Fermi GBM

14 years in the mission
2008 - 2022

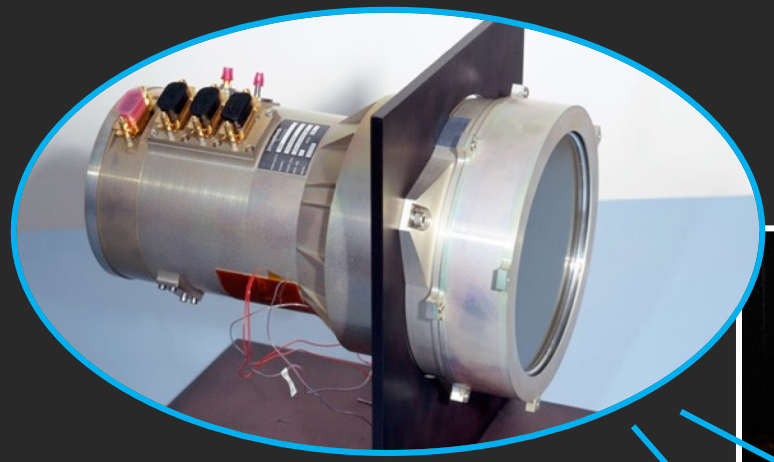
Andreas von Kienlin

Max-Planck-Institut für extraterrestrische Physik (MPE), Garching

on behalf of the *Fermi* GBM Science Team

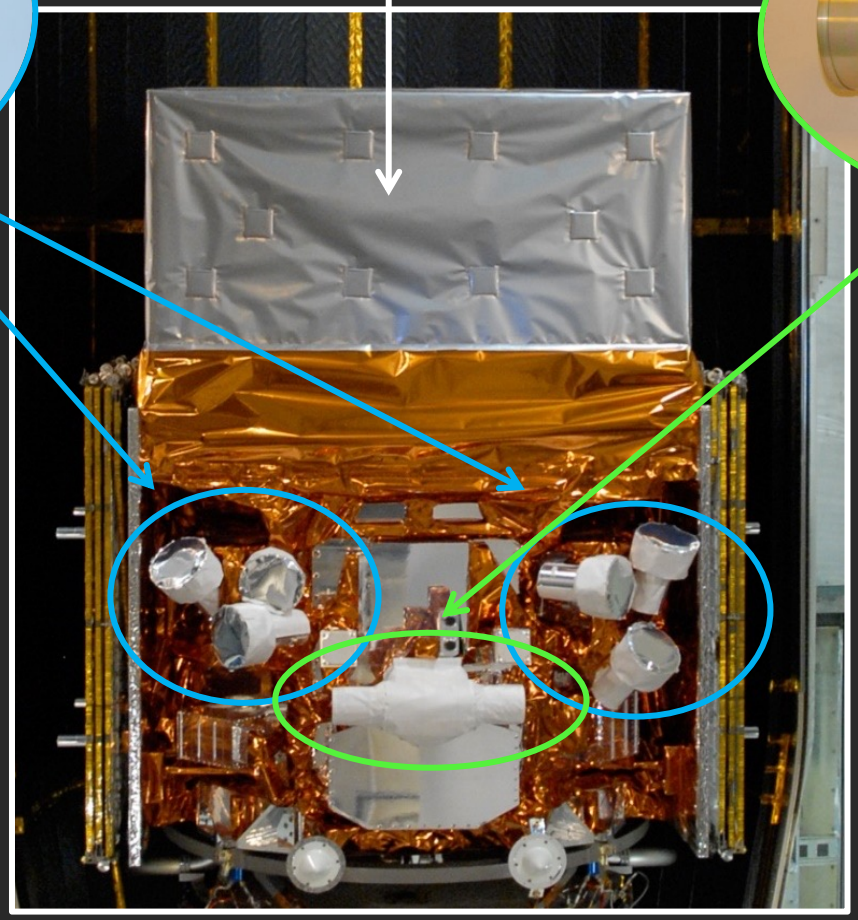
Fermi Gamma-ray Burst Monitor (GBM)

Sodium-Iodid Detector (NaI)



8 keV – 1 MeV

Large Area Telescope (LAT)



Bismuth Germanate (BGO)

150 keV – 40 MeV

MSFC/UAH
Huntsville, Al

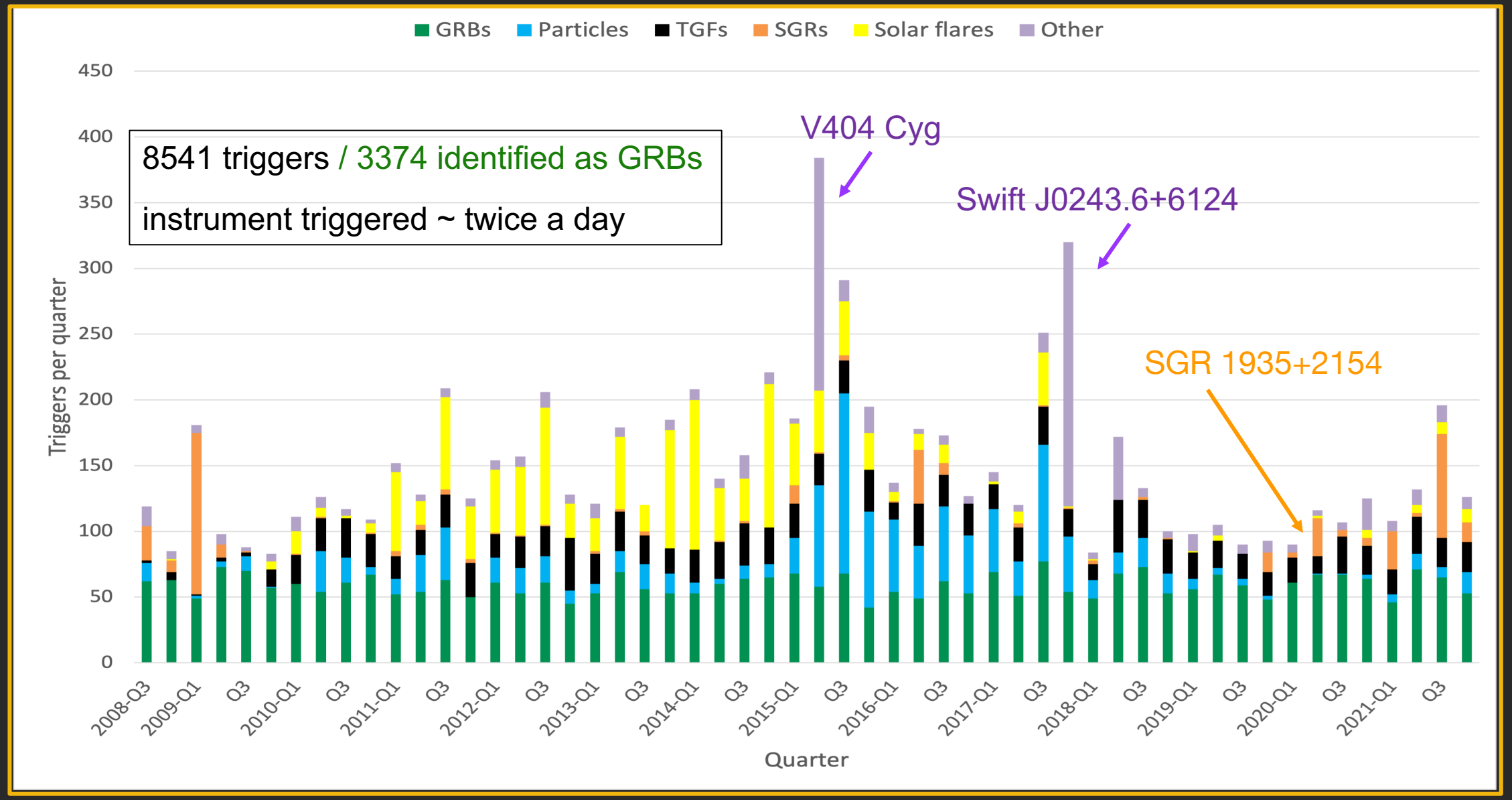
MPE
Garching

GBM Instrument paper:

Meegan, C. et al., ApJ 702, 791 (2009)

- 4 x 3 NaIs
- 2 x BGOs
- Power Box (PB)
- Digital Processing Unit (DPU)
- GBM Instrument Operations Center (GIOC) @ NSSTC

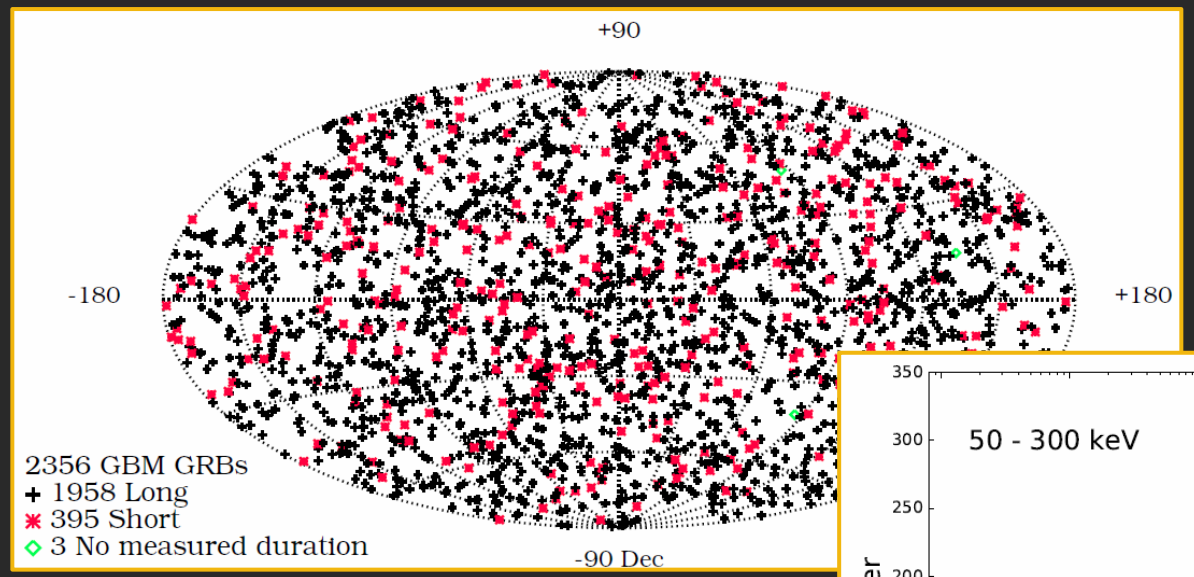
Fermi GBM Trigger History

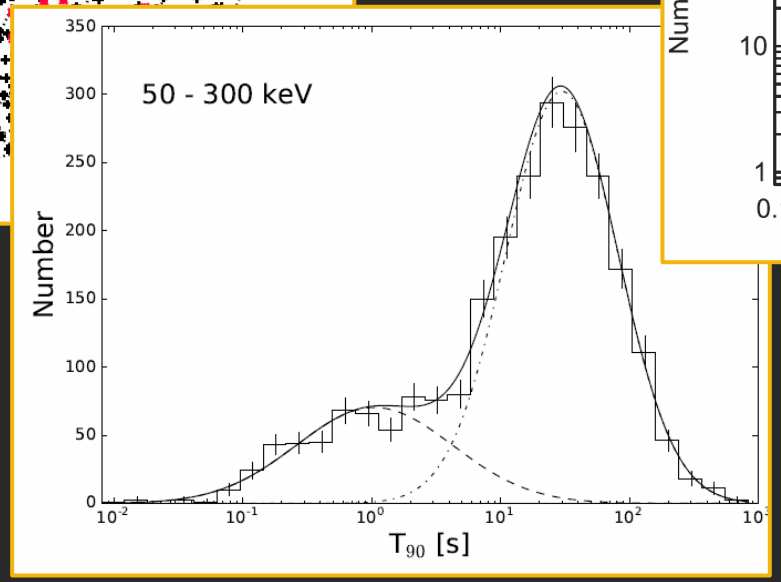


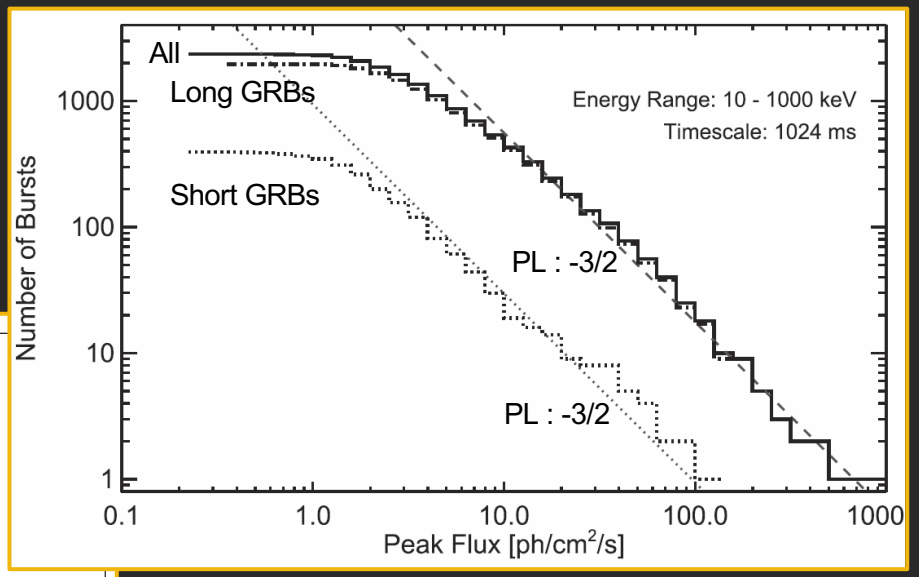
4th GBM GRB Catalog - 10 years of data

von Kienlin et al., 2020

- 1st, 2nd, 3rd catalog: 2 , 4, 6 years ⇨ Paciesas et al. 2012, von Kienlin et al. 2014, Bhat et al. 2016
- For each GRB: location, duration, peak flux & fluence (50 – 300 keV,10 – 1000keV) ⇨ standard tables
- + information on triggering criteria, exceptional operational conditions, GCN products







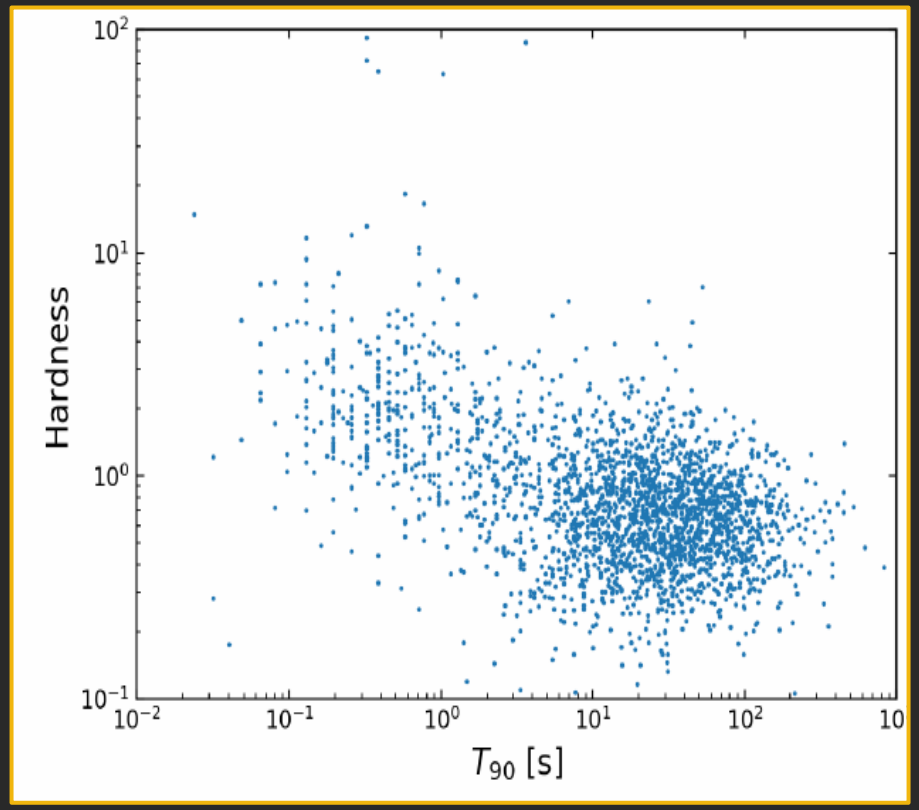
2008 July 12 – 2018 July 11

complete results available @ HEASARC

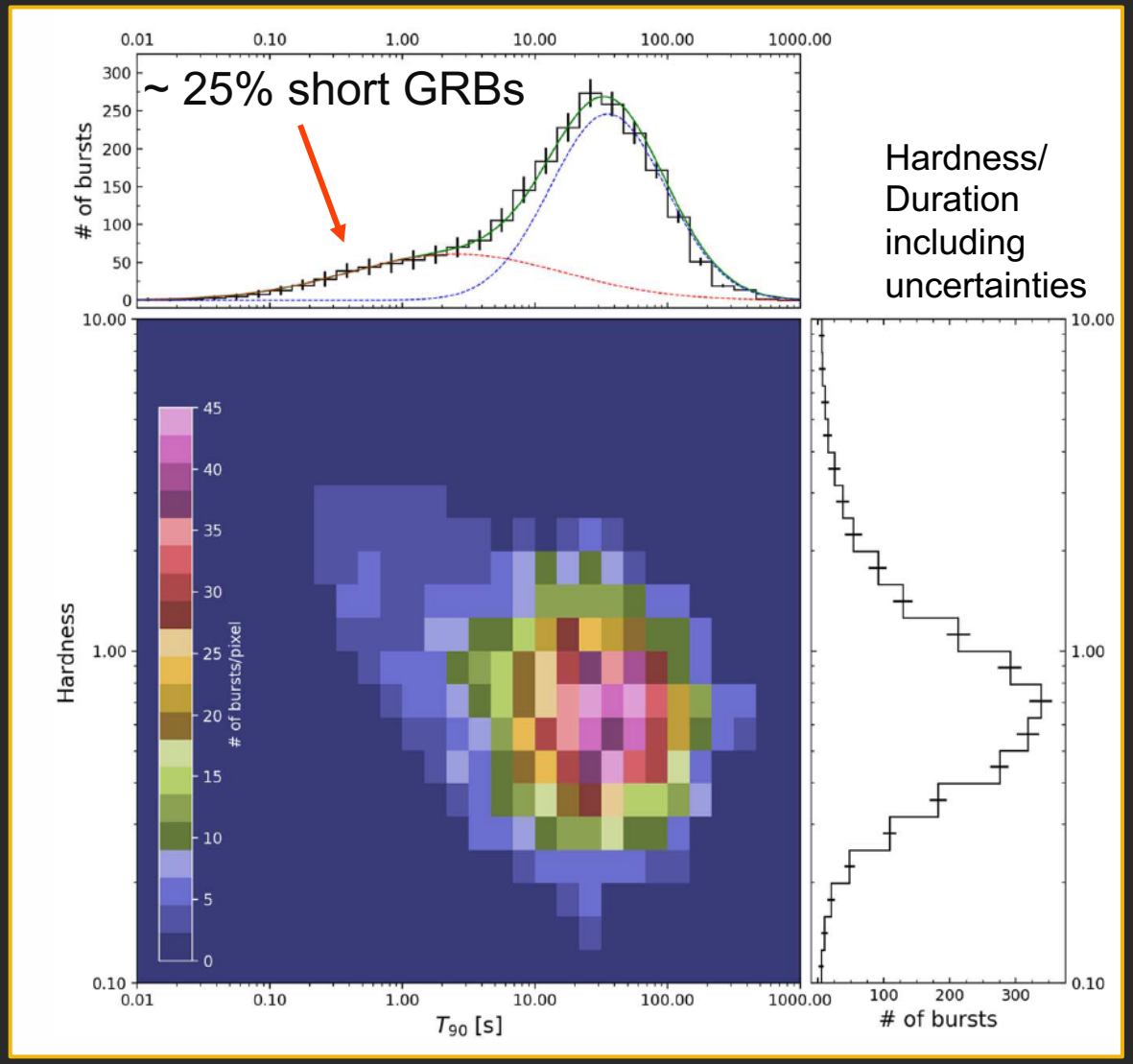
4th GBM GRB Catalog: Spectral Hardness vs. Duration

Hardness, ratio of flux density:

50–300 keV / 10–50 keV



Including parameter uncertainties:

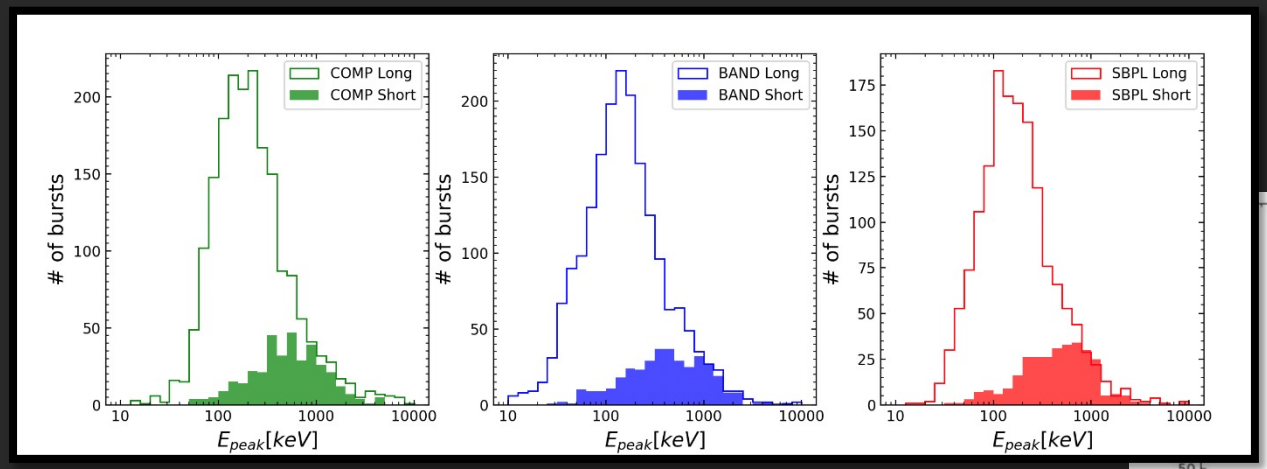


von Kienlin et al., 2020

GRB Spectral Catalog - 10 years of data

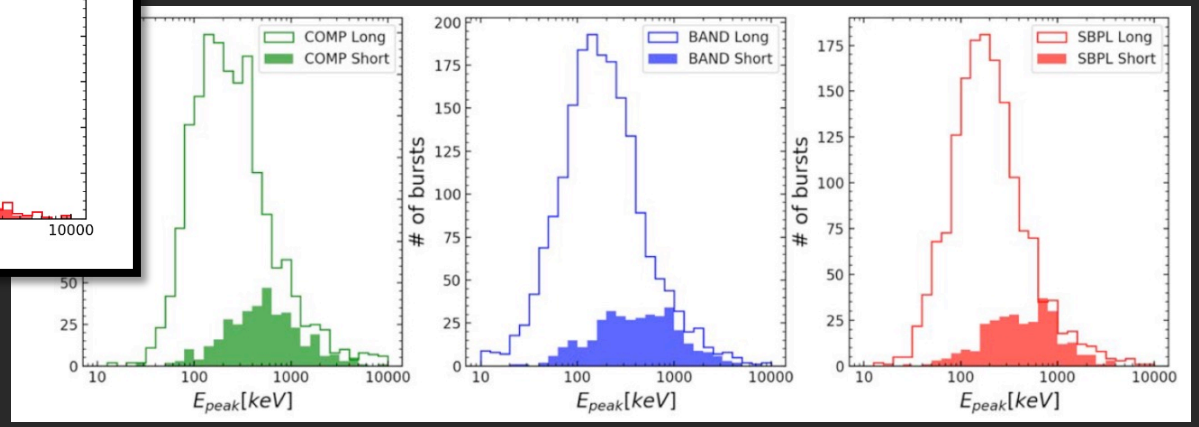
Poolakkil et al. 2021 ApJ, 913, 60

- Systematic spectral analysis of 2297 GRBs, two types of spectra:
  - time-integrated spectral fits ⇨ 'fluence' spectrum
  - spectral fits at the brightest time bin (1.024s / 64 ms) ⇨ 'peak flux' spectrum
  - New: introduce two-sided uncertainties for each fitted parameter (where it could be determined)
  - ⇨ resulting in a compendium of over 18000 spectra!
  - Update of 2-yr (Goldstein et al. 2012) and 4-yr (Gruber et al. 2014) catalogs (analysis results @ HEASARC)
- 4 different empirical spectral models
  - PLAW (A, λ) , COMP (A, α, E_{peak}), BAND (A, α, β, E_{peak}), SBPL (A, λ_1, λ_2, E_{break}, Δ)
- Parameter Distributions



Fluence spectral fits

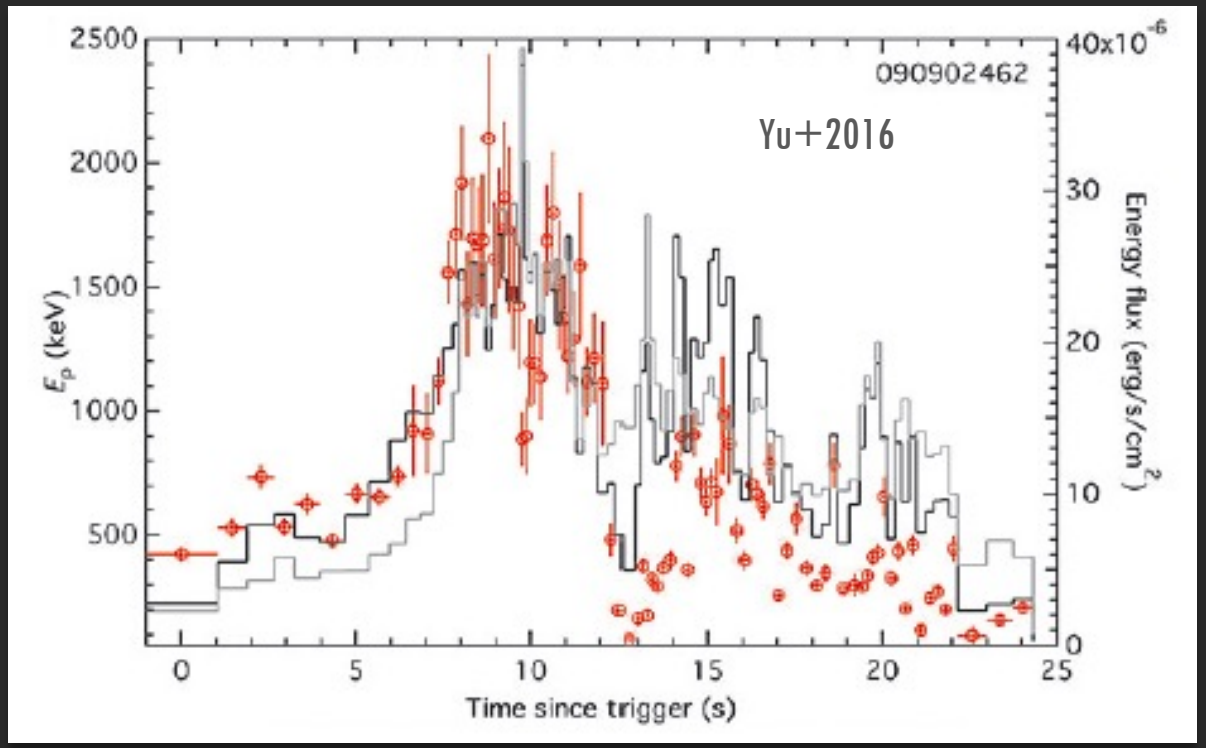
Comparison of E_{peak} between long and short GRBs

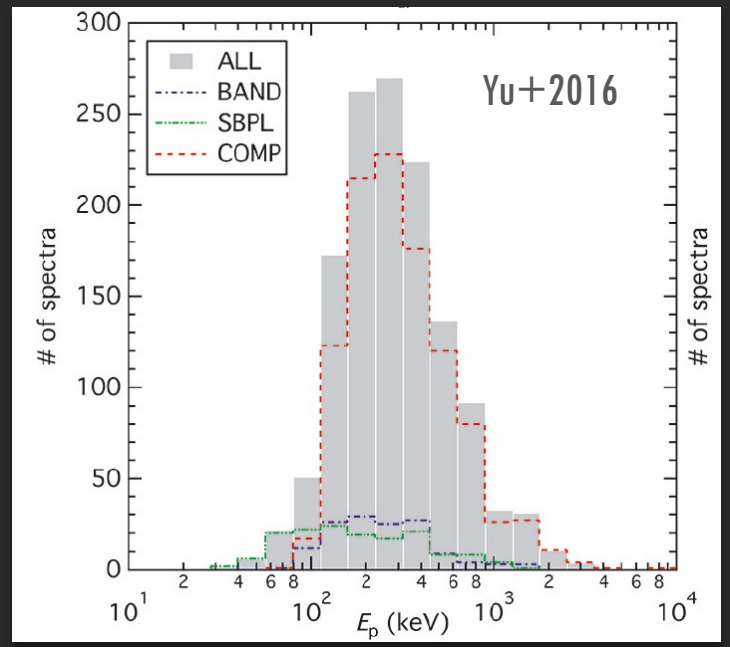


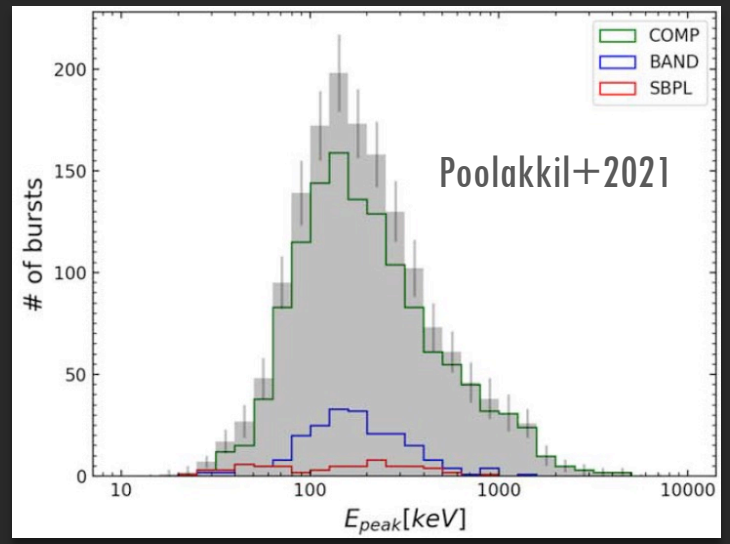
Peak flux spectral fits

Fermi-GBM time-resolved spectral Catalog

- 1st Time-resolved spectral catalog (Yu et al. 2016)
  - 4 years (2008-2012) – 954 triggered GRBs
    - Analyzed with GBM spectral analysis software RMFIT v4.3BA
    - Bright GRBs subsample criteria:
      $F > 4 \times 10^{-5}$ erg/cm^2, $F_{Peak} > 20$ph/cm^2/s, SNR>30
      ➔ 81 GRBs resulting in 1802 time bins

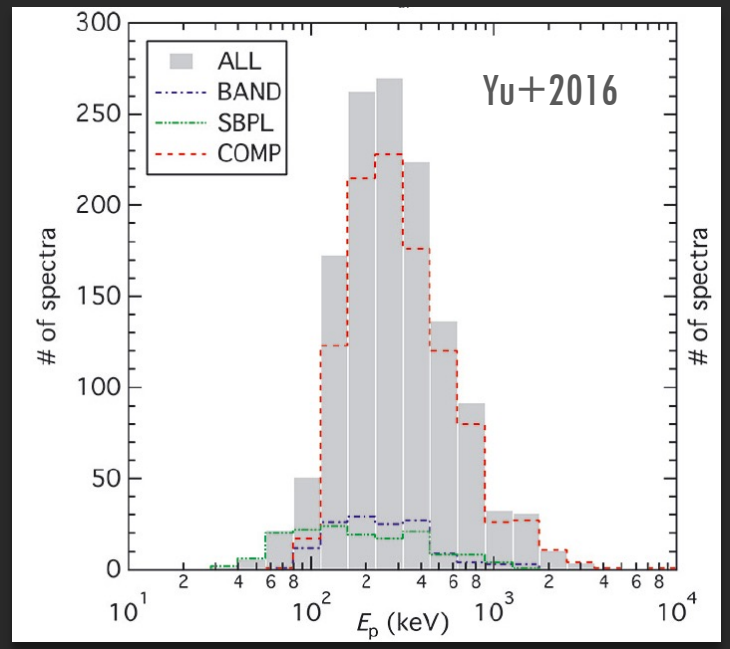




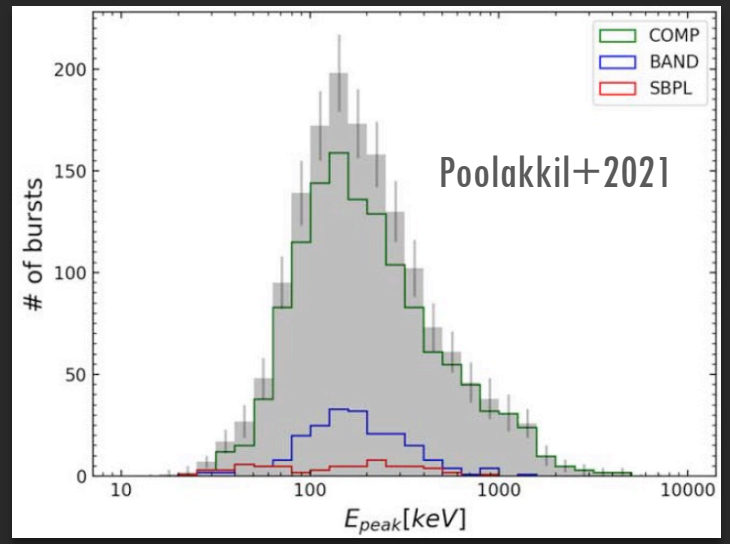


Fermi-GBM time-resolved Spectral Catalog

- 1st Time-resolved spectral catalog (Yu et al. 2016)
  - 4 years (2008-2012) – 954 triggered GRBs
    - Analyzed with GBM spectral analysis software RMFIT v4.3BA
    - Bright GRBs subsample criteria:
      $F > 4 \times 10^{-5}$ erg/cm^2, $F_{Peak} > 20$ph/cm^2/s, SNR>30
      ➔ 81 GRBs resulting in 1802 time bins



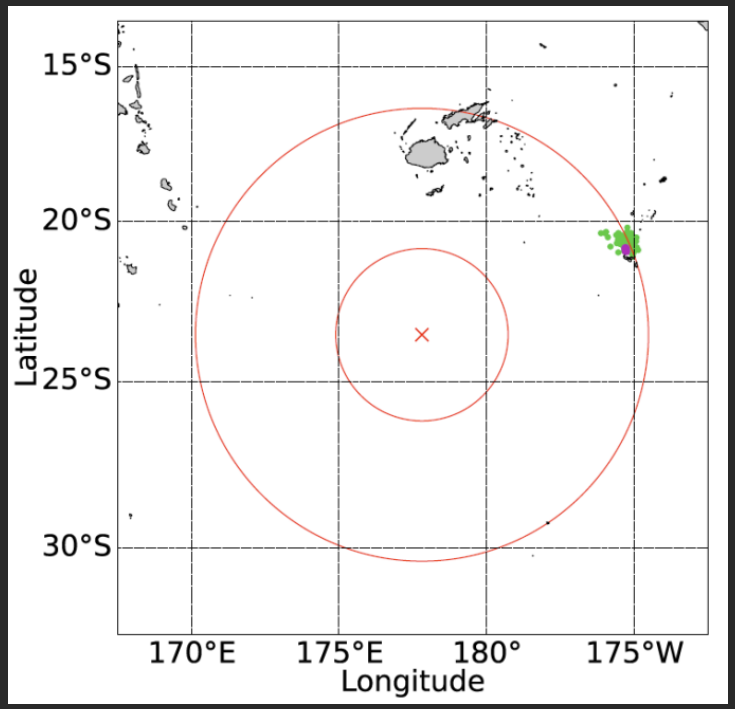
- 2nd: Ongoing work (Bissaldi et al.)
  - 10(+) years (2008-2018)
  - 2297 GRBs useful for spectroscopy
    - Based on 10-yrs GBM spectral catalog (time-integrated, Poolakkil et al. 2021, also analyzed with RMFIT)
    - NEW analysis with **Fermi GBM Data Tools v1.1.1**
      - Rebinning lightcurves with **Bayesian Blocks Analysis**
      - Currently **testing tools** with 25 brightest GRBs
      - Next: Automatic analysis of the full sample

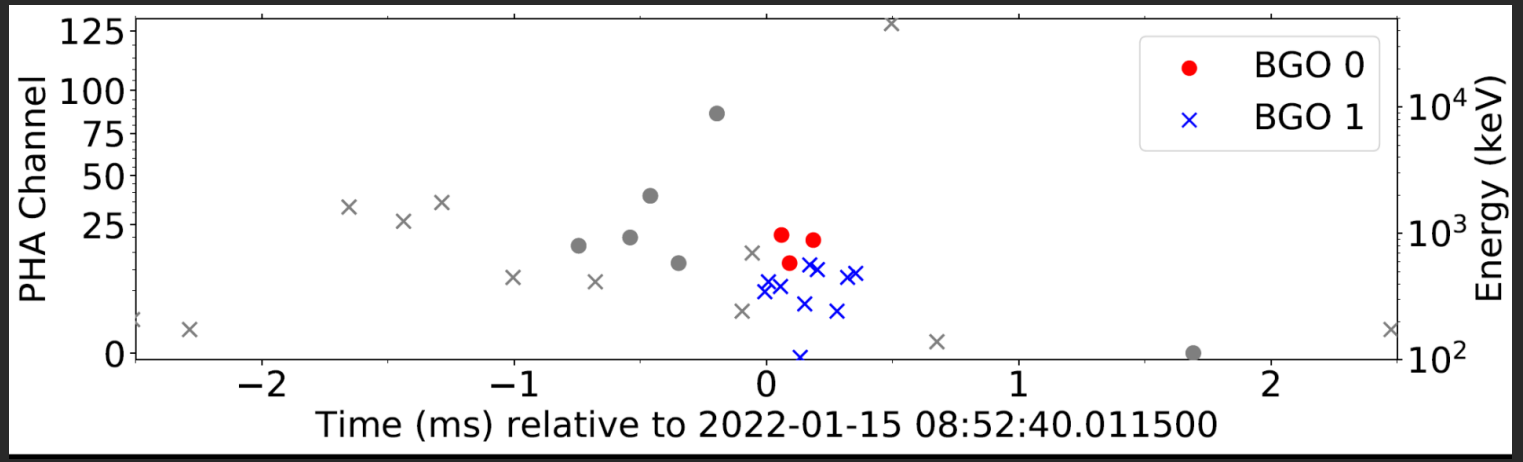


Fermi GBM detects gamma-rays from volcanic lightning

- A Terrestrial gamma flash (TGF) was detected with Fermi GBM from volcanic lightning from Hunga Tonga–Hunga Ha'apai on Jan 15, 2022
- GBM's observation of the TGF from space shows that electrons were accelerated upward by the volcanic plume
  - The only lightning detectable by GBM was from the volcano (green dots).
  - Red cross shows the location of Fermi. Red circles show the extent of GBM TGF sensitivity
    - Briggs, Lesage, Schultz et al. 2022, Geophysical Research Letters https://doi.org/10.1029/2022GL099660

lightning radio signals, TGF ± 1 min

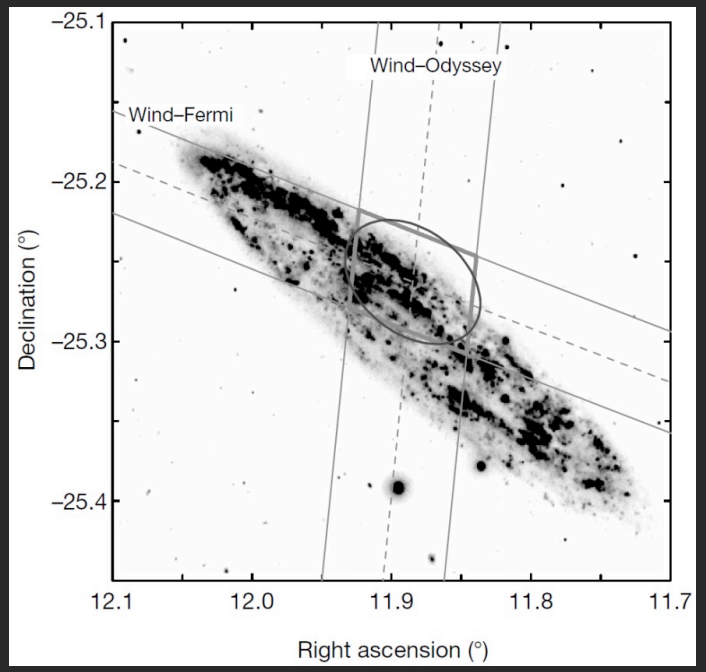




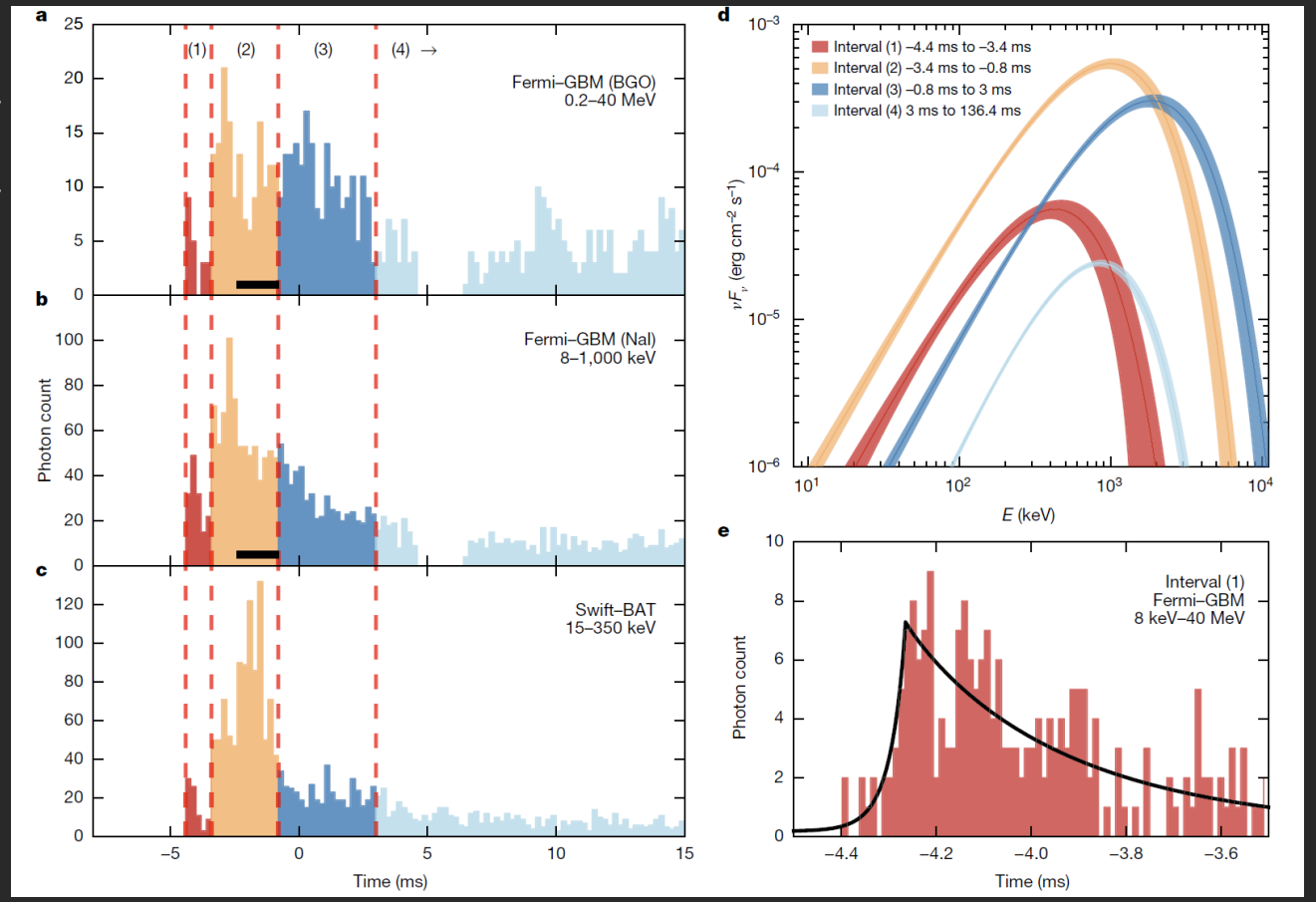
Magnetar Giant Flare

- GBM + LAT short GRB 200415A
  + INTEGRAL, Konus

IPN localization: 7-arcmin^2 region,
Overlaps with Sculptor galaxy (NGC 253)



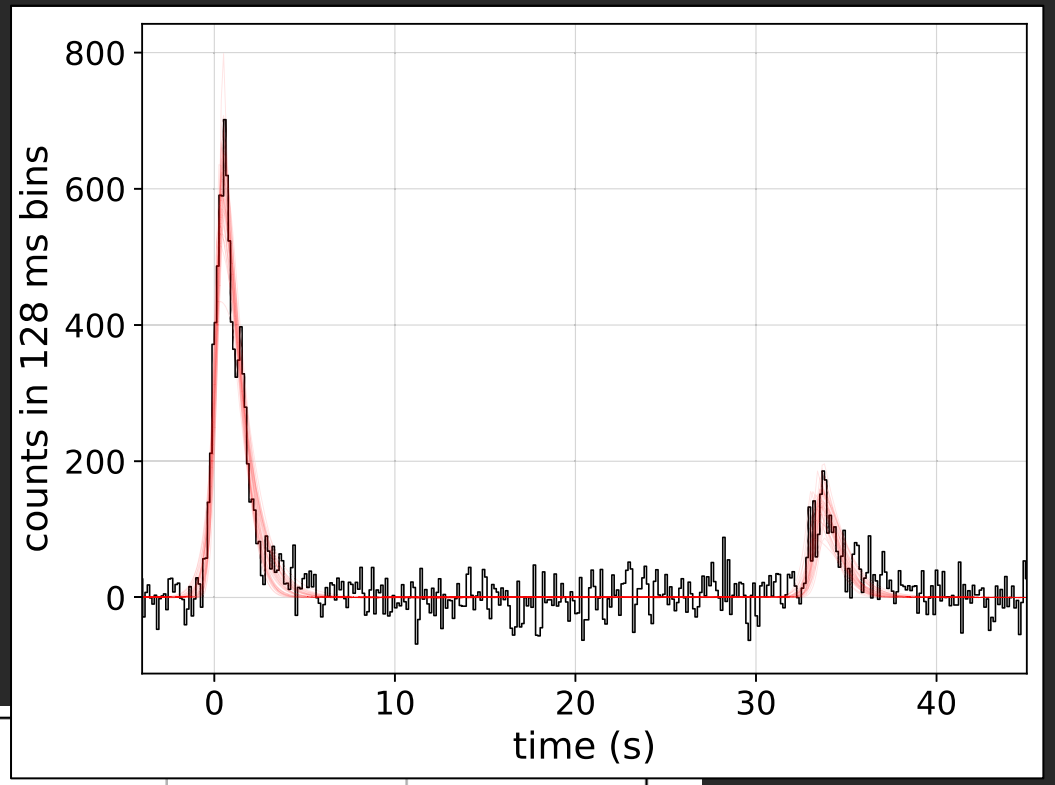
Svinkin, D. et al. Nature 589, 211 (2021)

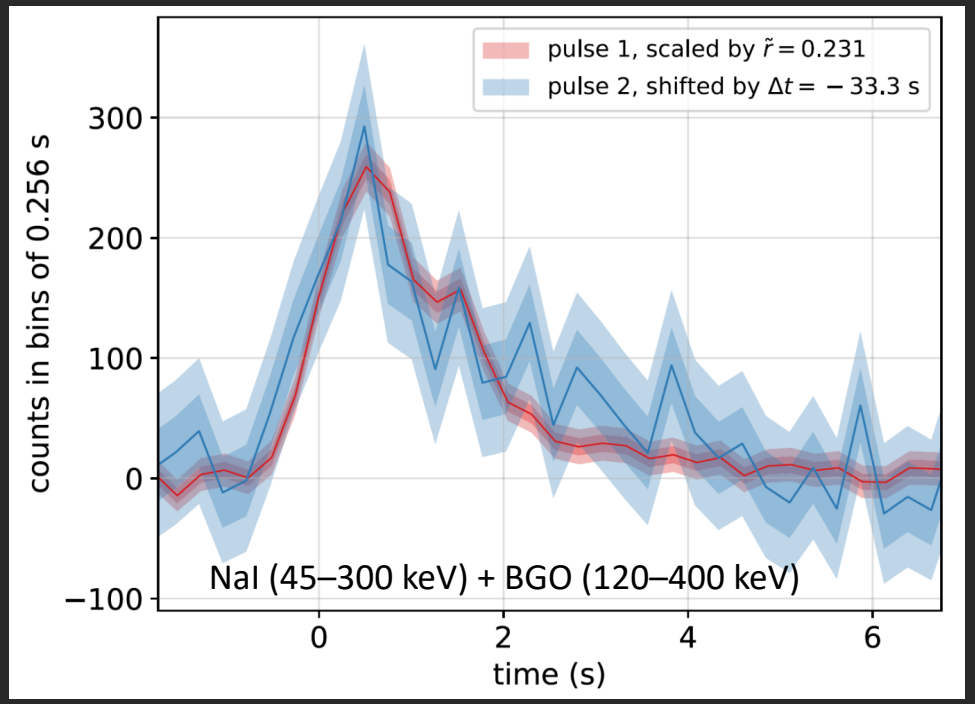


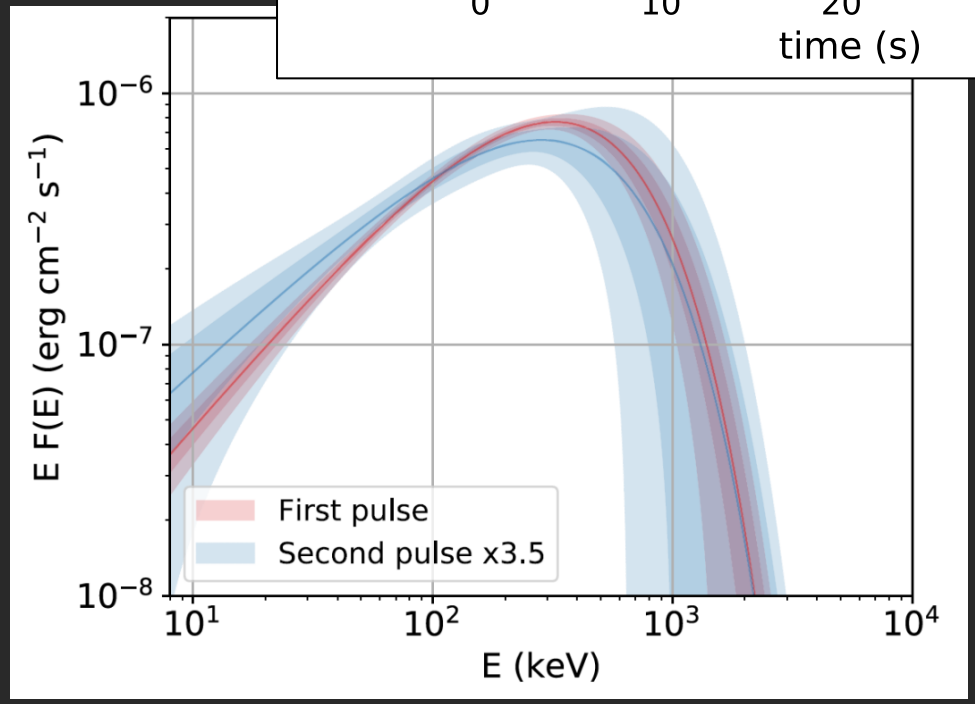
- first detailed spectral analysis of a giant flare by GBM (no saturation)
- shortest measured timescales in γ-rays (77 μs)
- first direct evidence for relativistic outflows in MGFs
- first detection at GeV energies of a giant flare with the LAT
- archival extragalactic MGF searches ⇨ about 1 extragalactic MGF per year among the GBM GRBs (Burns et al. 2021)

Gravitationally lensed GRB

- Veres et al. 2021 – ApJ, 291, L30
- GRB 210812A – two peaks
- ~33 s time delay
- Consistent spectra & pulse
- Lens: about 1 million Solar mass





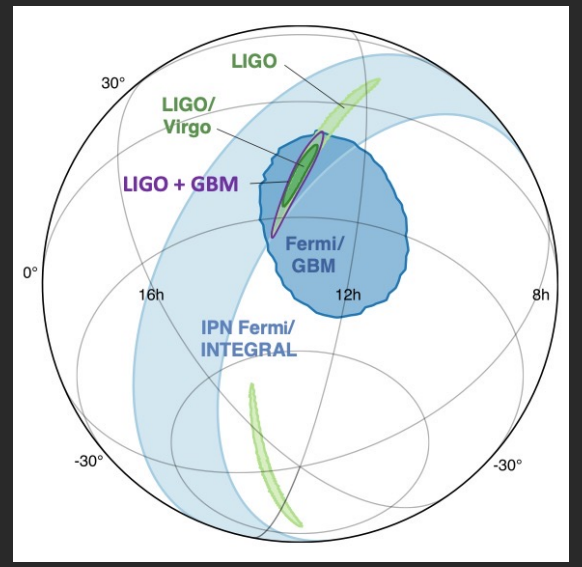


Follow-up and Collaborative Projects

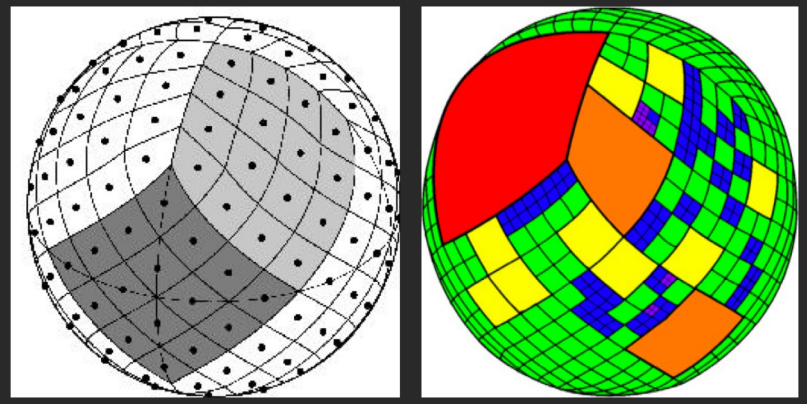
- GBM routinely follows up external triggers ⇨ Sub-Threshold Targeted Search Goldstein et al. 2019
  - GRBs detected by other instruments (& not triggered GBM), IceCube neutrino alerts, FRBs
  - Interesting cases for GBM Sub-Threshold detections:
    - Swift GRB 191016A, detection of OT by TESS (Smith et al. 2021)
    - Swift GRB 210905A, GBM GCN #30779, VLT/X-shooter: z=6.318
    - Swift GRB 220117A, GBM GCN #31497, VLT/X-shooter: z=4.961
    - First millimeter afterglow by ALMA (Laskar et al. 2022), Swift/BAT-GUANO SGRB 211106A (INTEGRAL SPI/ACS notice), GBM GCN #31055
- Untargeted Sub-Threshold Search https://gcn.gsfc.nasa.gov/fermi_gbm_subthresh_archive.html
  - New: advanced background, runs on all data, Bayesian classification of events
- GBM as trigger for Swift-BAT GUANO :
  - recovers Swift-BAT event data and provide arcminute-scale locations
- IceCube follow-up of Swift/GBM triggers ⇨ Abbasi et al. 2022
- Search for gamma-ray counterparts to O3 GW events ⇨ next talk by Joshua Wood

GBM - LVK O4 Preparations

LVK Engineering Run: April 2023; Observing Run: March 2023



- LVK collaboration with GBM team (GRB-GW working group):
  - Support innovative joint observations and sub-threshold searches
  - Consistent contact with LVK members
- Joint detections of a BNS mergers, both in GW and γ-rays (GRB)
  - LV O2: GW170817 / GRB 170817A
  - LV O3: -
  - LVK O4: with the anticipated improvements in sensitivity: $R^{O4}_{GW-GRB} = 1.04^{+0.26}_{-0.27}\ yr^{-1}$ (arXiv: 2111.03608v1)



- GBM preparations include:
  - GBM data tools: native support for MOC map format
  - Reducing localization systematics for targeted search
  - Targeted search, new information on: probability for a short GRB, inclination angle of the source (in progress)

Conclusion

- Fermi-GBM: running smoothly for 14 years – no degradation observed
- Most recent catalogs:
  - 4th GBM GRB catalog – A. von Kienlin et al. 2020
  - GRB spectral catalog – Poolakkil et al. 2021
- Catalogs in preparation:
  - 2nd time resolved spectral catalog – E. Bissaldi et al.
  - TGF catalog – O. Roberts et al. (10 years of data, ~1200 TGFs per year)
- GBM produces exciting results:
  - “Vulcanic” TGF
  - Extragalactic Magnetar Giant Flare
  - Lensed GRB
- Eagerly anticipating the next BNS merger events in LVK O4