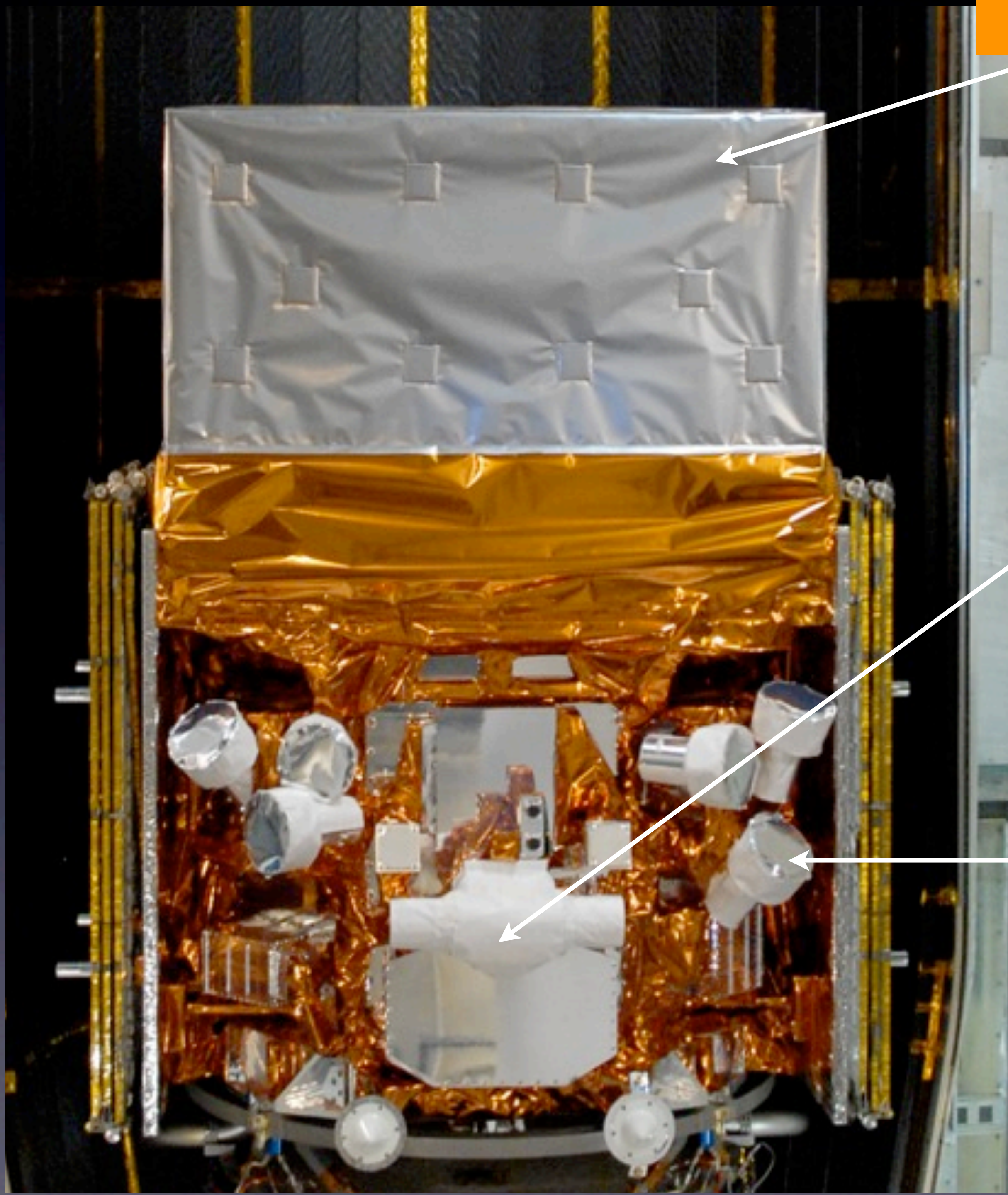
Fermi GBM Science.

Valerie Connaughton of the GBM Team.

Gamma-Ray Burst Monitor (GBM) on Fermi Spacecraft.



The Large Area Telescope (LAT)

GBM BGO detector.
200 keV -- 40 MeV
126 cm^2, 12.7 cm
Spectroscopy
Bridges gap between NaI and LAT.

GBM NaI detector.
8 keV -- 1000 keV
126 cm^2, 1.27 cm
Triggering, localization, spectroscopy.

Fermi comparison with CGRO

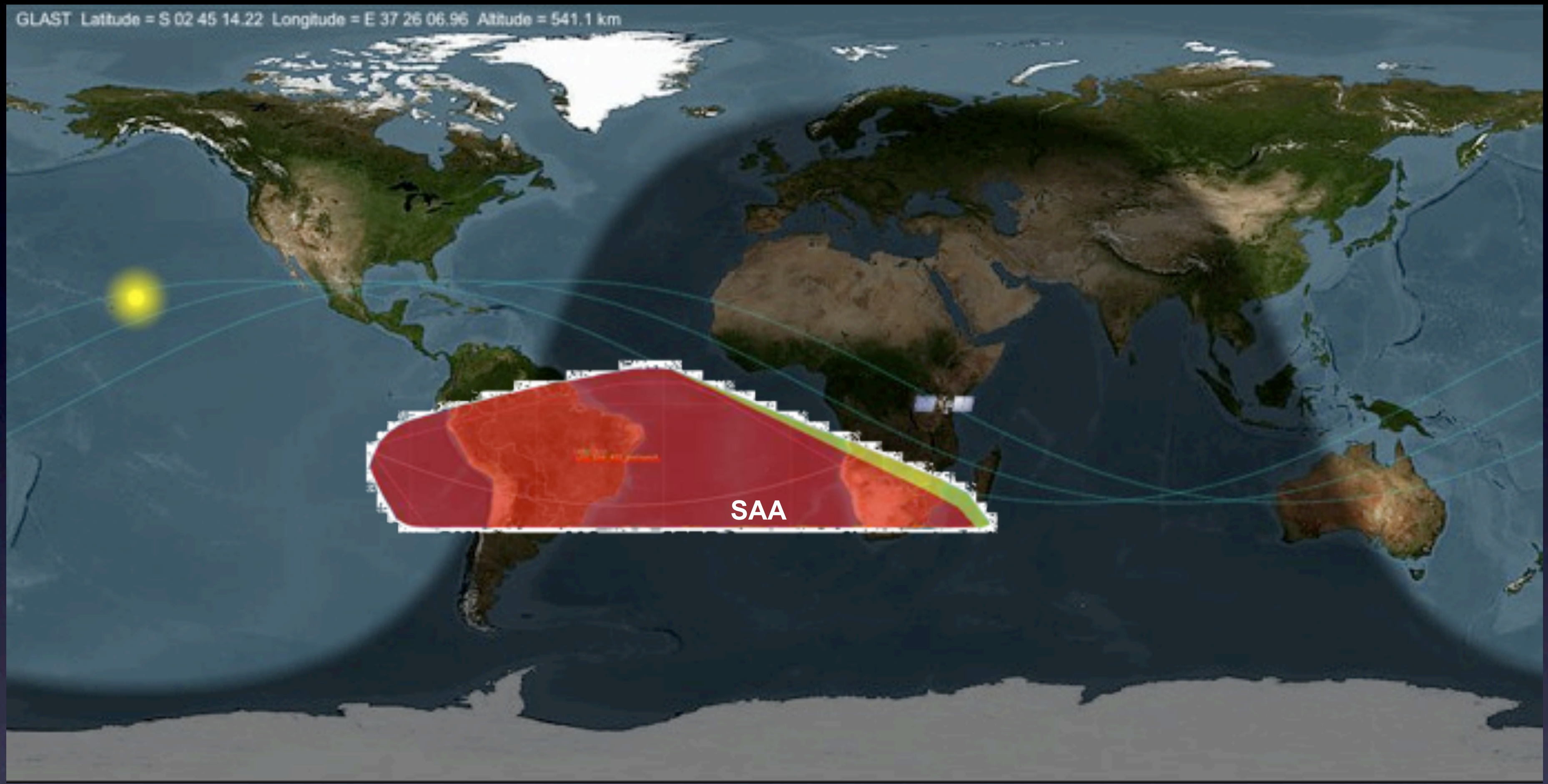
- LAT is a souped-up EGRET from Compton Gamma-Ray Observatory.
- GBM is a scaled-down BATSE... but with improvements.

	LAT	EGRET
Energy range	20 MeV to >300 GeV	20 MeV – 30 GeV
Energy resolution (on axis, 100 MeV – 10 GeV)	<10%	10%
Peak effective area	9000 cm^2	1500 cm^2
Angular resolution (single photon, 10 GeV)	0.15°	0.54°
Field of view	>2.2 sr	0.4 sr
Deadtime per event	27 us	100 ms

	BATSE	GBM
TOTAL MASS	850 kg	115 kg
TRIGGER THRESHOLD	~0.2 ph/cm^2/s	0.61 ph/cm$^{2/}$s (true threshold)
TELEMETRY RATE	3.55 kbps	15 - 25 kbps
	Large Area Detectors	Low-Energy Detectors
Material	NaI	NaI
Number	8	12
Area	2025 cm^2	126 cm^2
Thickness	1.27 cm	1.27 cm
Energy range	25 keV to 1.8 MeV	8 keV to 1 MeV
	Spectroscopy Detectors	High-Energy Detectors
Material	NaI	BGO
Number	8	2
Area	126 cm^2	126 cm^2
Thickness	7.62 cm	12.7 cm
Energy range	30 keV to 10 MeV	150 keV to 30 MeV

Instrument details:
Meegan et al. 2009 ApJ 702 p.791

The Fermi Orbit

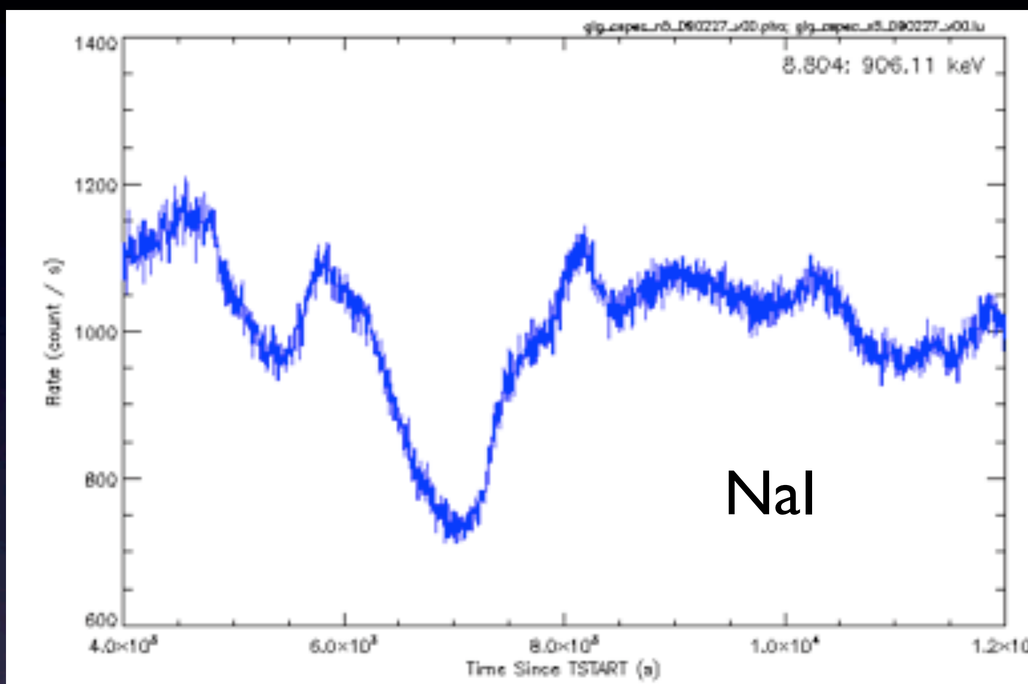


Fermi is now in 25.6° orbit 565 km above Earth with 96 min orbit. Both LAT and GBM record data continuously except when HV are turned off in SAA.

GBM continuous data

2 Varieties: CSPEC (4.096 s, 128 energy channels),

CTIME (0.256 s, 8 energy channels).



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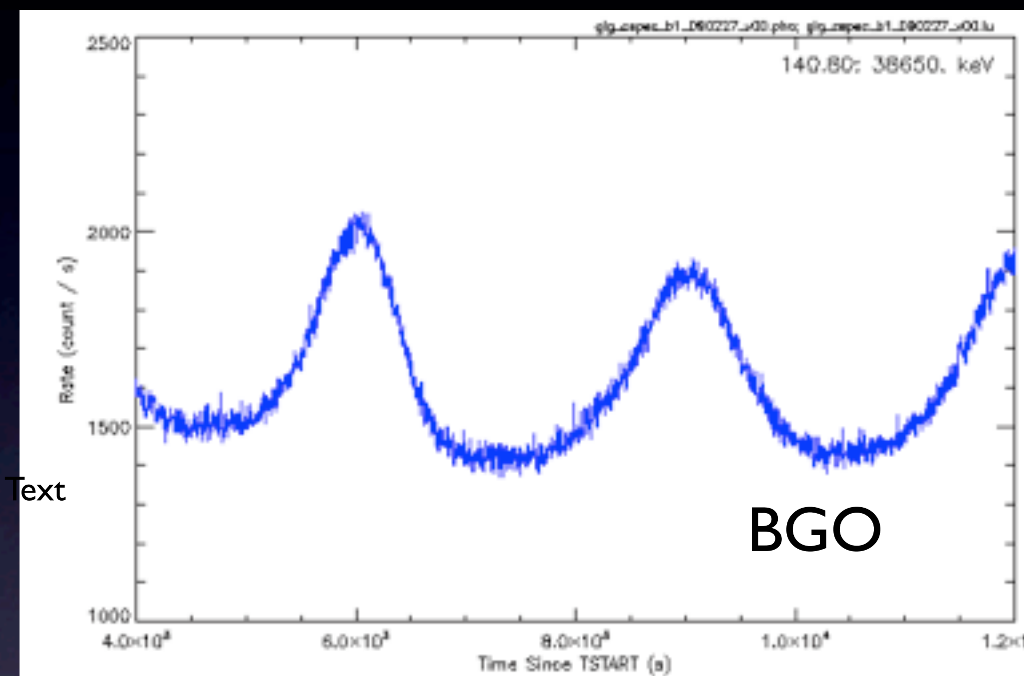
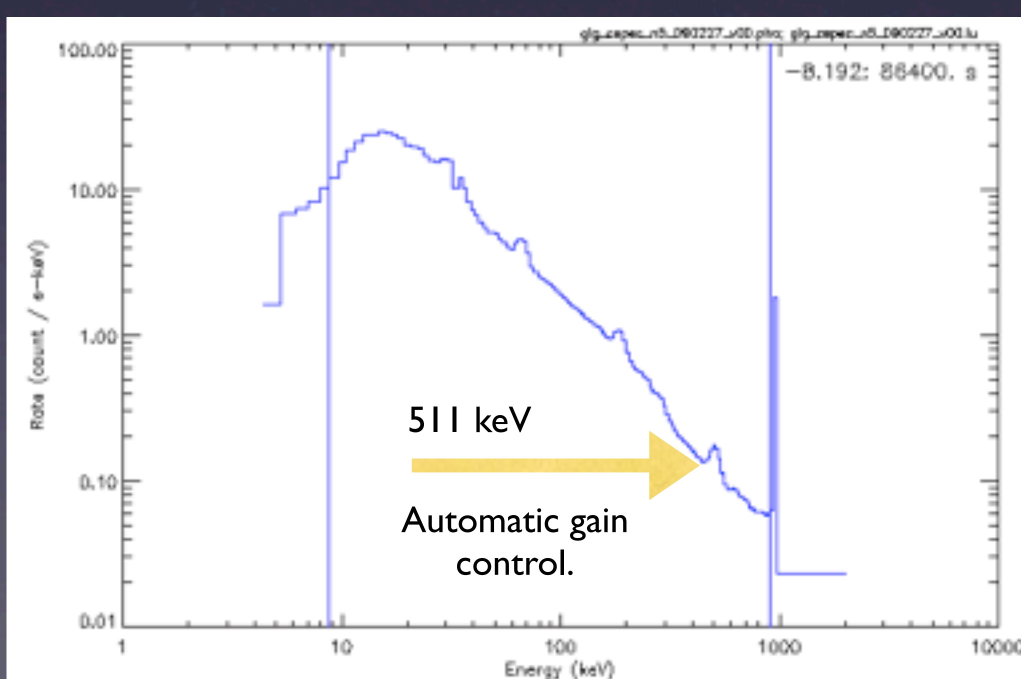
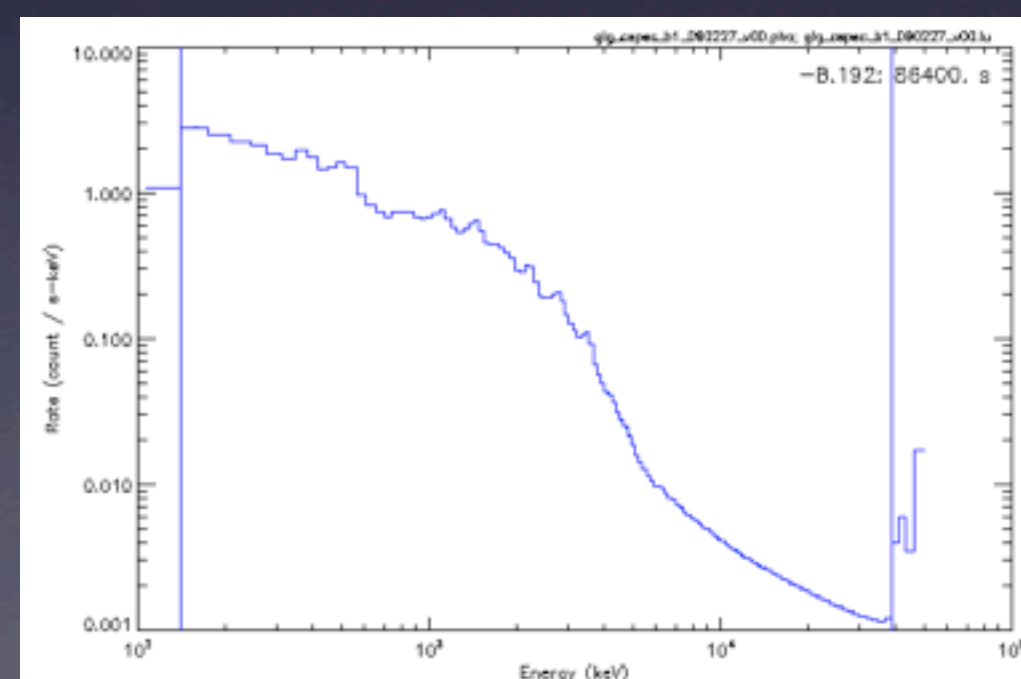


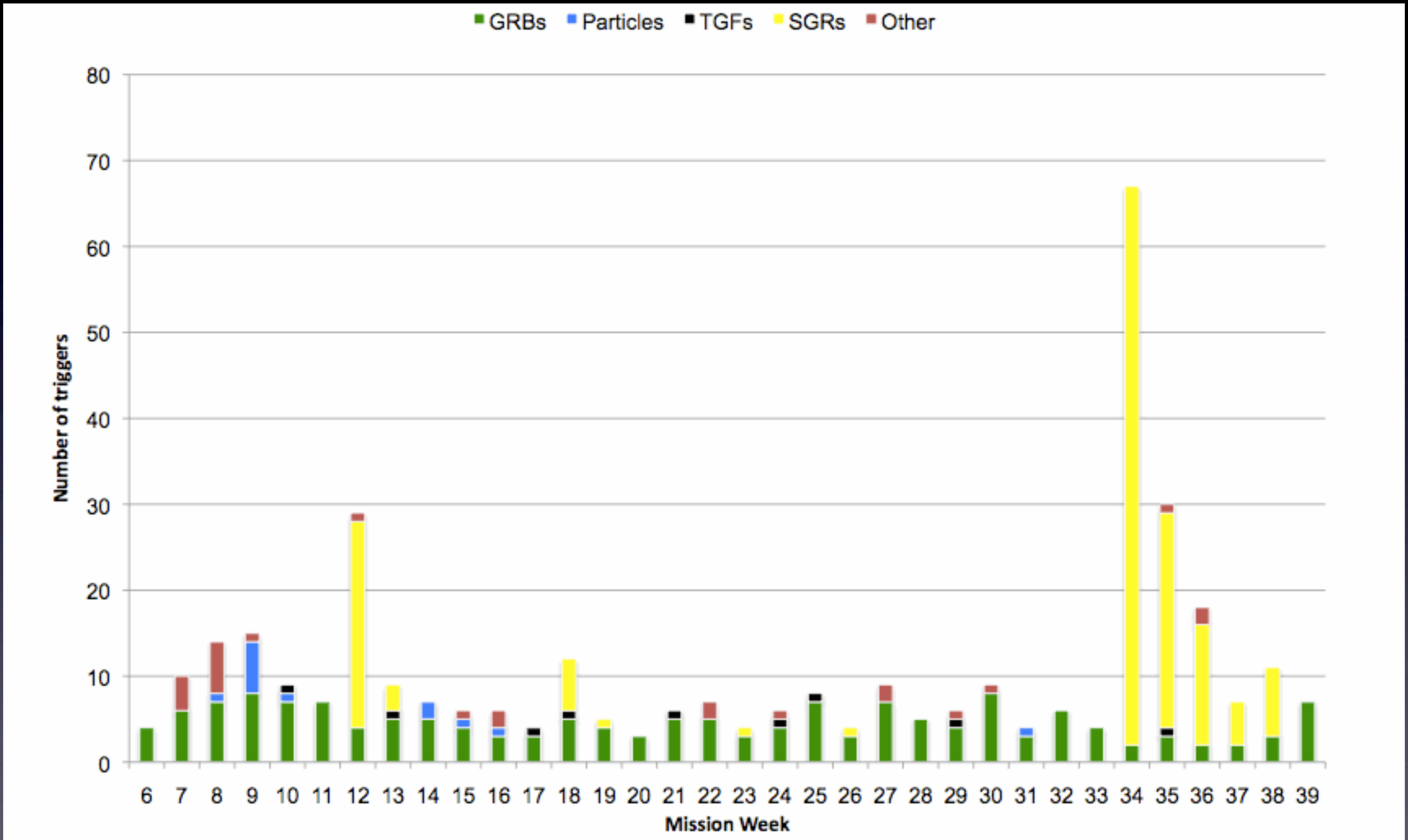




GBM Triggering

- GBM is a background-limited instrument though we shall see that its background is profoundly rich!
- GBM triggers when 2 or more detectors exceed background by n sigma over t timescale in e energy band.
- 62 algorithms operating simultaneously.
    - $4.5 \leq n \leq 7.5$ (cf 5.5 sigma for BATSE)
    - 16 ms $\leq t \leq$ 8.096 s (cf 64, 256, 1024 ms for BATSE)
    - e = one of 25 - 50 keV, 50 - 300 keV, 100 - 300 keV, > 300 keV (only 1 energy range at a time for BATSE)
- On triggering, CSPEC and CTIME are accelerated (1.024 s and 64 ms resolution). TTE (Time-Tagged Events) are produced for ~ -25 s -- 300 s from trigger time. These record time to 2 microsecond precision.
- What does GBM trigger on?

GBM Weekly Triggers

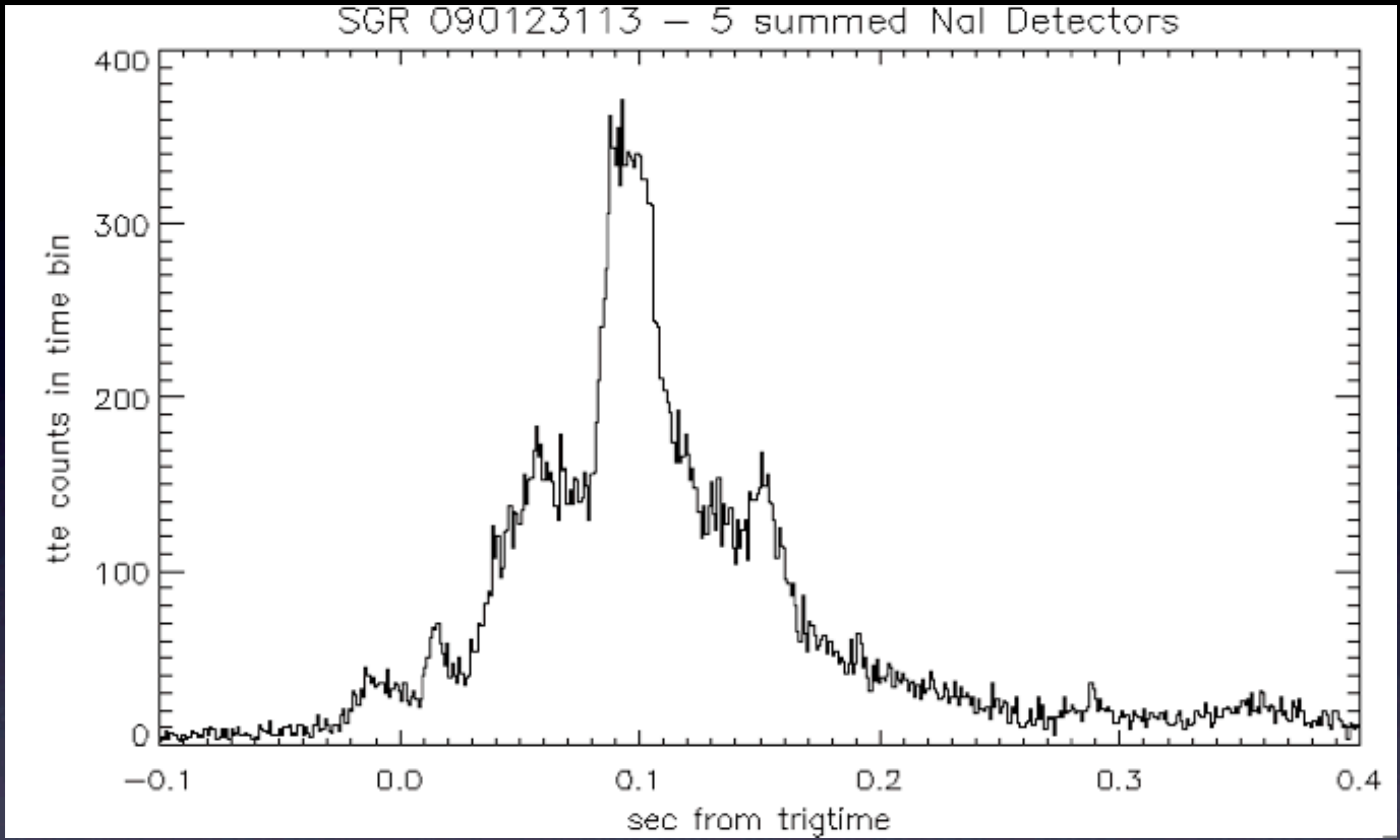


Valerie Connaughton

GBM Yearly Trigger Summary

- 253 GRBs
- 62 commanded (test)
- 168 SGRs -- most on soft, short trigger algorithms.
- 14 TGFs -- all on hard, short trigger algorithms.
- 1 solar flare
- Others are Cyg X-1 rises, accidentals, and particle events.

Soft Gamma-ray Repeaters



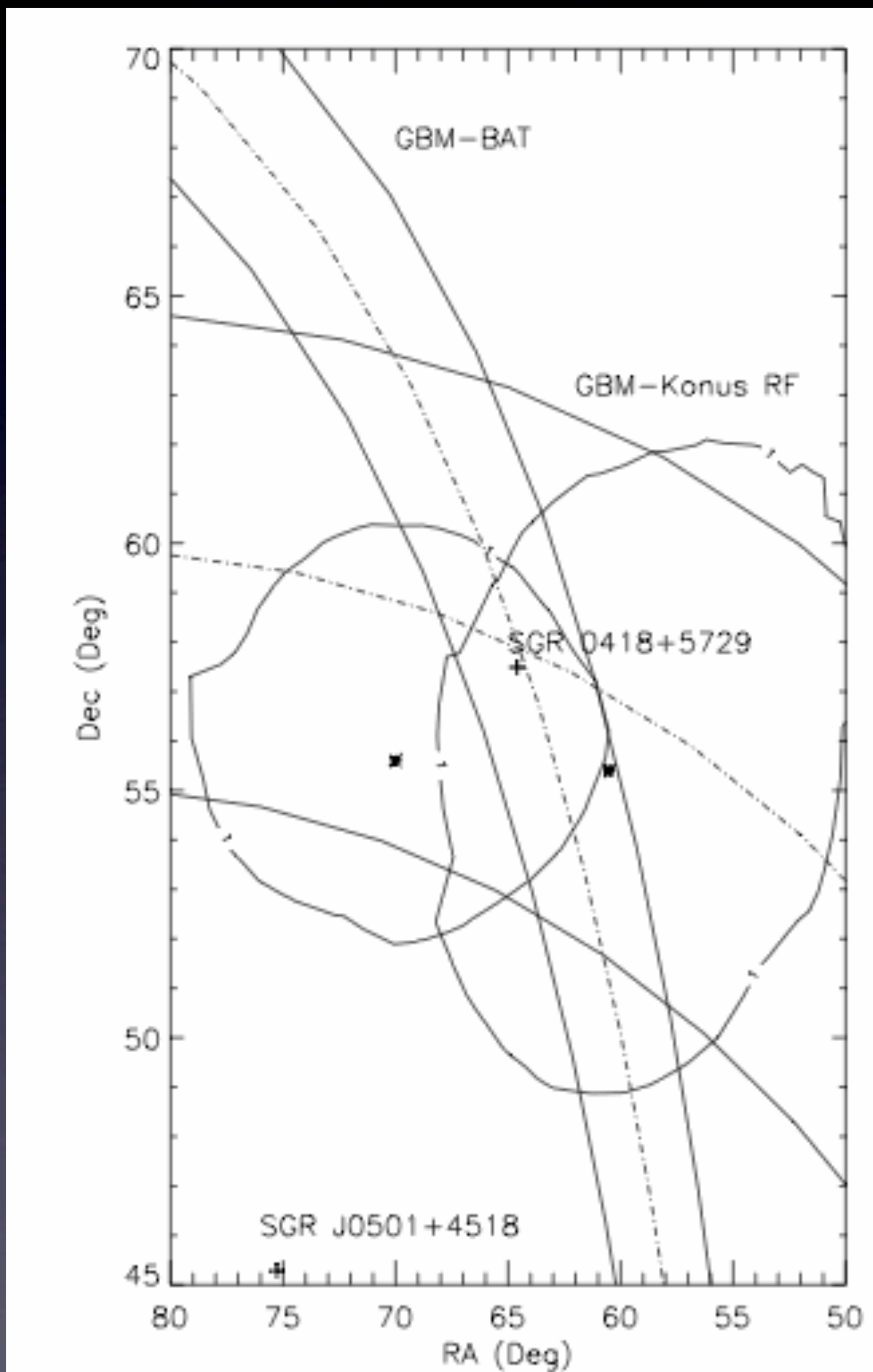
4 different sources, one of them seen in 2 outbursts, 1 of them newly discovered using the GBM triggers to identify source as an SGR.

http://gammaray.nsstc.nasa.gov/gbm/science/magnetars

DISCOVERY OF A NEW SOFT GAMMA REPEATER: SGR J0418 + 5729

A. J. van der Horst[1], V. Connaughton[2], C. Kouveliotou[3], E. Göğüş[4], Y. Kaneko[4], S. Wachter[5], M. S. Briggs[2], J. Granot[6], E. Ramirez-Ruiz[7], P. M. Woods[8], R. L. Aptekar[9], S. D. Barthelmy[10], J. R. Cummings[10], M. H. Finger[11], D. D. Frederiks[9], N. Gehrels[10], C. R. Gelino[12], D. M. Gelino[13], S. Golenetskii[9], K. Hurley[14], H. A. Krimm[10], E. P. Mazets[9], J. E. McEnery[10], C. A. Meegan[11], P. P. Oleynik[9], D. M. Palmer[15], V. D. Pal'shin[9], A. Pe'er[16], D. Svinkin[9], M. V. Ulanov[9], M. van der Klis[17], A. von Kienlin[18], A. L. Watts[17] C. A. Wilson-Hodge[3]

Draft version January 6, 2010



2 GBM bursts... inconsistent with known SGRs but seem to have a common origin => one seen also with Konus and Swift BAT.

Follow-up observations with Chandra reveal a source with a spin period of ~ 9 s.

ArXiv: 0911.5544

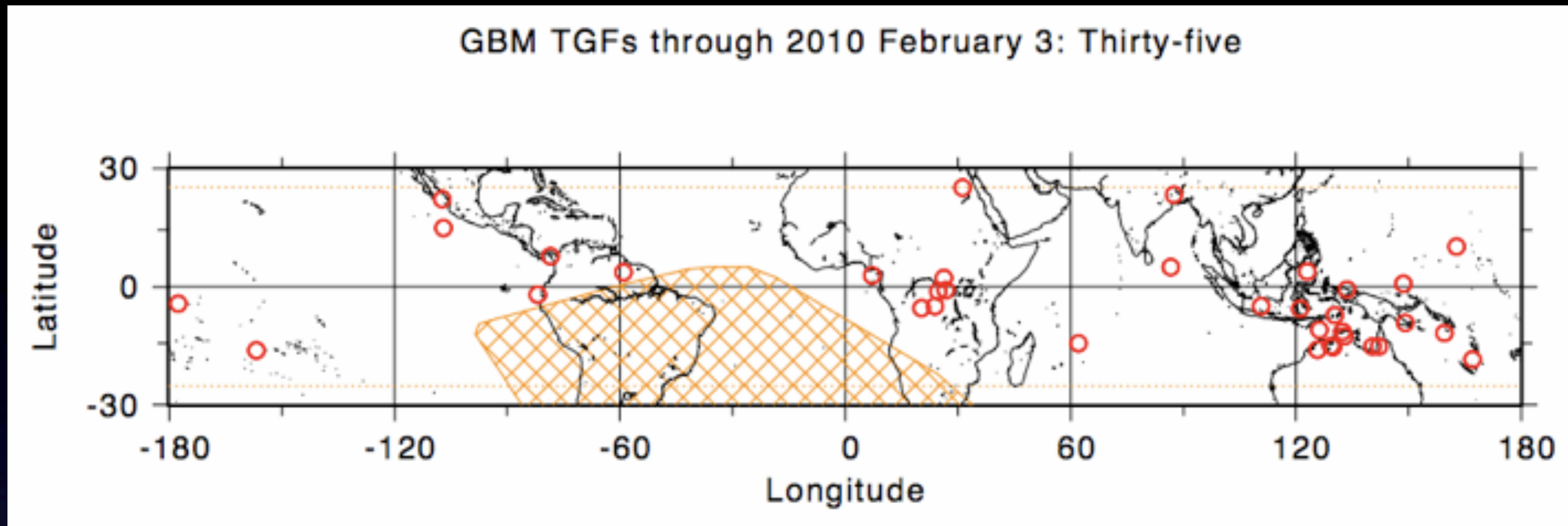
Spectroscopy of SGR bursts.

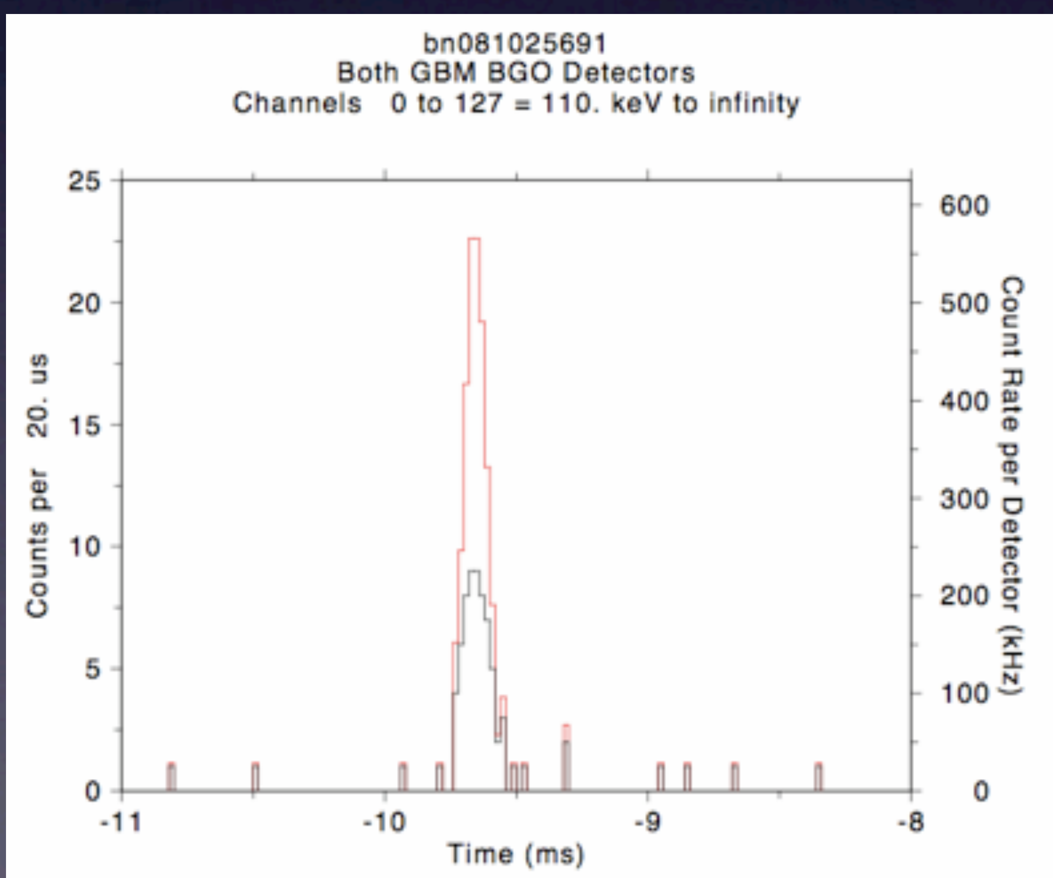
- A burgeoning field!
- Power-law with exponential cut-off? Black-body? Optically-thin thermal Bremsstrahlung (OTTB)?
- GBM is suited to test these models because of its wide energy coverage.

MAGNETAR TWISTS: FERMI/GAMMA-RAY BURST MONITOR DETECTION OF SGR J1550-5418

Yuki Kaneko et al 2010 ApJ 710 1335-1342

Terrestrial Gamma-ray Flashes



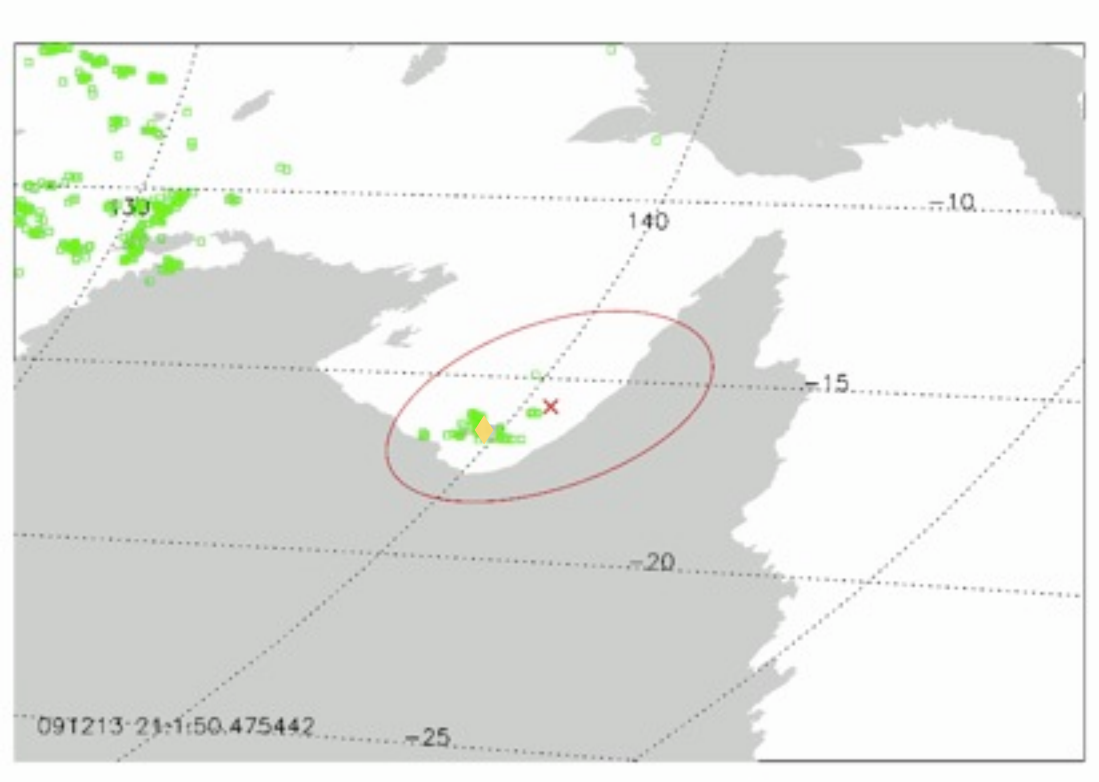


First GBM TGF Science in:
Briggs et al. and Fishman et al. submitted to JGR.

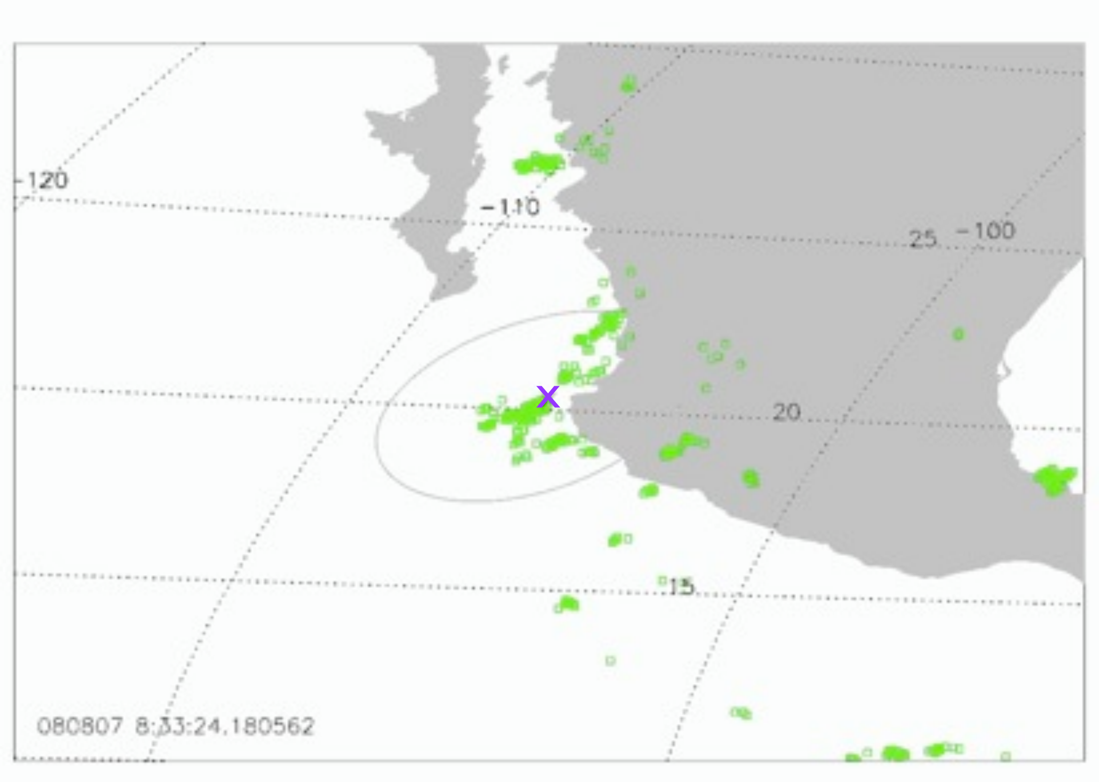
< 1 - 25 ms duration (most < 1 ms).
V. Hard spectra > 30 MeV
Associated with thunderstorms.
"Runaway electron" processes.
35 of these so far.

TGFs and lightning

- Association with storm systems near sub-spacecraft postion... and in 9 cases, individual lightning strokes.   (Connaughton et al. in preparation). This uses World Wide Lightning Locator Network (WWLLN) data.



- Some are puzzling... no storm systems under Fermi. These are more likely lepton events from magnetic footprint. These events are longer (> 1 ms) and softer.

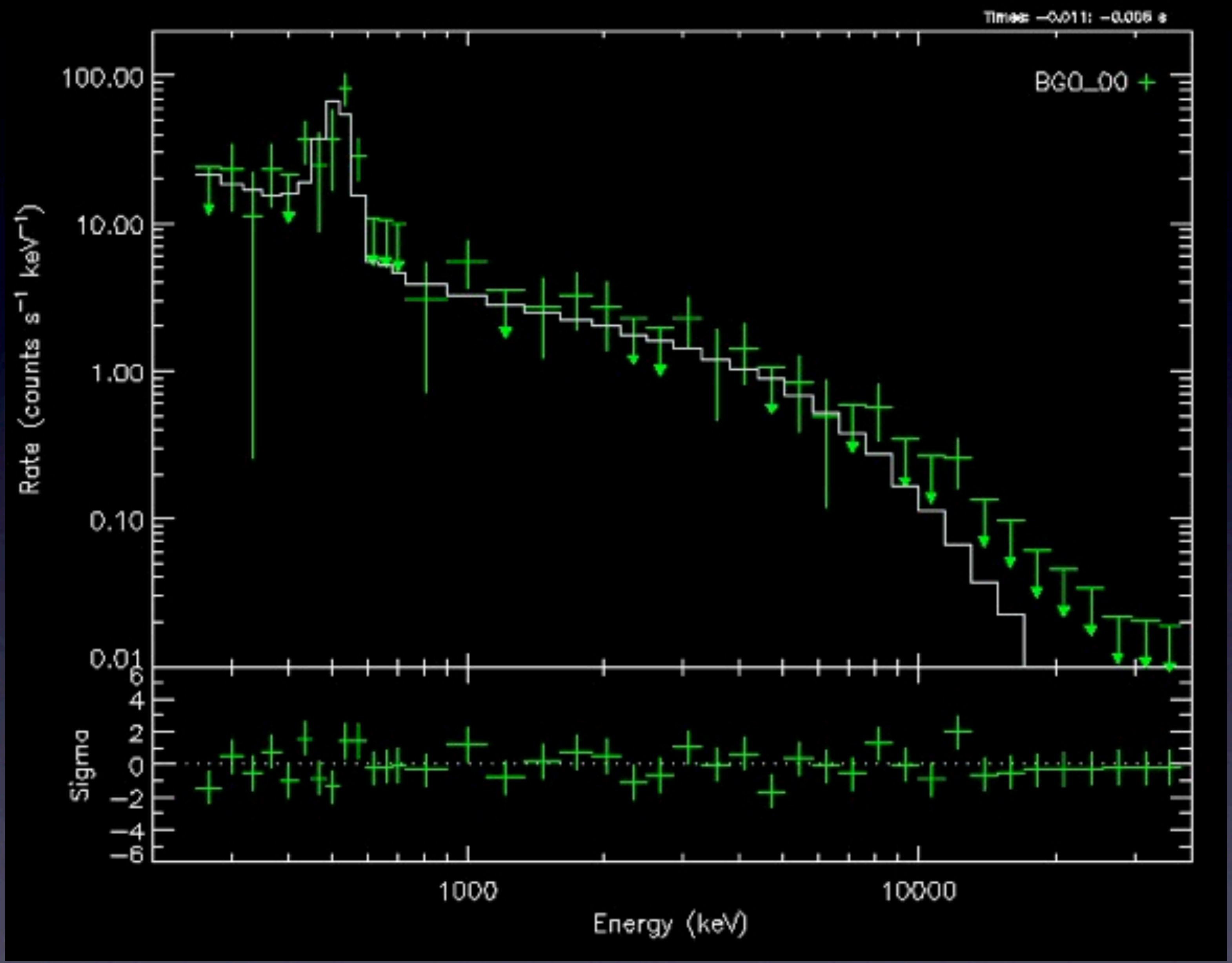


Leptonic TGFs - positrons!

P=1.1E-8

(Gaussian equivalent: 5.6σ)

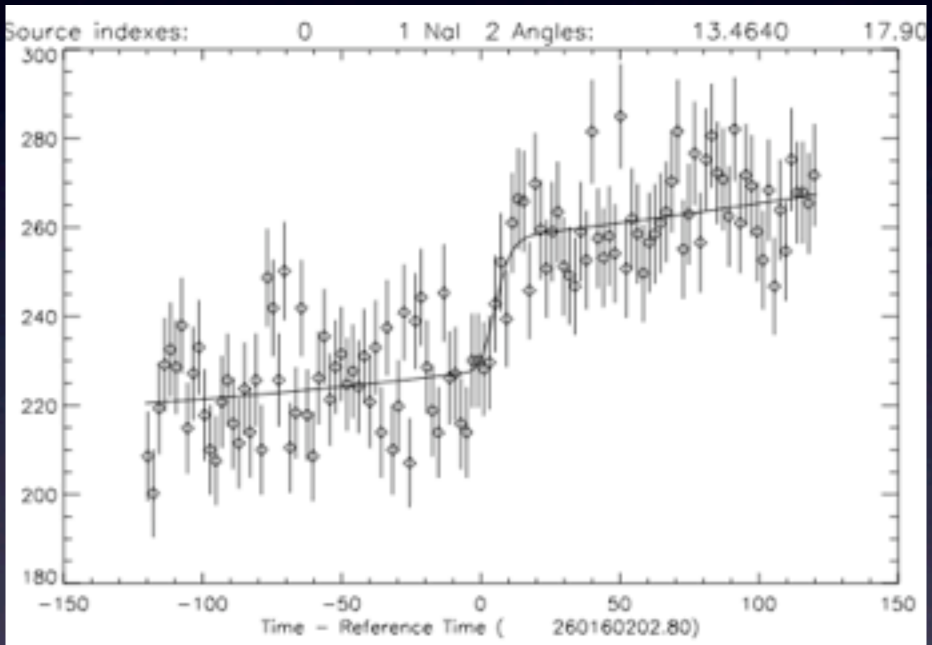
Fit with a mixture of electrons & positrons incident on *Fermi*. Positron fraction is 22 ± 3%.



M.S. Briggs et al. in preparation.

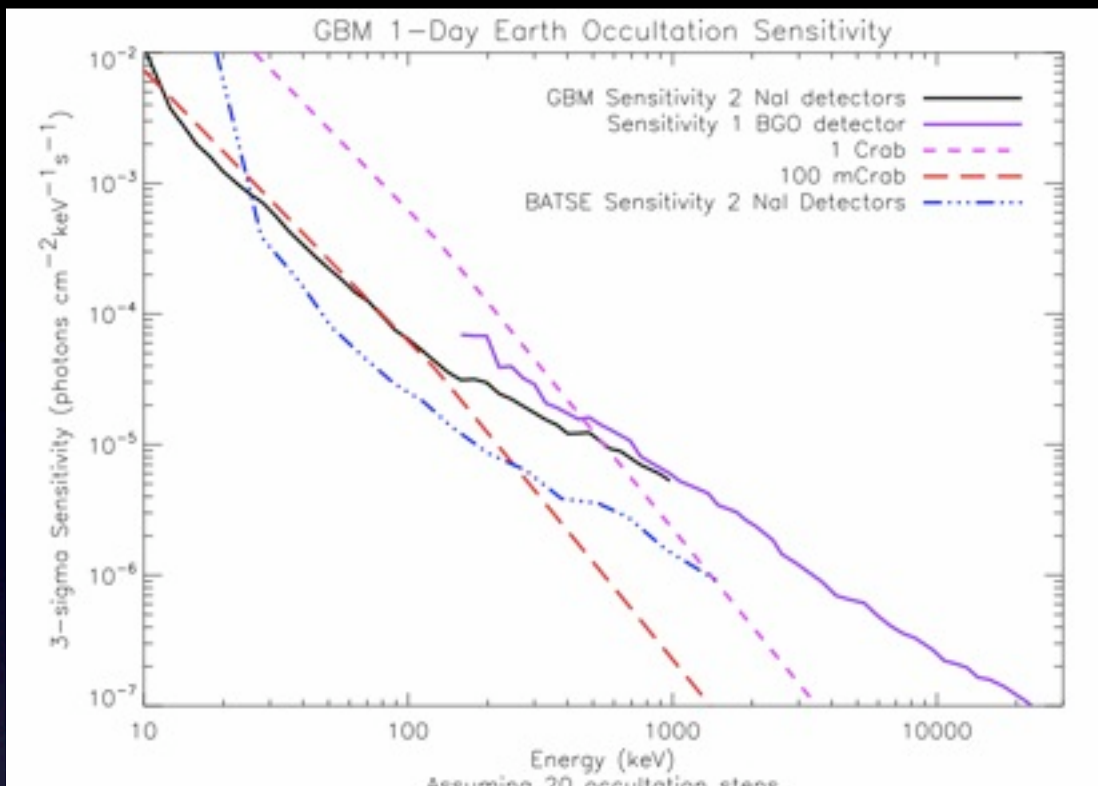
"Background" Investigations

- Earth Occultation Technique: Every orbit, sources hide behind and rise from the Earth's limb when viewed from Fermi. Can we measure the contribution these sources make to the rates measured in the GBM detectors?
  All-Sky Earth Occultation Observations with the Fermi GBM, Wilson-Hodge et al., arXiv0912.3831

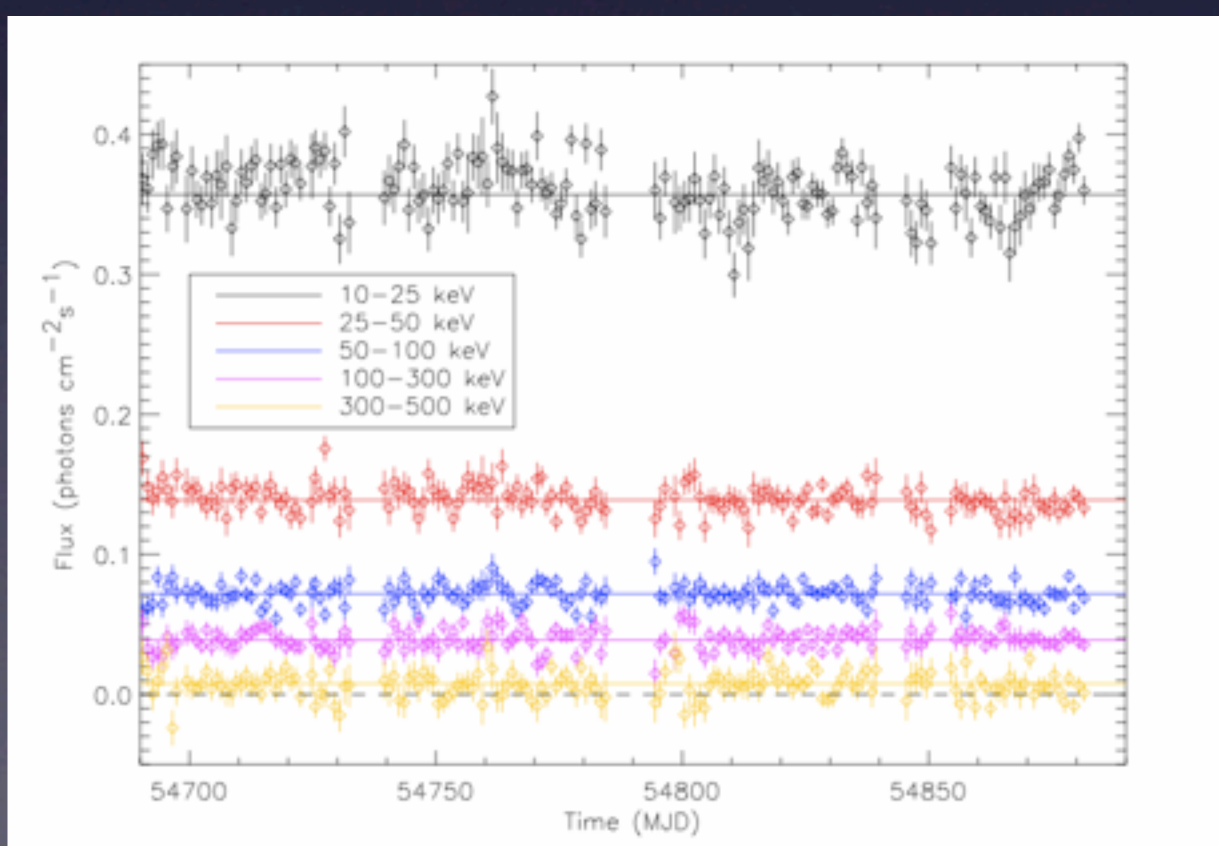


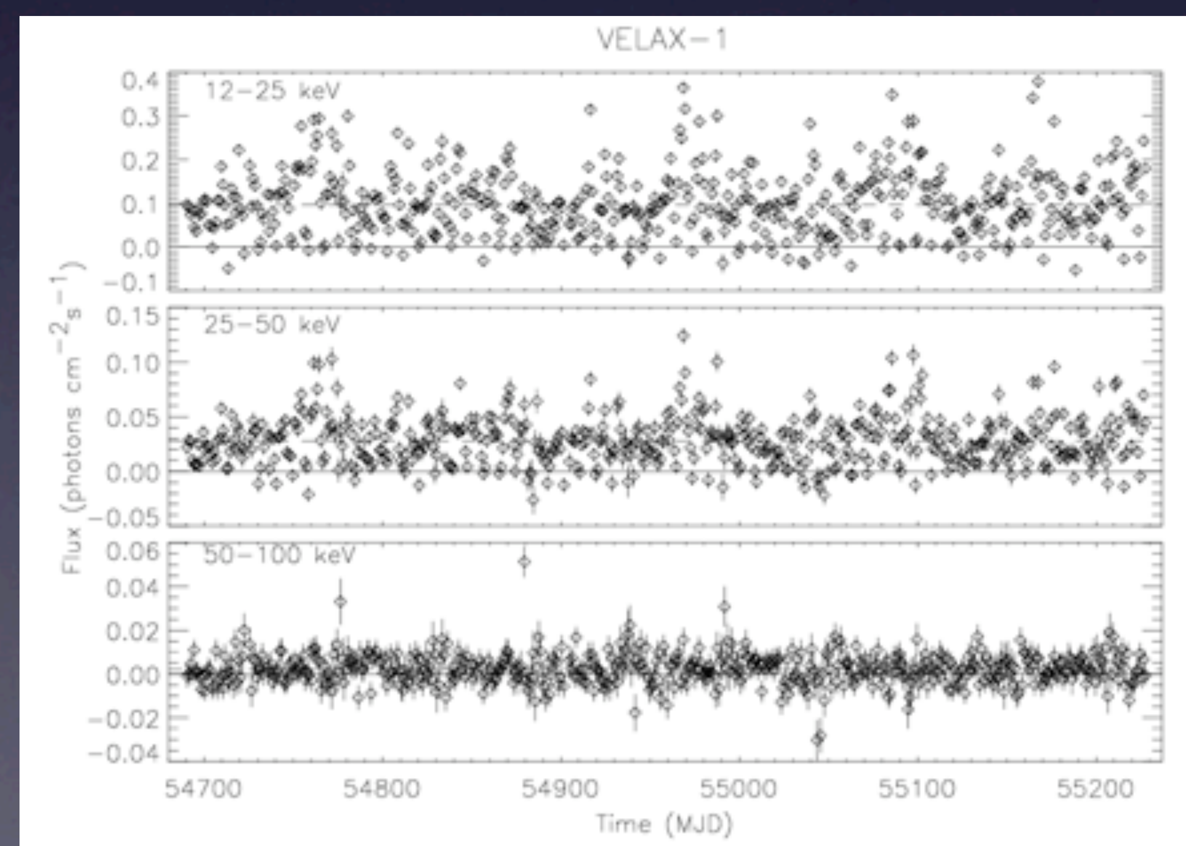
- Pulsars: By fitting and subtracting the obvious trends in the GBM data, including bright source occultations, and excluding periods of obvious "noise" (triggers!), can we measure in the residuals the temporal signature of expected and new pulsars?
  Long-term Monitoring of Accreting Pulsars with Fermi GBM, Finger et al., arXiv0912.3847.

GBM Occultation Results



- Technique picks up steady, variable, & periodic sources.
- Long-term monitoring including "look back".
- New transients.
- Starting to look in BGO.
- Starting to monitor AGN (see Cen A).

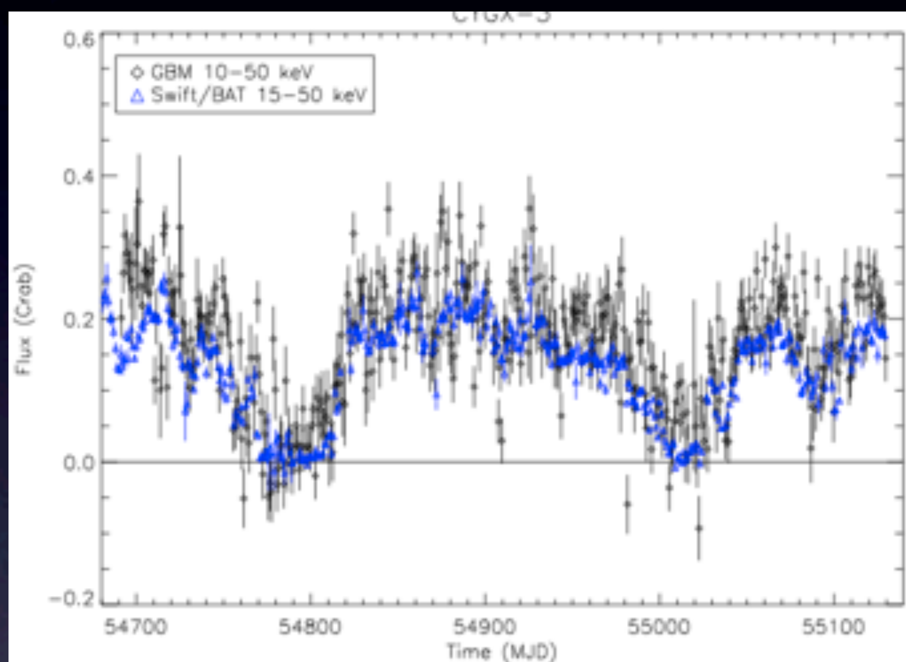


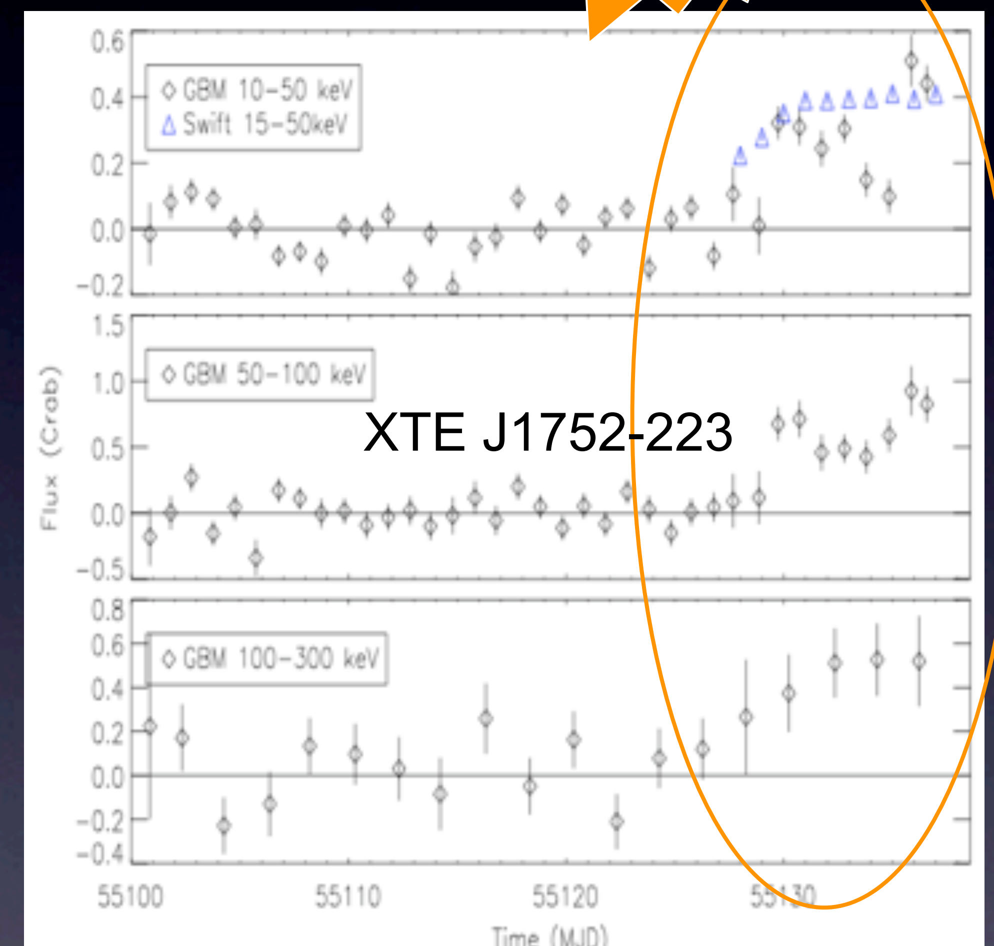


GBM Occultation Results

New BH Transient!

GRS 1915+105 - consistency with Swift BAT





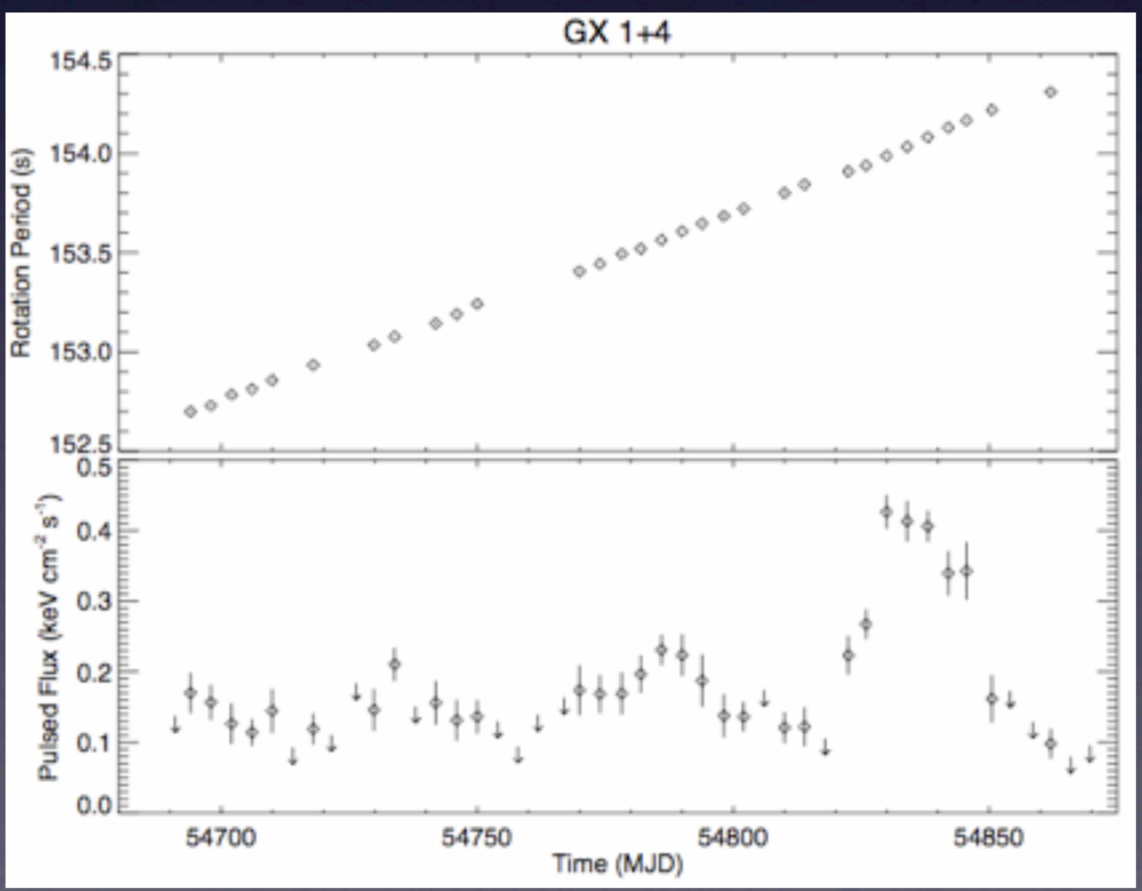
Not so sensitive as BAT but wider energy coverage (low and high) and complementary when Swift BAT cannot view a source.

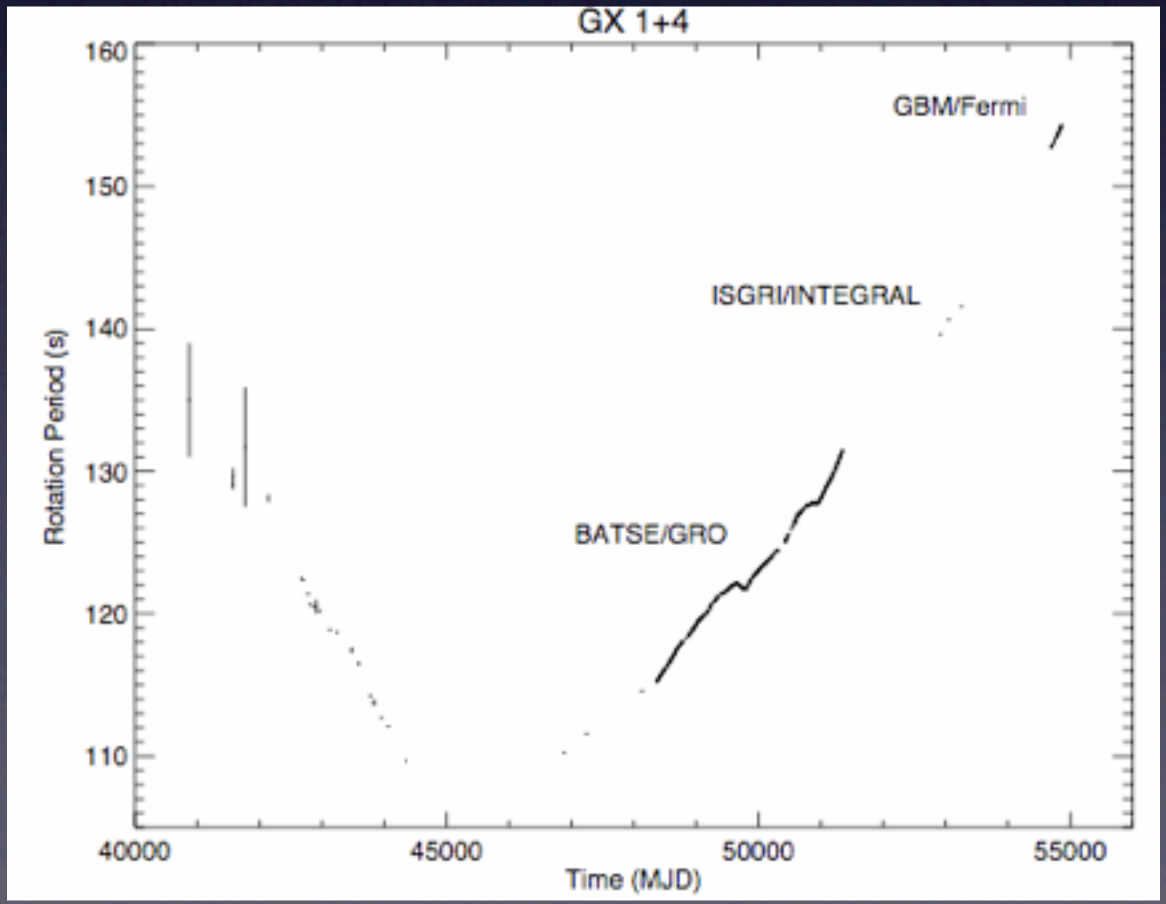
http://gammaray.nsstc.nasa.gov/gbm/science/occultation

GBM Pulsar Results

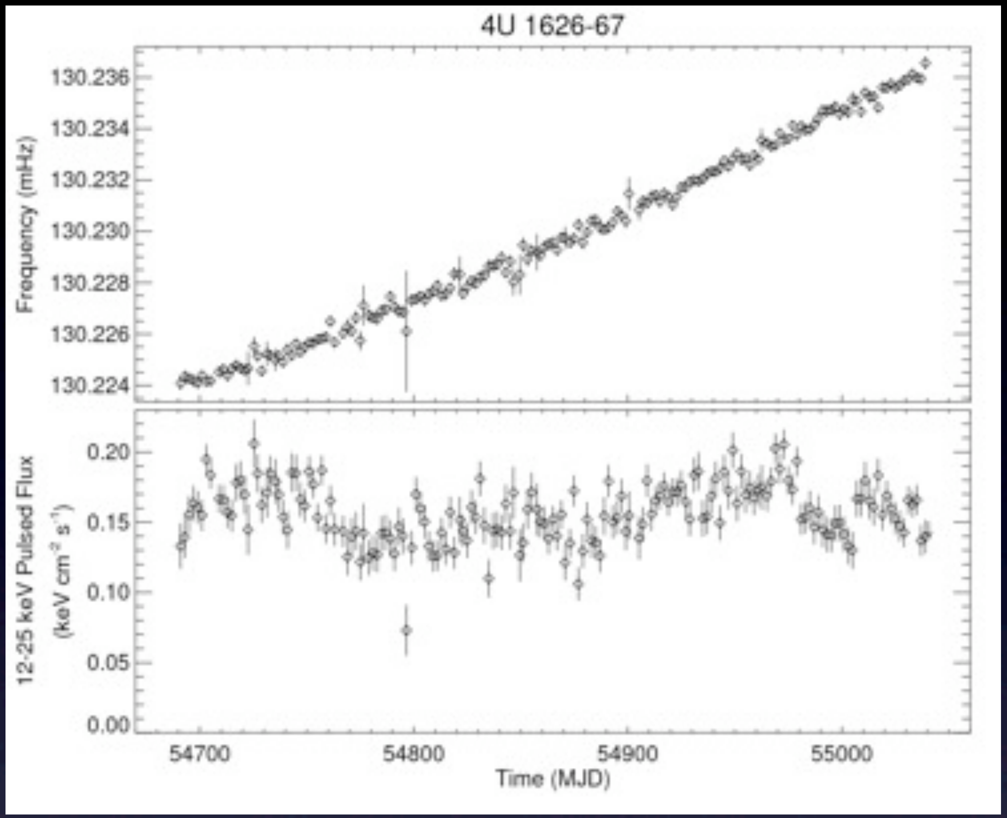
- Search for pulsars from 1 mHz -- 2 Hz in CTIME data.
- Several seen routinely: 4U 1626-67, Cen X-3, OAO 1657-415, GX 1+4, Vela X-2, GX 301-2.
- Several seen only in parts of orbit: Her X-1.
- Several seen in outburst: EXO 2030+375, A 0535+6, A 1118-615.

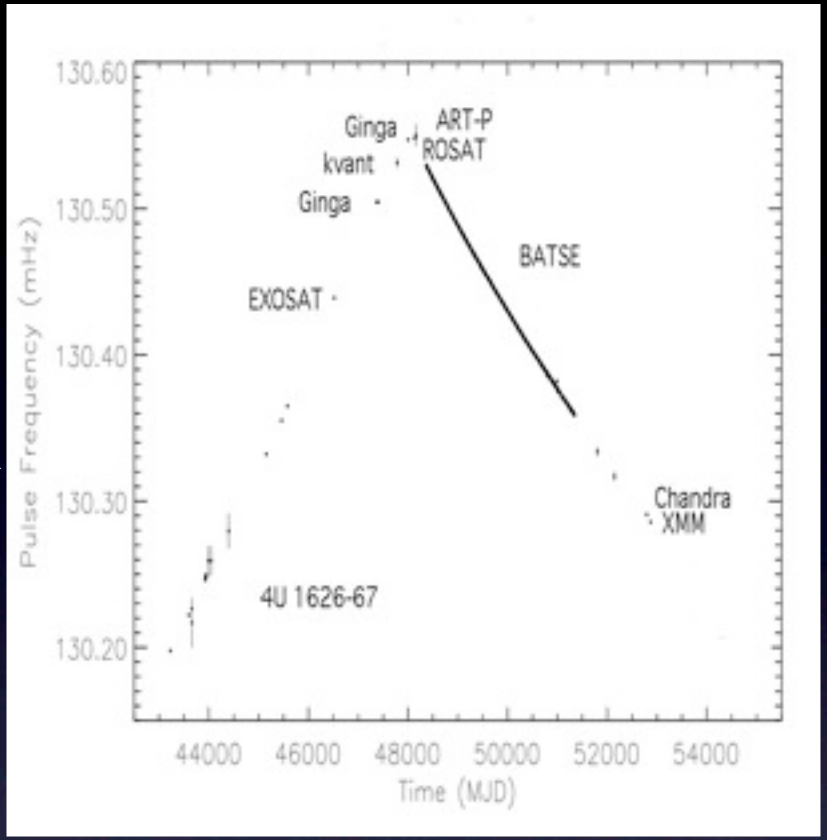
http://gammaray.nsstc.nasa.gov/gbm/science/pulsars



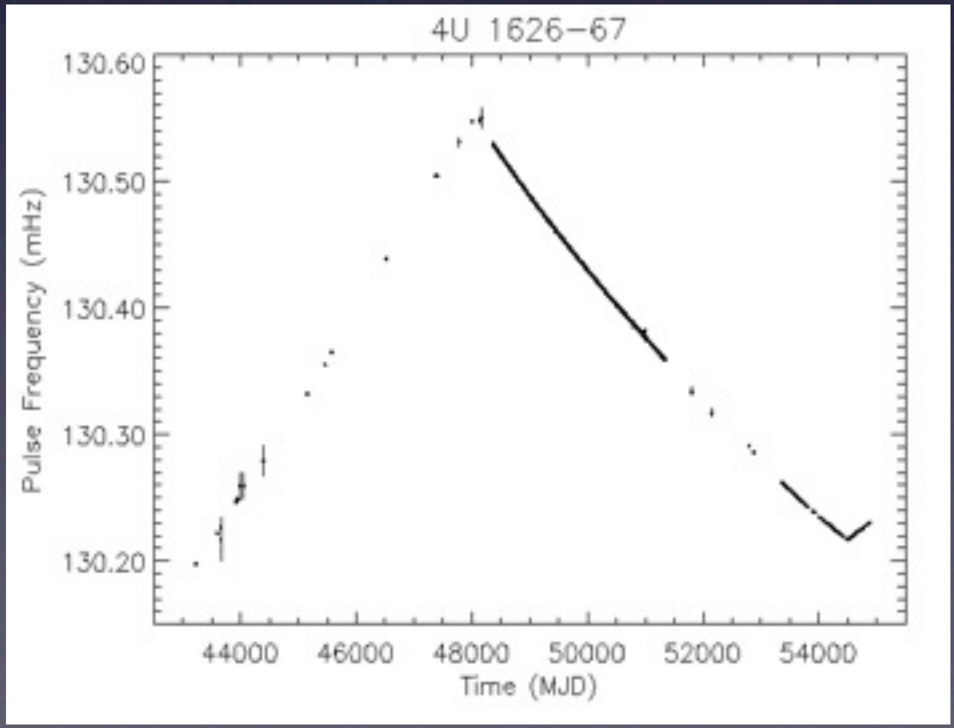


The unusual case of 4U 1626-67





Fill gap with BAT

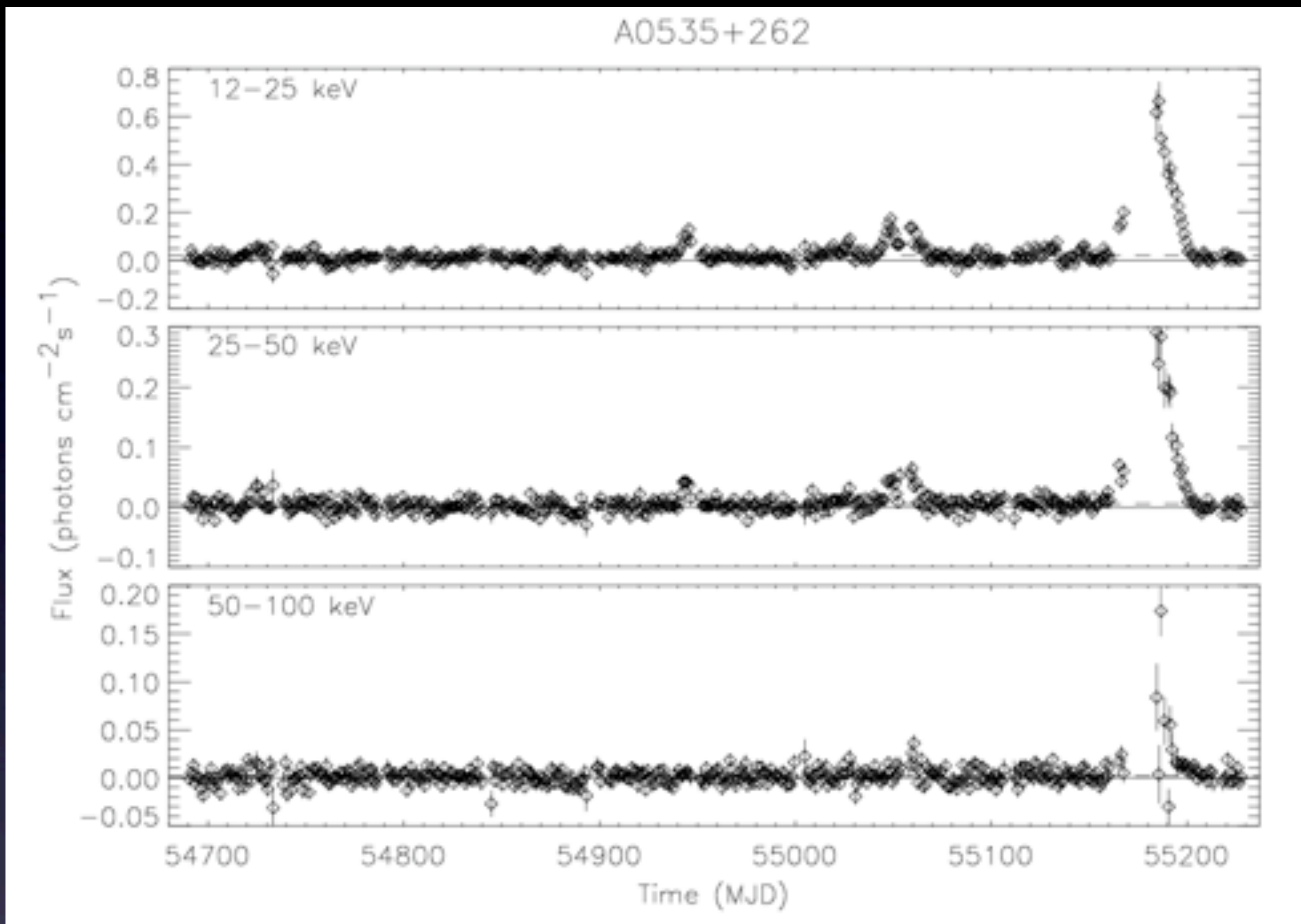


New Torque Reversal and Spin-Up of 4u 1626- 67 Observed by Fermi/GBM, uncovered in Swift/BAT.

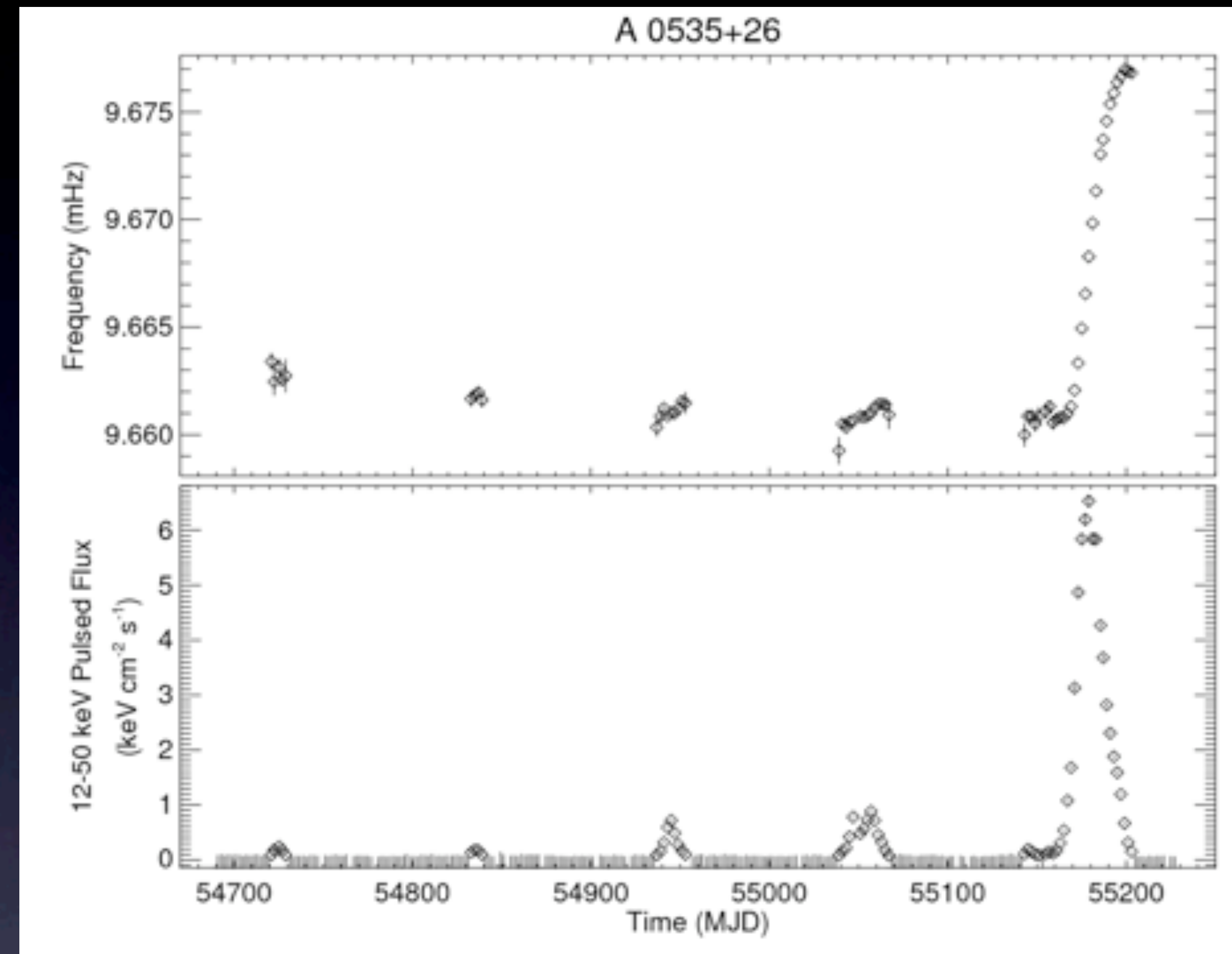
Camero-Arranz et al. ApJ 708, p1500 (2010)
arXiv:006.4224

GBM as pulsar outburst monitor

Occultation



Pulsar monitoring



Rapid Brightening of A0535+26 Observed by Fermi GBM

ATel 2434 (Wilson-Hodge et al.)

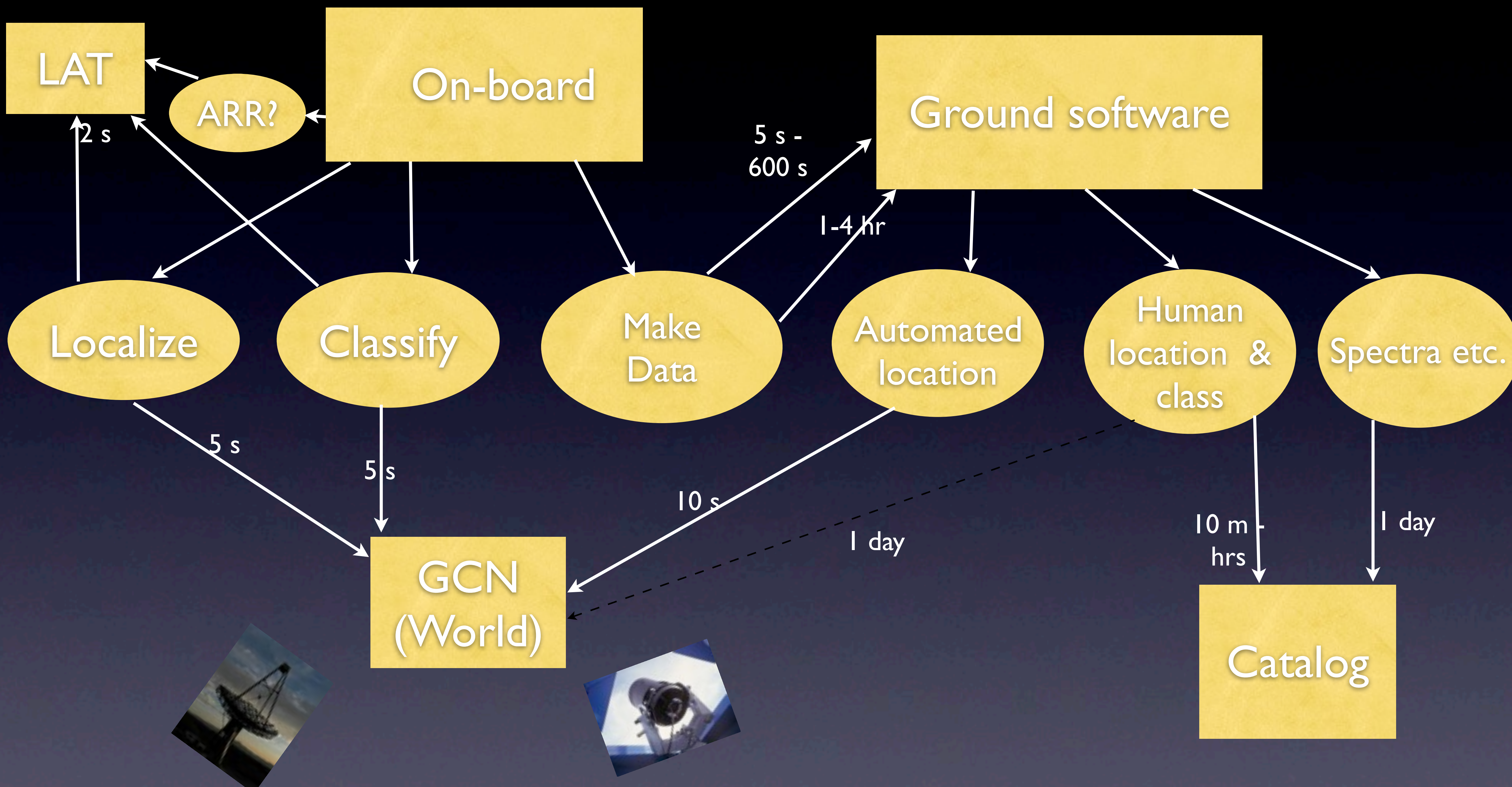
Quasi-Periodic Oscillations detected in the hard-X ray flux of A 0535+26 by Fermi/GBM

ATel 2346 (Finger & Wilson-Hodge)

GBM Science in First Year+ of Fermi

- GBM is triggering on GRBs, SGRs, TGFs and contributing to what we learn about these sources.
- GBM continuous data is rich in science, but does not give it up easily!
- Occultation monitoring is up-and-running, complementing Swift BAT in observations of the hard X-ray sky.
- Pulsar monitoring reveals long-term behavior of accretion-powered pulsars and alerts us to any outbursts.

GBM Actions on Triggering



All GBM Data are public at the FSSC:

- *http://fermi.gsfc.nasa.gov/ssc/data/access/*

Earth Occultation Step Fitting

- Predict occultation times
- Determine detectors viewing source of interest
- Fit to each detector and energy channel
  - Background model
  - Model count rates for each source
    - Detector responses
    - Assumed energy spectrum
    - Atmospheric transmission
- Compute best scale factor for all detectors to estimate fluxes.