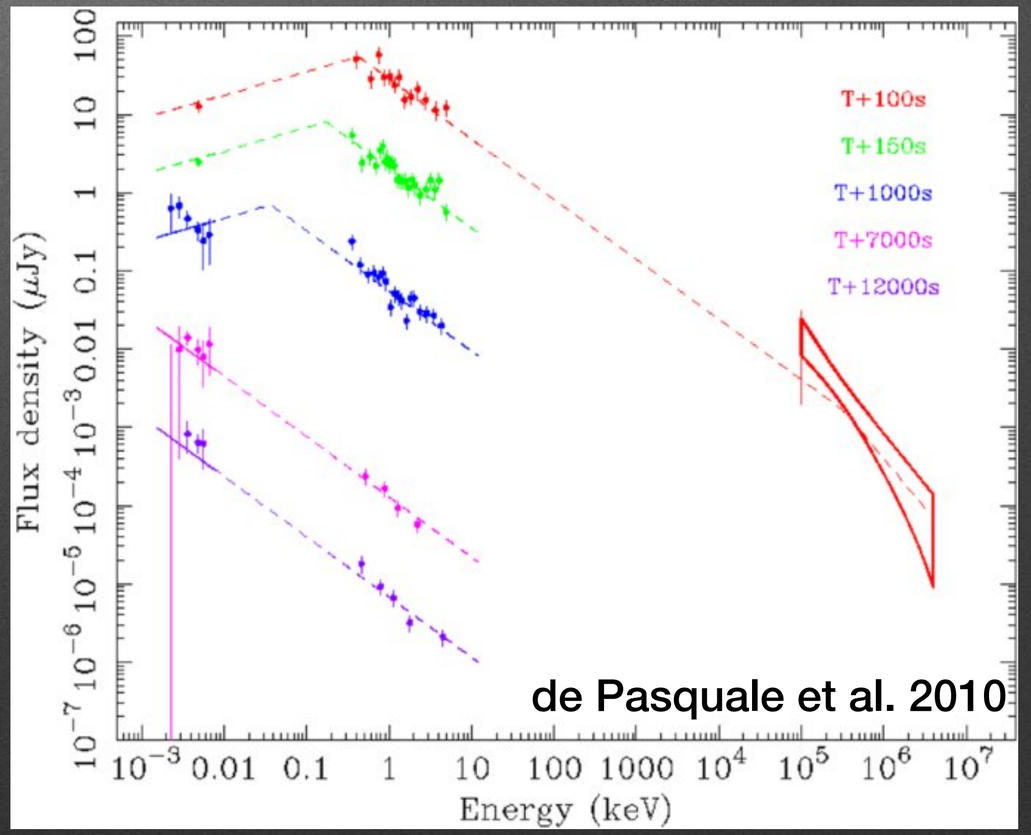
Judy Racusin (NASA GSFC)



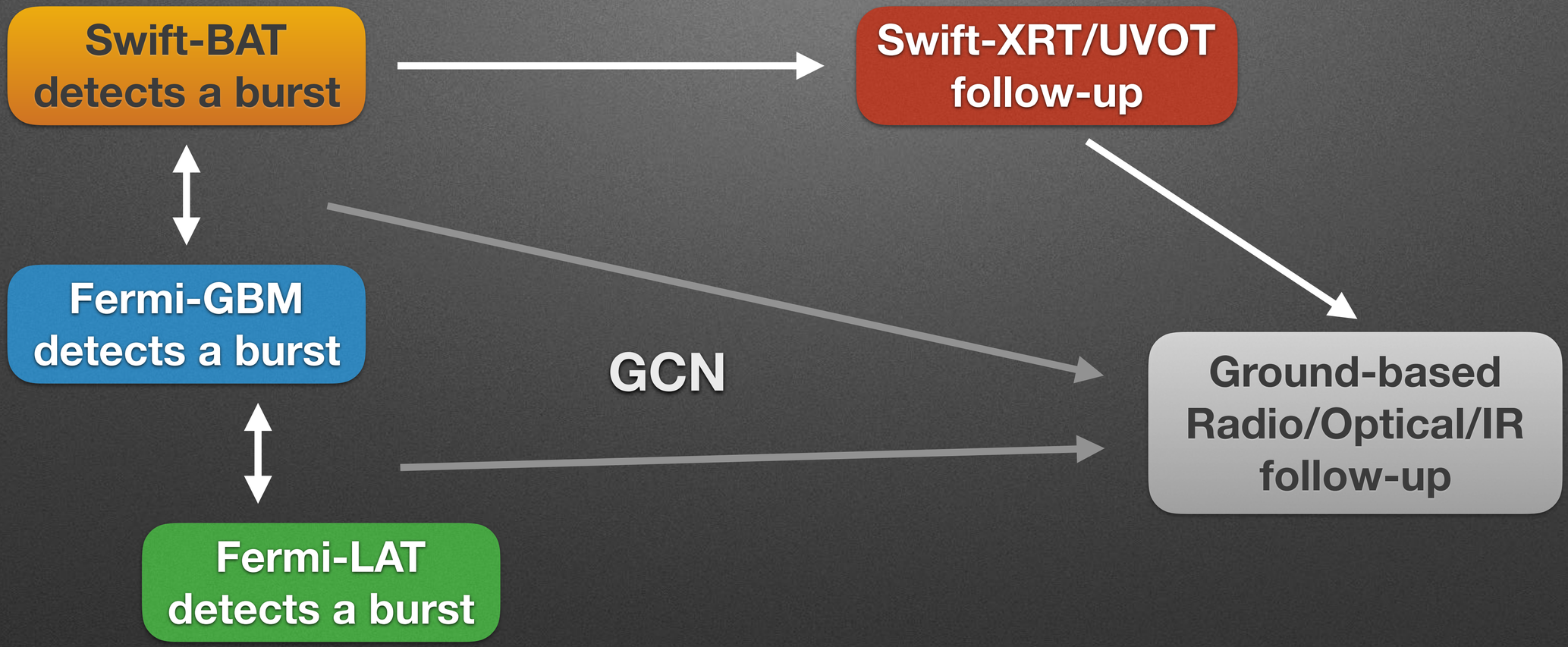
Neil Gehrels Memorial Symposium, NAS, DC, May 22, 2018

Swift and *Fermi*: Working Together to Study Transients Over 10+ Orders of Magnitude of Energy

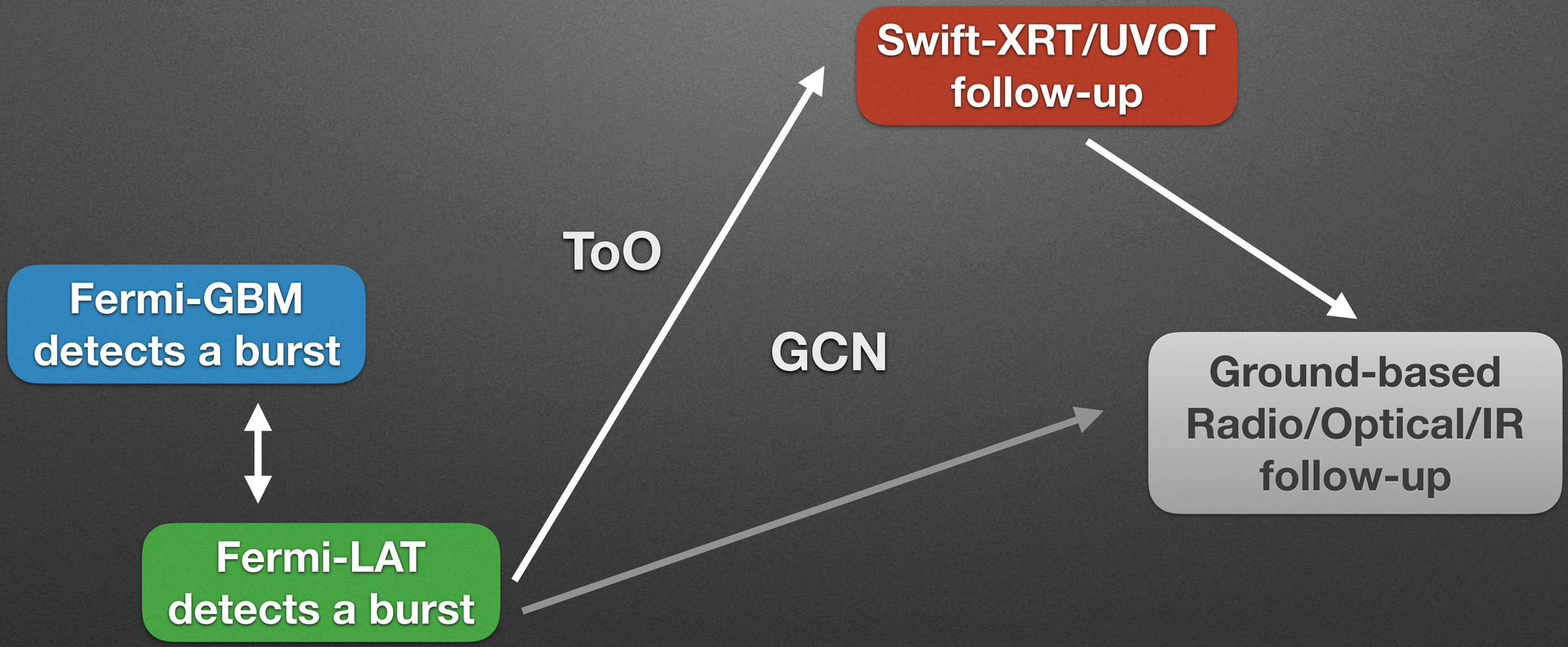
- *Swift* detects GRBs - *Fermi* GBM/LAT sometimes co-detect
- GBM/LAT detects GRBs - *Swift* follows them up
- LAT detects flaring AGN (and other sources) - XRT/UVOT follow them up
- BAT detects transients and sources in outburst - Check LAT data
- Most of this was facilitated by Neil



Swift and *Fermi* GRB Response



Swift and *Fermi* GRB Response



Learning from *Swift*

- *Swift* GRB response is incredibly efficient
- LAT GRBs are interesting subset and multiwavelength data are key
- Practice makes perfect, and LAT GRBs occur only 1-2 per month, so team response was a bit slow and chaotic
- Triggering Swift wasn’t always the highest priority of the LAT BA
- Instituted LAT GRB telecons (group chats)
- Automated pipelines
- Identifying which GRBs are likely to have GeV counterparts
- *Swift* ToO requests
- Tiling
- Automate everything!

☆ **Swift ODS List <swiftods@swift.psu.edu>** 2015 September 3, 2015 at 3:02 AM Hide

[BA] ToO request for GRB 150902A approved

SL

Dear Dr. Fermi,

This email is to inform you that the *Swift* PI, Neil Gehrels, has approved your ToO request to observe GRB 150902A.

The target ID assigned to your observation is 20549.

This ToO request will be scheduled on a best-effort basis. Observations that cannot wait until the next pre-planned schedule will be uploaded directly to the satellite. If your observation has been scheduled as a pre-planned target, the planned observing time can be found in the *Swift* observing schedule, which is posted at http://www.swift.psu.edu/operations/obsSchedule.php.

We do not notify observers when their data is available. The data will be posted at the *Swift* Data Center's Quick-Look Data site (http://swift.gsfc.nasa.gov/cgi-bin/sdc/ql?), usually within 2 hours of the end of each observation snapshot (or visit), although the delay can be longer depending on the availability of ground station passes. Your observation can be located by its observation IDs, which are composed of 3 leading zeroes, the 5-digit target ID, and a 3 digit segment number. We remind you that there is no proprietary period for *Swift* data. Since the data are public, we suggest that you analyze your data and announce any important results promptly.

In some cases there is more than one ToO requester for a given source. A list of approved ToO requests is given at https://www.swift.psu.edu/secure/toop/summary.php. If appropriate, we encourage communication and/or collaboration between requesters.

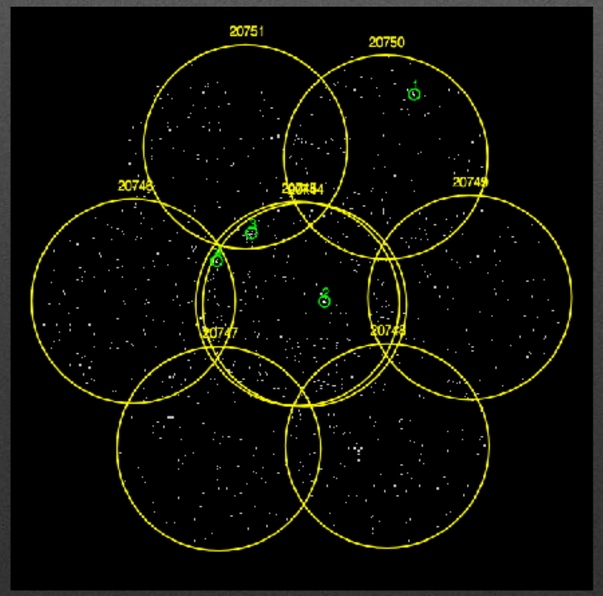
We will attempt to schedule your observation by September 10th, 2015. Please be aware that *Swift* ToO observations may be interrupted or rescheduled if a new gamma-ray burst occurs. Your observations may be postponed or not observed if the observations prove to be detrimental to other higher priority scheduling requirements (including anti-sun pointing and XRT temperature management). If for some reason we are unable to schedule this observation by September 10th, 2015, we will drop the observation from our schedule and you will need to resubmit your request if the observation is still scientifically important.

Sincerely,

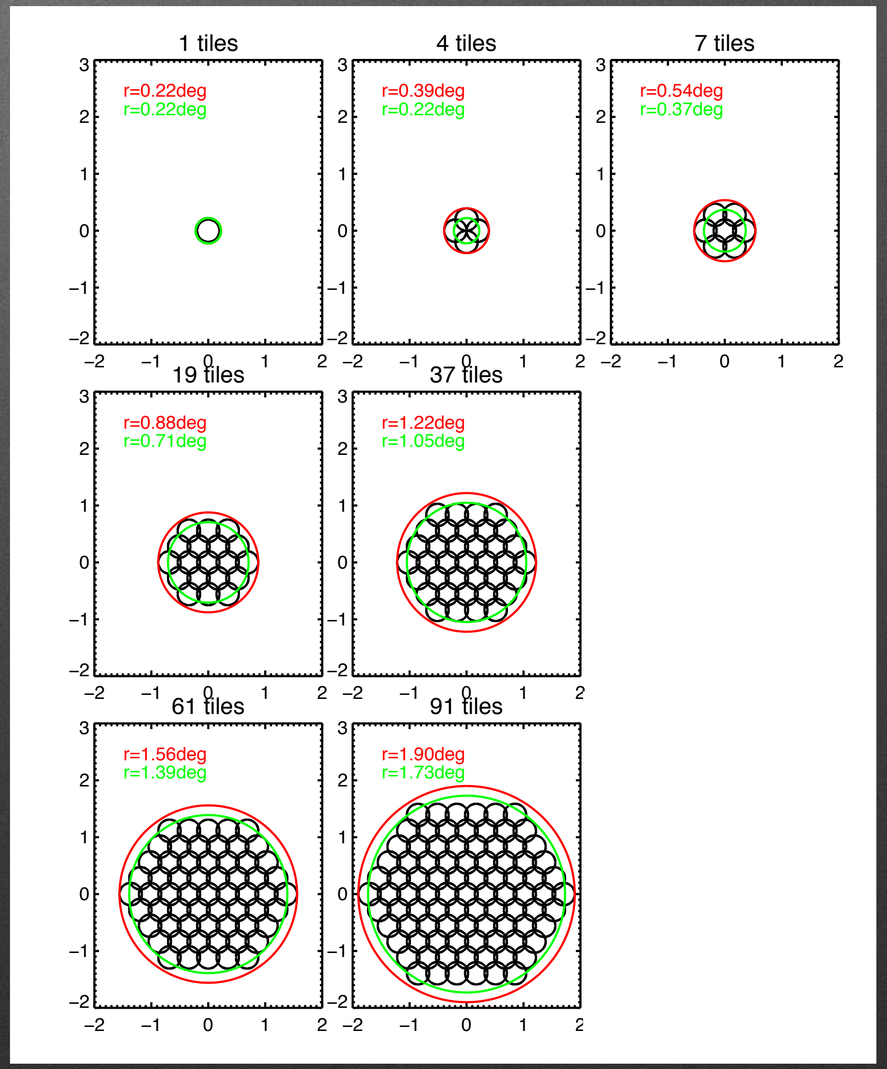
B. Sbarufatti
Swift Observatory Duty Scientist
swiftods@swift.psu.edu

Swift Tiling - LAT as a Testbed for LIGO

- LAT localizations - ~0.1-1 deg radius
- Usually only follow-up events with localization < 0.5 deg radius
- 1, 4, or 7 tiles covers that
- Leicester pipeline that automatically processes and searches for sources
- Improvements underway to provide arbitrary tiling patterns (ground replanning and on-board)

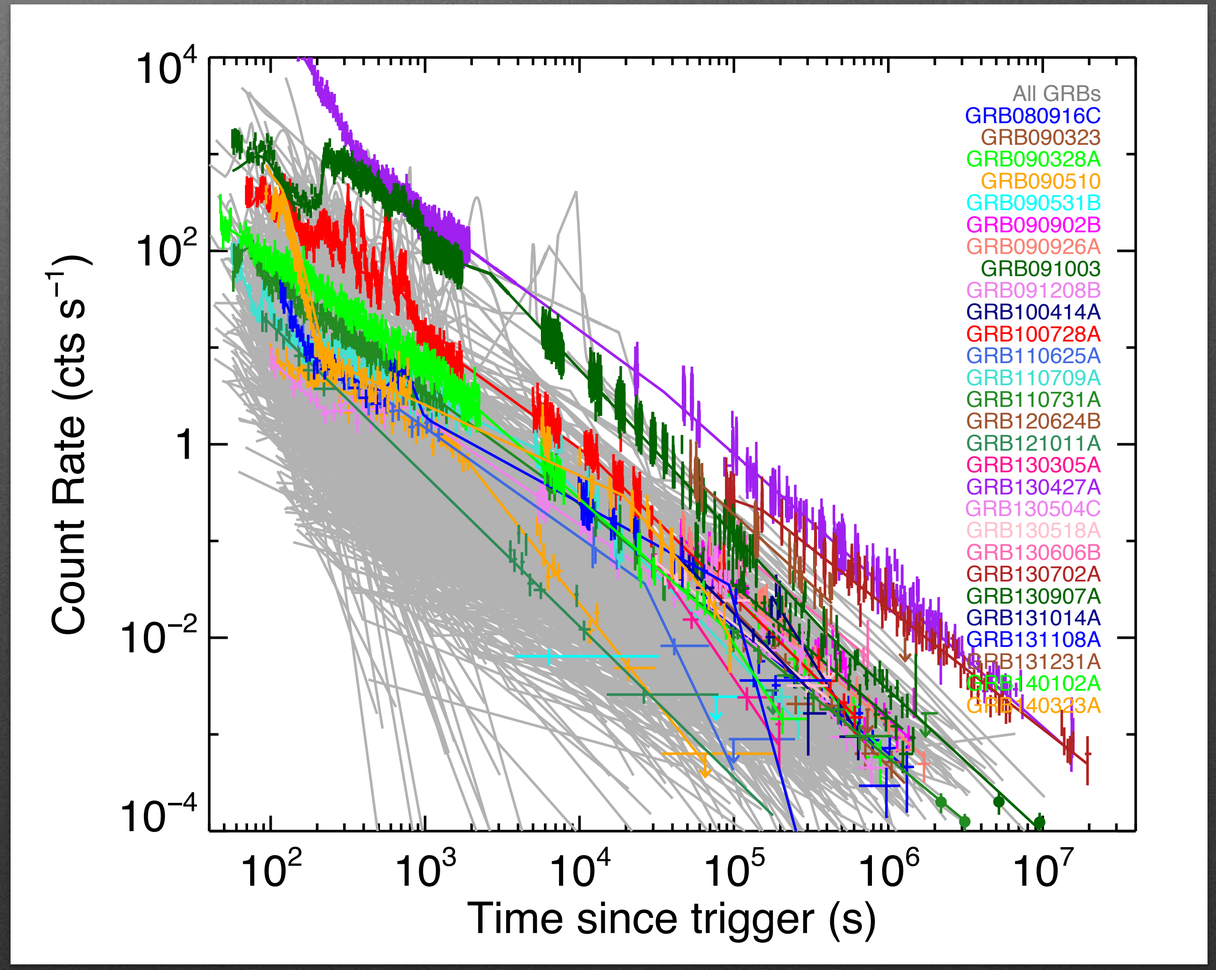


http://www.swift.ac.uk/xrt_products/TILED_GRB00065/



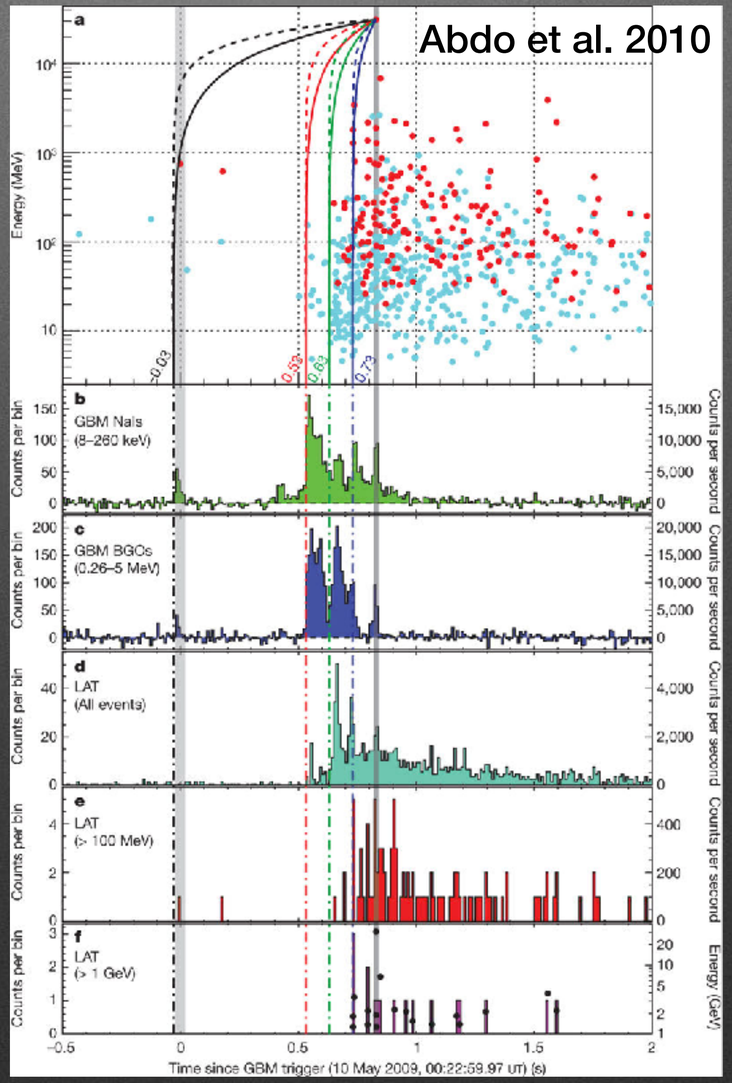
Swift-XRT Observations of LAT GRBs: Follow-up Successes

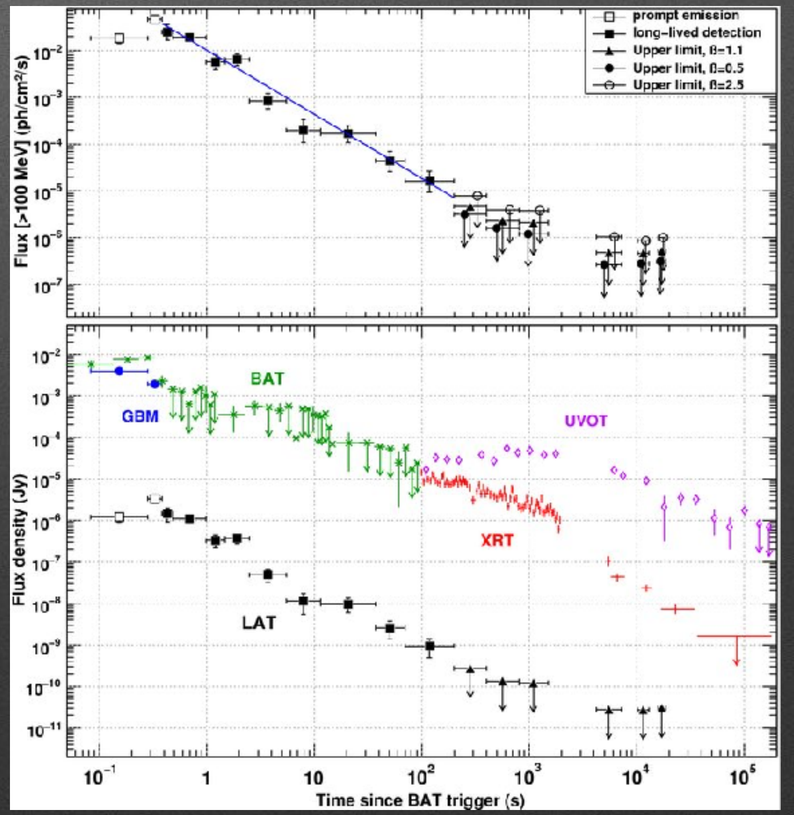
- 148 LAT detections (new catalog in prep)
- 26 BAT/GBM/LAT co-detections
- 60 detected by XRT
- 67 followed-up by XRT
  - 23 tiled
    - 9 w/ 7 tile pattern (3 det)
    - 11 w/ 4 tile pattern (2 det)
    - 3 w/ other patterns (mainly older bursts) (0 det)
  - 44 single pointing (29 detected)



GRB 090510
The Most Energetic Short GRB

- Bright Short GRB z=0.903
- Co-detected by *Swift* & *Fermi*
- First evidence of short GRB GeV afterglow
- LAT onboard trigger
- Lorentz Invariance Violation limits

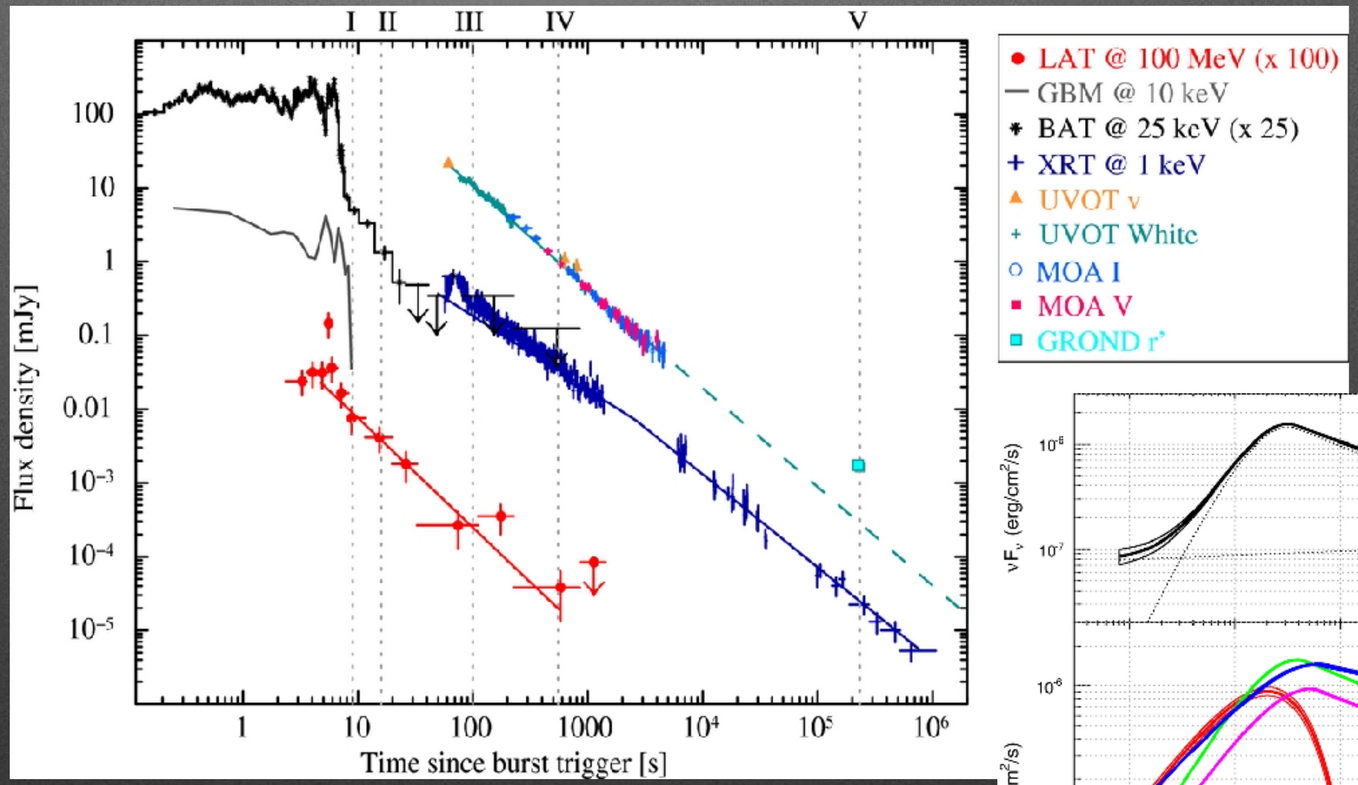


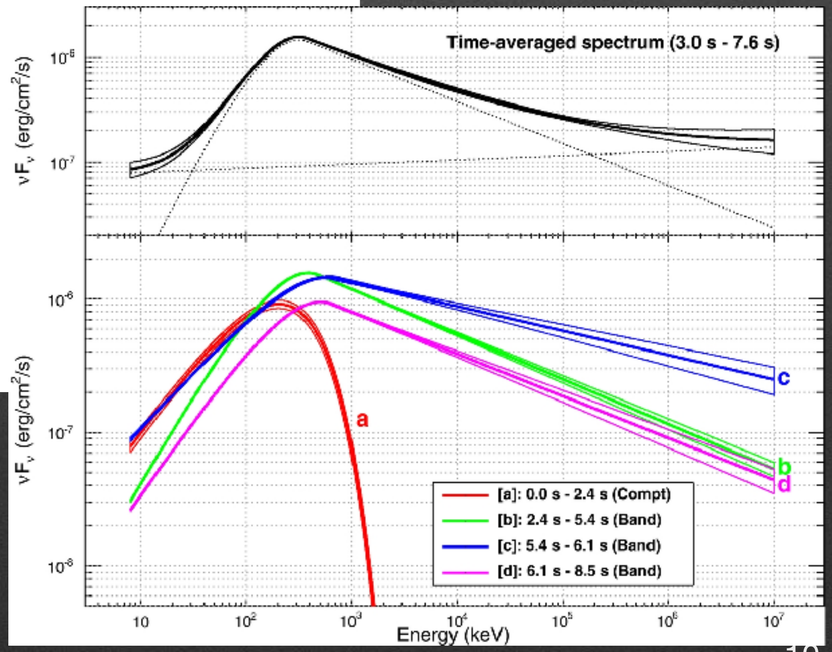


de Pasquale et al. 2010

GRB 110731A
A Well-Observed Joint Detection

- Best evidence for GeV extended emission afterglow origin
- z=2.83
- Co-detected by *Swift* & *Fermi*

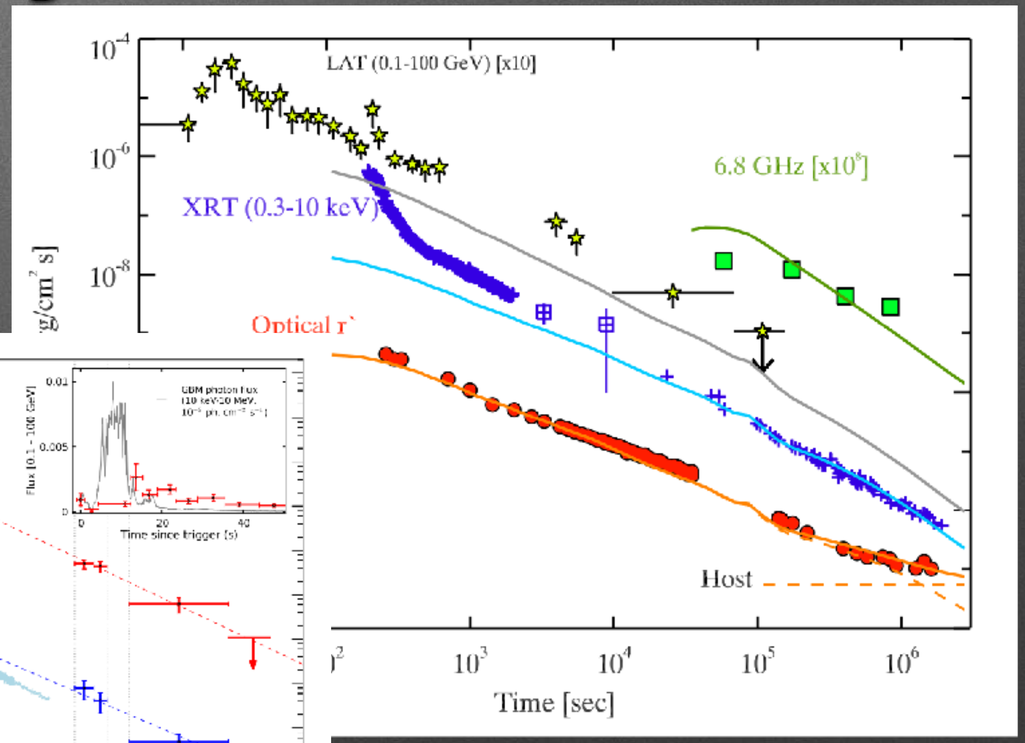




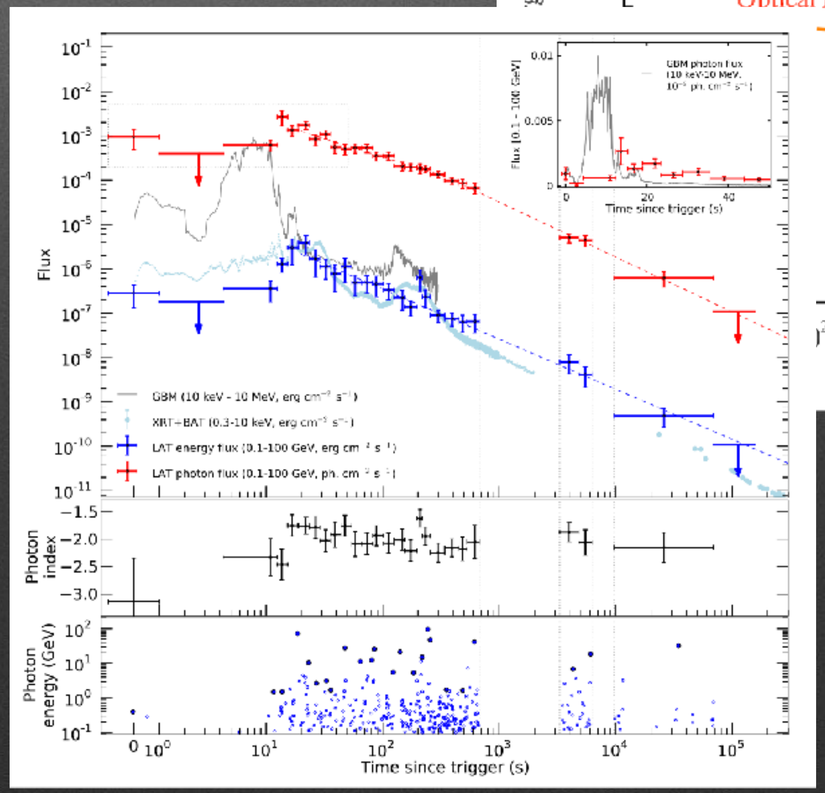
Ackermann et al. 2013

GRB 130427A
The Nearby Ordinary Monster

- Cosmological-like GRB at z=0.34
- Bright 7th magnitude prompt optical flash
- Co-detected by *Swift* & *Fermi*
- Long-lived GeV afterglow (20 hours)
- Beautiful broadband dataset
- Highest-energy photon
  - 95 GeV (128 GeV in rest frame) @244 s
  - 32 (43) GeV @ 9 hours
  - violates most models of maximum Synchrotron energy



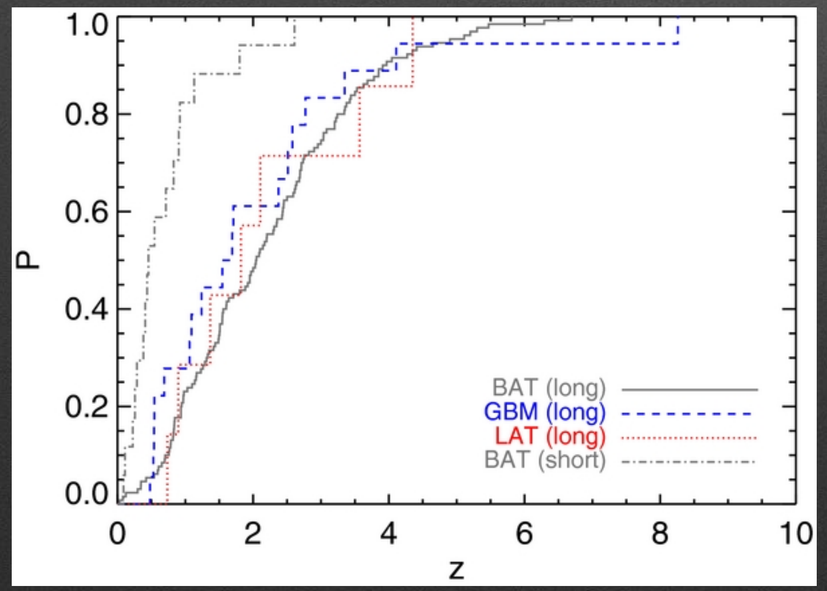
Maselli et al. 2013

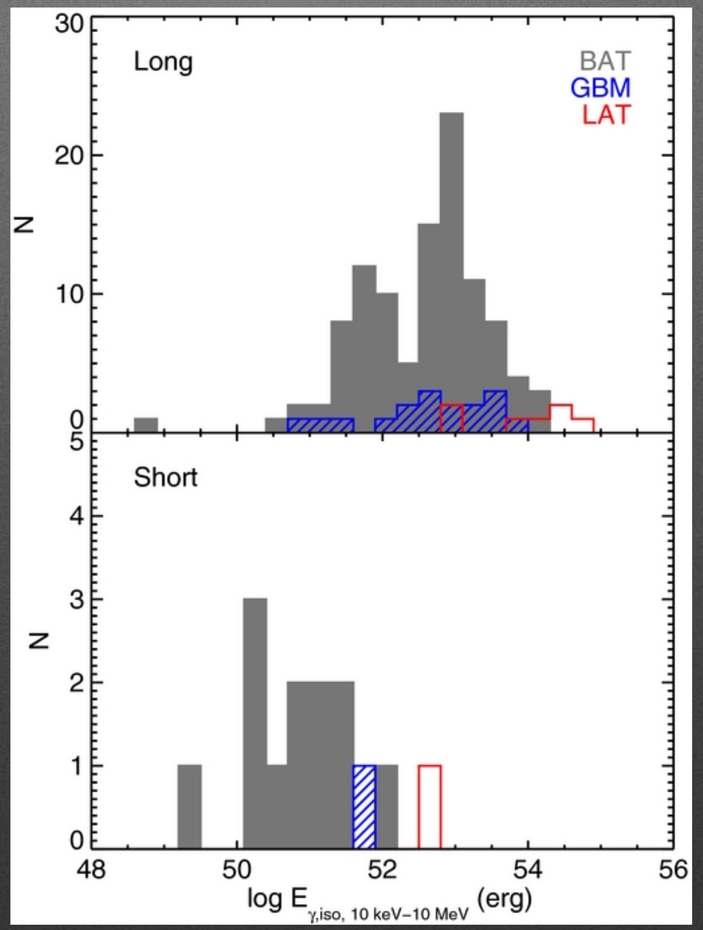


Ackermann et al. 2013

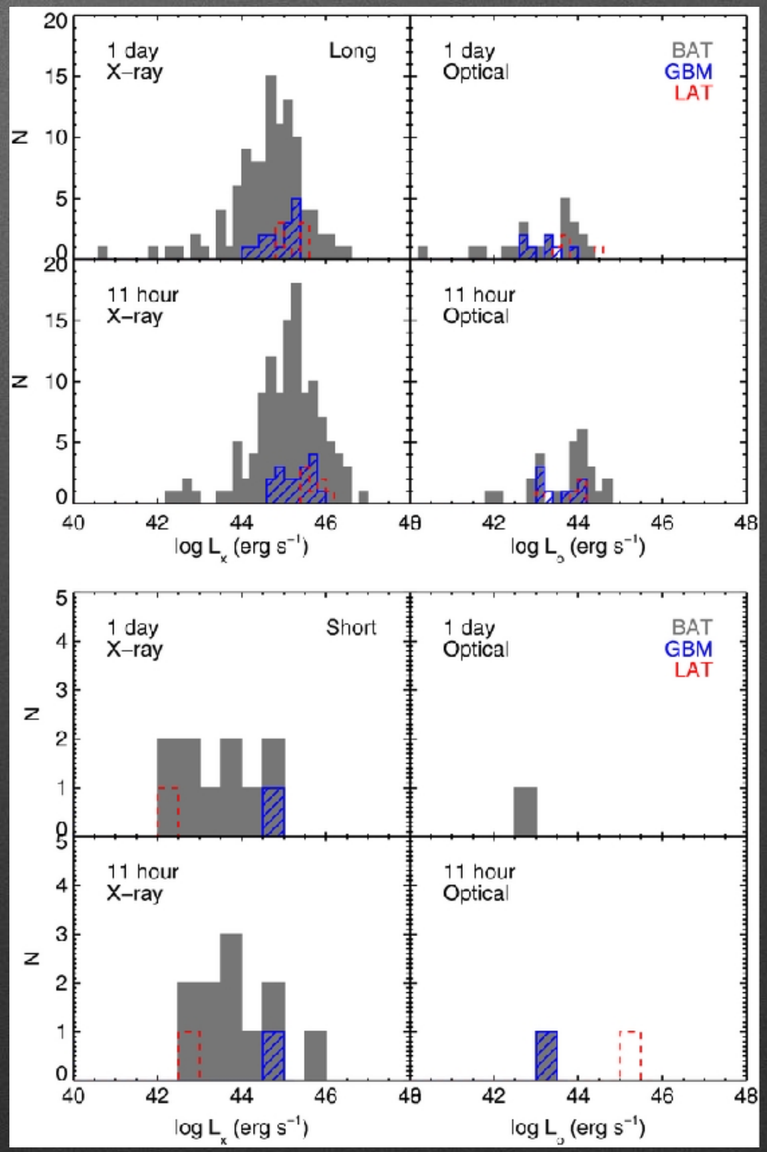
GRB Population Studies

- LAT GRBs seem to be an energetic subset of the GRB population
- Higher bulk Lorentz factors than typical GRBs
- See also Cenko et al. 2010, McBreen et al. 2010



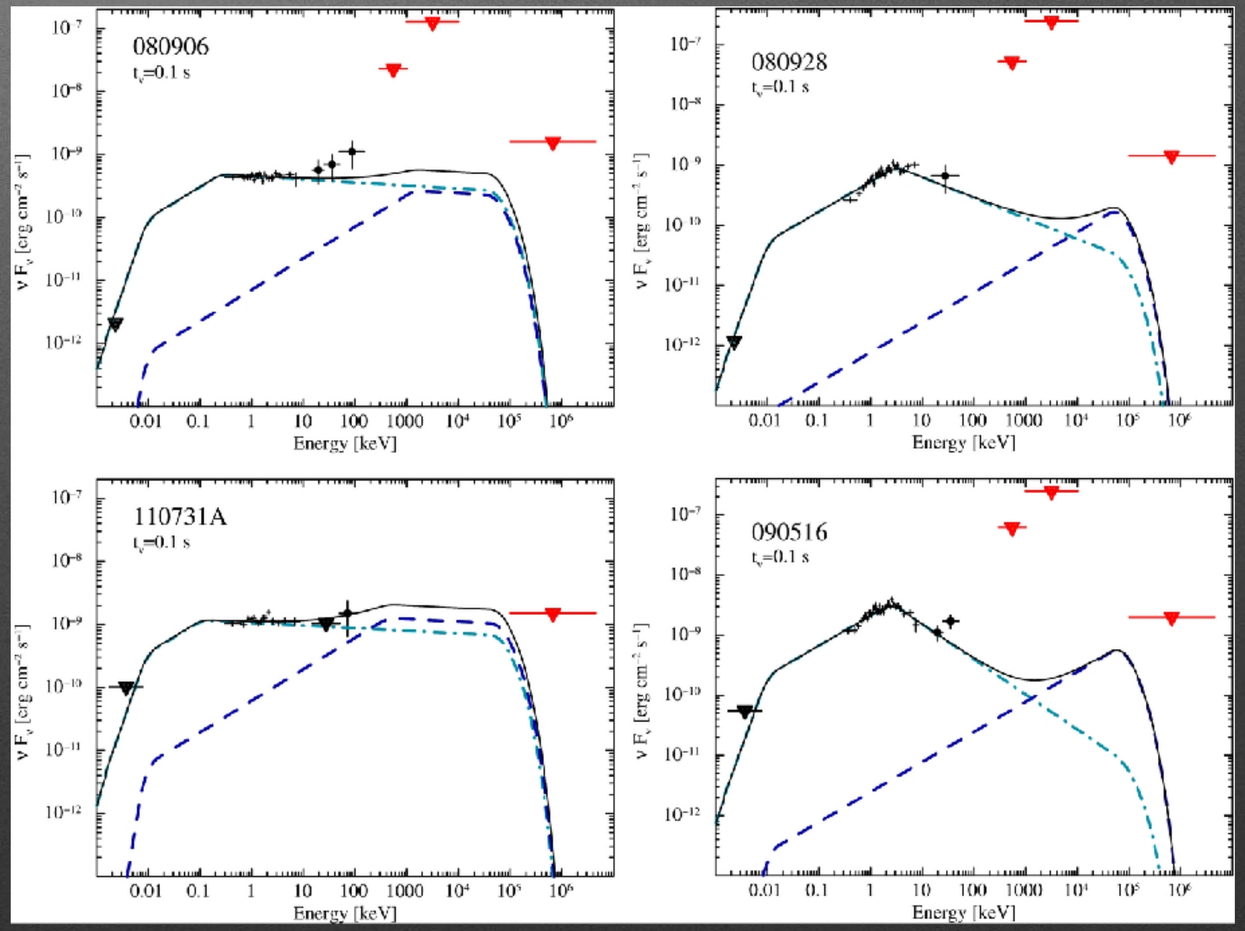


Racusin et al. 2011



X-ray Flares and GeV Emission

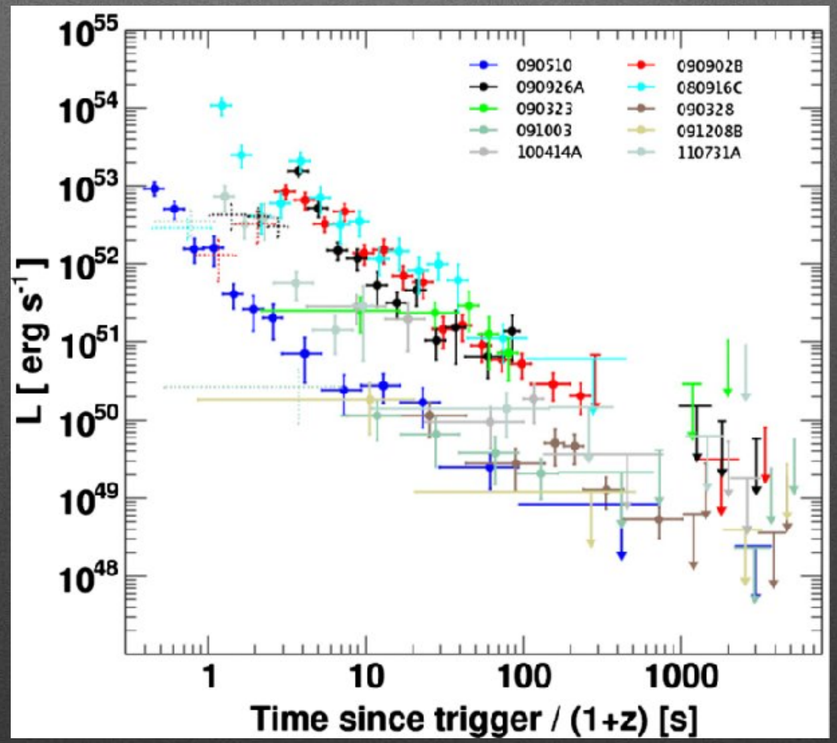
- No optical/gamma-ray flares during X-ray flares
- Disfavors inverse Compton origin of flares
- Favors late internal shock origin ($\Gamma > 50$ outflow at $R \sim 10^{13}$-10^{14} cm)
- Troja et al. 2015



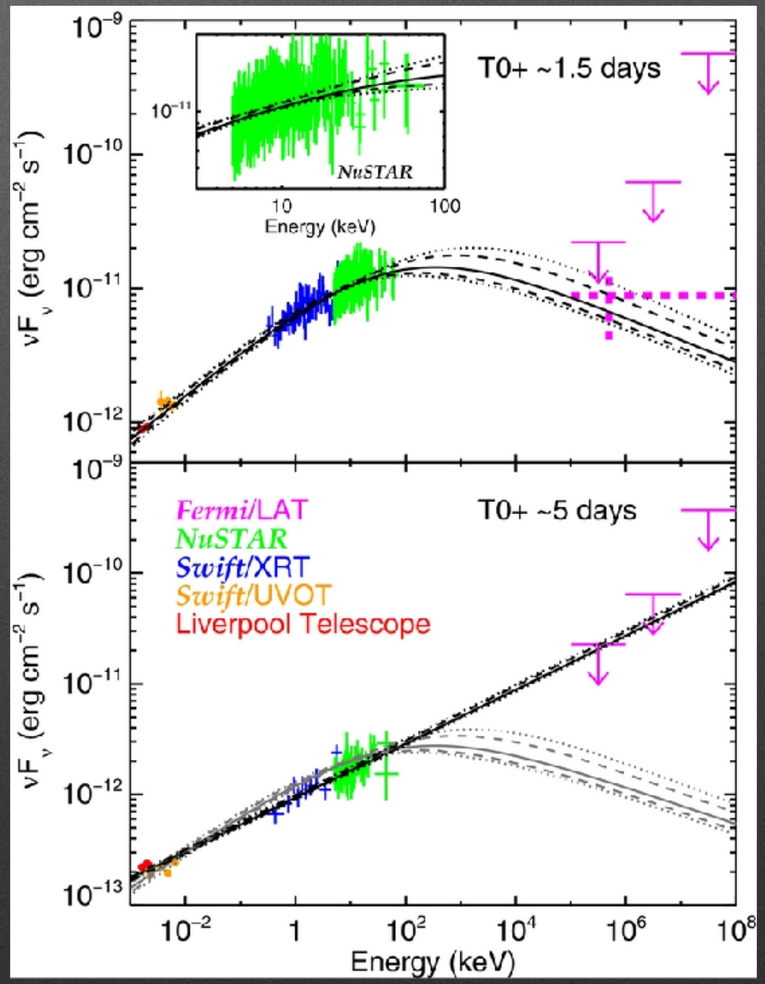
Troja et al. 2015

Gamma-ray Afterglows

- Fermi-LAT has detected long-lived (minutes-hours) emission from bright GRBs
- Often accompanied by an extra power-law spectral component
- Consistent with a single spectral component from radio-optical-X-ray-GeV



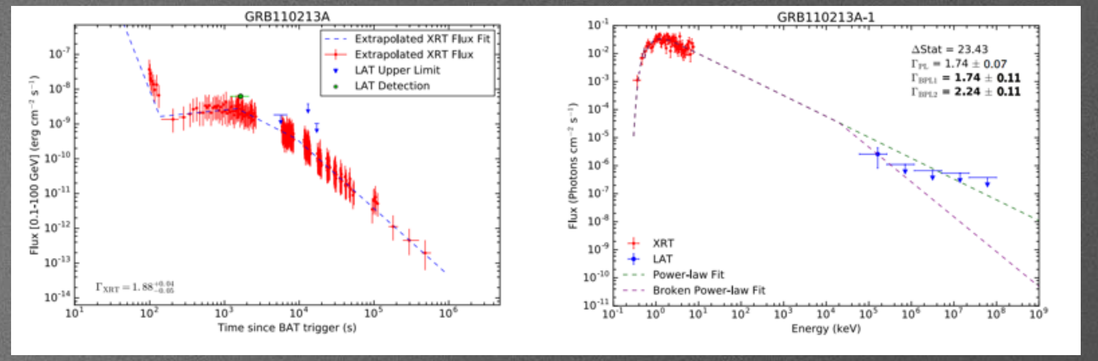
Ackermann et al. 2013

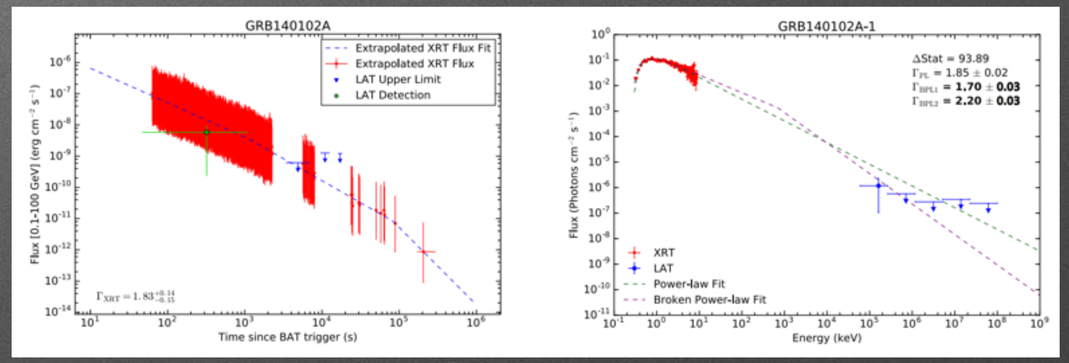


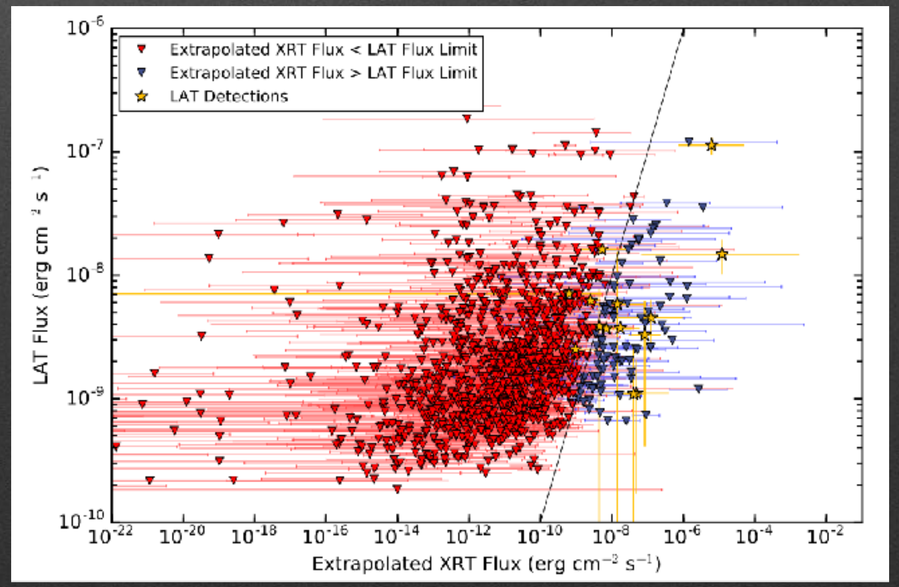
Kouveliotou et al. 2013

Origin of GeV Afterglows

- Extrapolating XRT spectra/lightcurves into GeV band to compare with LAT
- Fit either power laws or broken power laws (with delta of 0.5 for cooling break)
- No evidence of additional spectral component - no dominant SSC component in 100 MeV - 10 GeV range
- Lack of movement of cooling break hints that LAT GRBs may be preferentially in low-density wind-like environments
- Ajello et al. 2018 (submitted, contact authors Kocevski & Racusin)







In Summary

- *Swift* and *Fermi* have done a lot of great science together, much of it directly involving, inspired by, or built upon work by Neil, and will hopefully continue to do so for many more years
- Neil inspired all of us, and the missions that will fly in the coming decades