Update on GOTO – CTA-LST1 Activities on La Palma

Kendall Ackley, Monash University

CTA-Oz | 02 November 2020

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GRAVITATIONAL–WAVE OPTICAL TRANSIENT OBSERVER

- *Specifically designed and optimised* for rapid response GW-EM searches

- Wide area capability to sufficient depth

- Aim to catch counterparts early to allow follow-up with other facilities

- Funding for GOTO-South site at Siding Spring Observatory

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Working Groups

- Kilonovae
- GRBs
- Supernovae
- Host Galaxies
- TDEs and nuclear transients
- *External Follow-up and coordinated observing*
- Accreting Binaries
- Stellar Activity
- Binary millisecond pulsars (spiders)
- White Dwarfs
- Other variable sources
- Asteroid search
- Technical working group

Key Areas for cooperative observing

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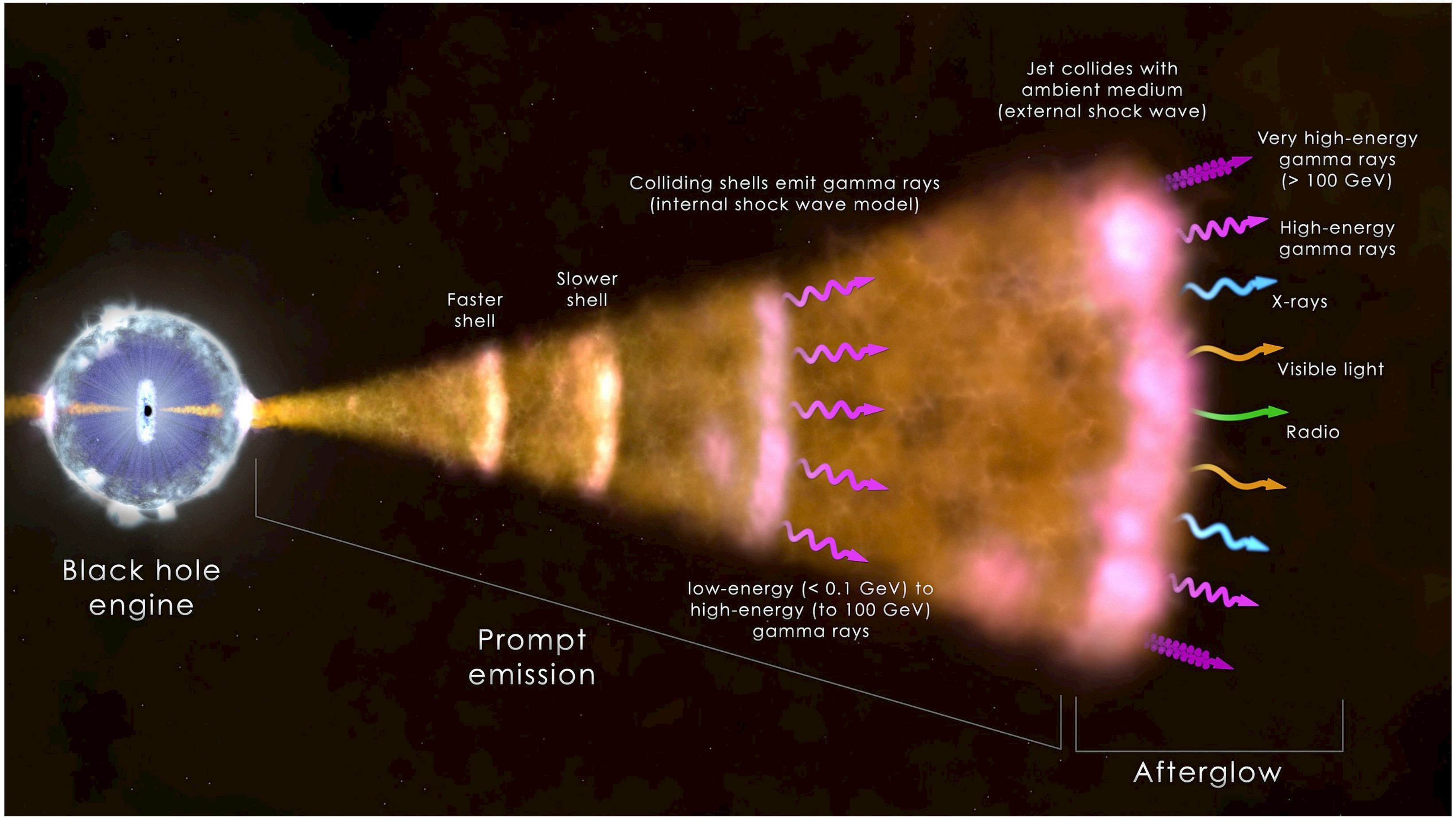
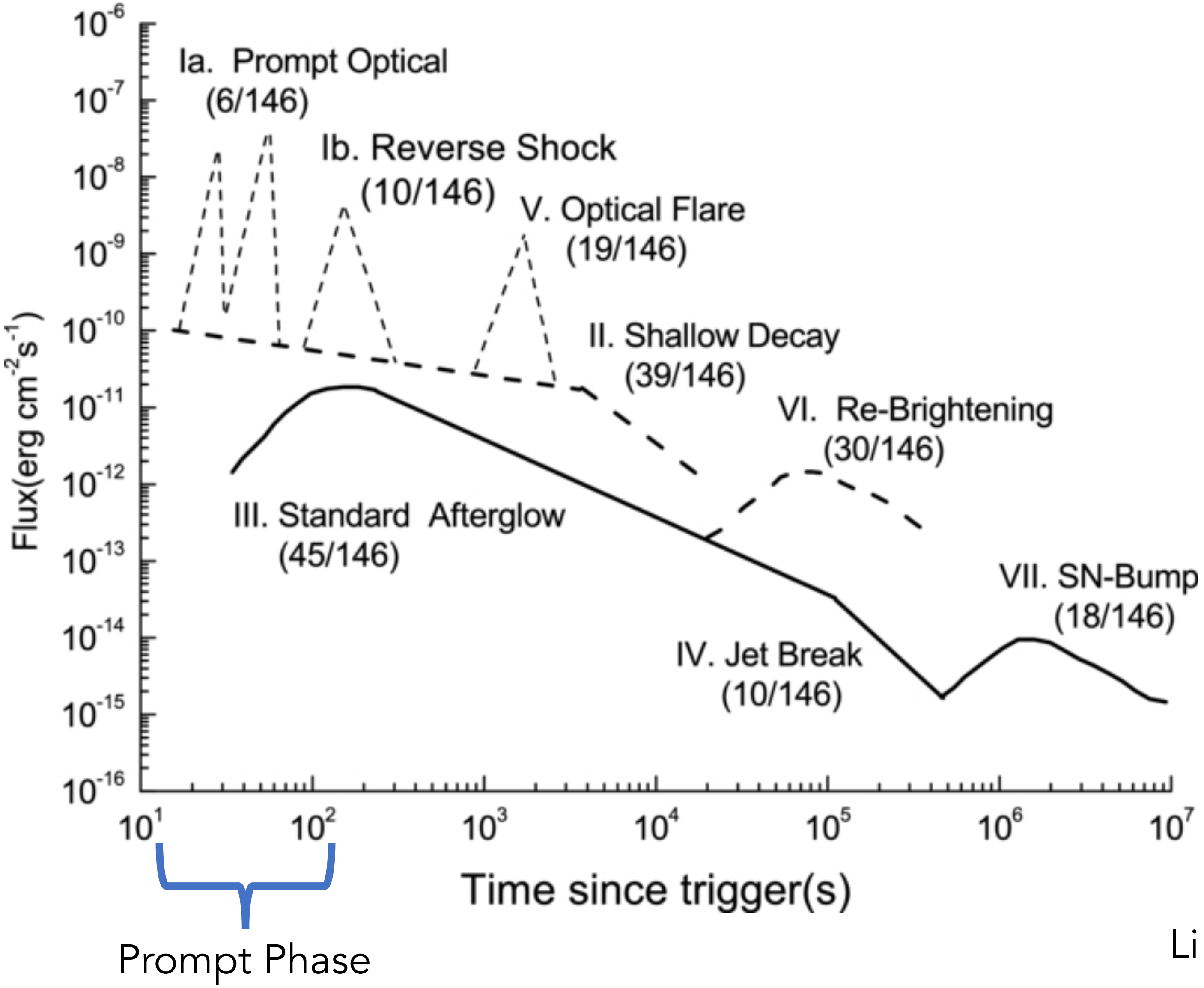
- Science-Targeted (co-monitoring or simply providing data)
  - *Fermi-LAT triggered*
  - Transient Phenomena
  - AGN Monitoring
- Galactic Plane survey
  - 1) Monitoring optical properties of Galactic very-high energy (VHE) gamma-ray source populations, namely supernova remnants (SNRs), pulsar wind nebulae (PWNe) and binary systems
  - 2) monitoring optical properties of identified targets for follow-up observations, such as new gamma-ray binaries and PeVatron candidates
  - 5) discovering new and unexpected phenomena in the Galaxy, such as new source classes and new types of transient and variable behaviour.
- Extragalactic survey
  - serendipitous detection of fast flaring sources, not detectable in short observation time (hours) by lower sensitivity observatories like Fermi-LAT and HAWC

GRB Emissions – Standard Model



- The blast wave that produces the initial, bright prompt emission collides with the external material (the circumburst medium) and creates shocks
- These external shocks accelerate charged particles → produces photons through synchrotron radiation

GRB Emissions – Optical Flares



- Optical flare and early shallow-decay components likely related to long-term central engine activities.
- Similar to prompt optical emission that tracks **γ**-rays, optical flares are also related to the erratic behaviour of the central engine
- Shallow decay component likely related to a long-lasting spinning-down central engine or piling up of flare materials onto the blast wave
- The observed relations between $E_{\gamma,iso}$ or $L_{R,iso}$ and t_p indicate that the prompt gamma-ray emission and late optical flare emission could have the same physical origin

With 146 GRB observations (Li *et al* 2012):

- 19 GRBs show 24 optical flares (14 clear flares) → related to Xray flares?

Li *et al.* 2012 *The Astrophysical Journal* **758** 27

GRB 190114C

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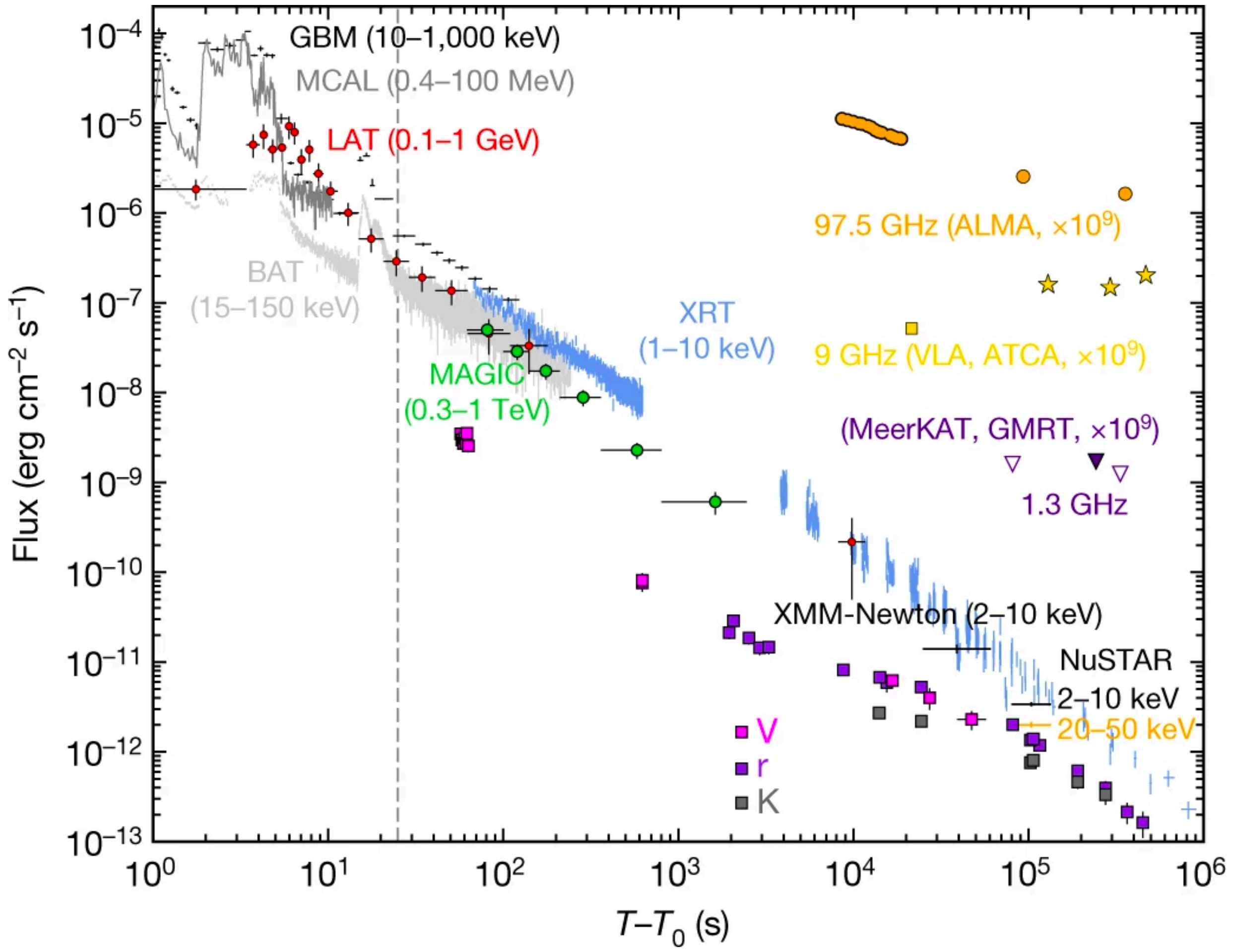
Article | Published: 20 November 2019

Observation of inverse Compton emission from a long γ-ray burst

MAGIC Collaboration, P. Veres, […] D. R. Young

Nature **575**, 459–463(2019) | Cite this article



- γ-rays were observed in range 0.2–1 TeV from ~1 – 40 minutes after the burst
- Distinct spectral component with power comparable to synchrotron component
- The observed similarity in the radiated power and temporal behaviour of the TeV and X-ray bands → inverse Compton up-scattering of synchrotron photons by HE electrons as mechanism of TeV emission

GRB 130427A

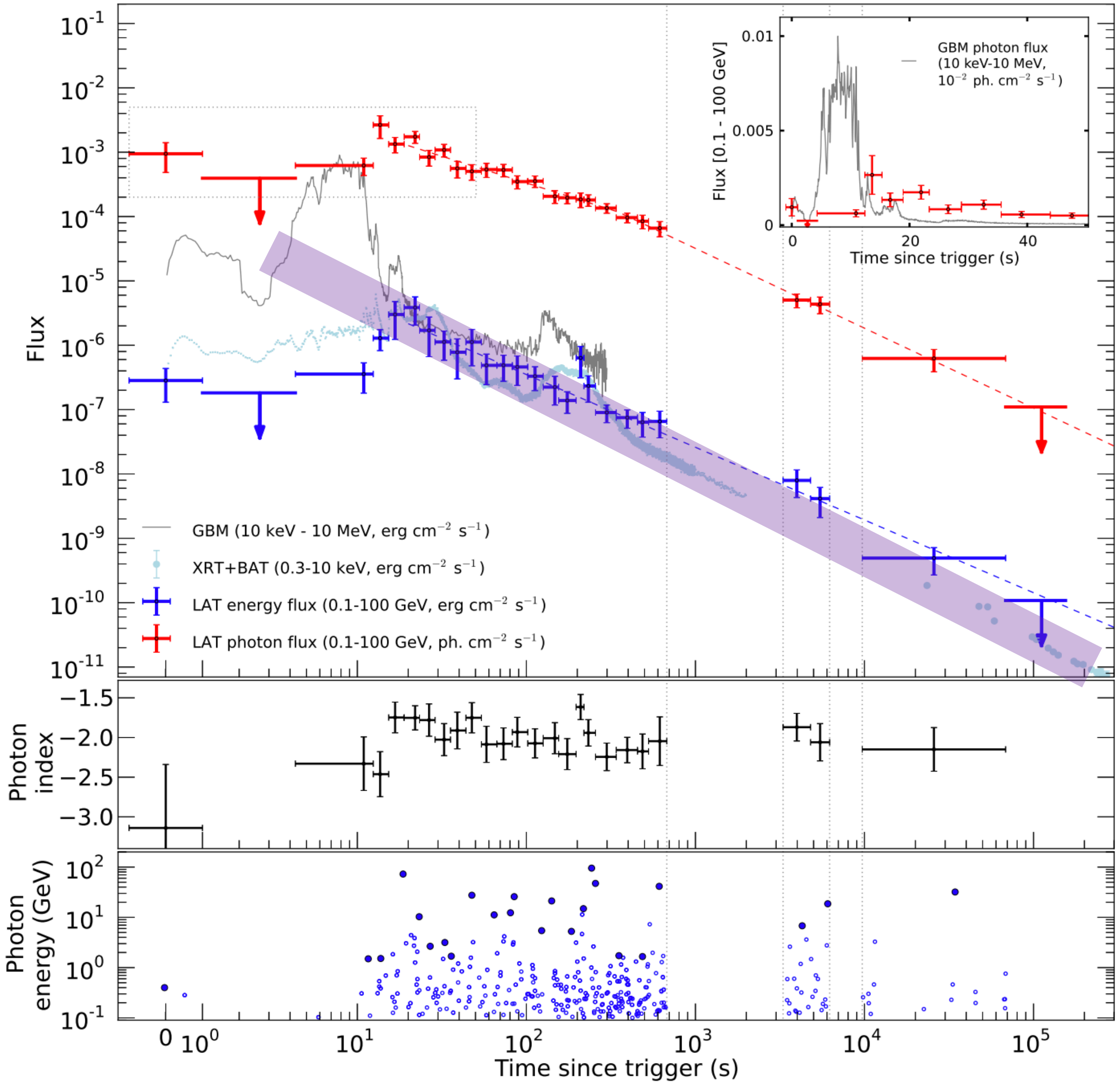
- GRB 130427A had the:
  - largest fluence
  - highest energy photon (95 GeV)
  - longest **γ**-ray duration (20 hours)

  ever observed from a GRB

- Associated with SN 2013cq → SNe for all bursts, not just low-energy

- The X-ray afterglow of the burst was so bright that Swift was able to observe it for the next six months

- Temporal and spectral analyses challenge the model that non-thermal high-energy emission in the afterglow phase is *synchrotron emission* radiated by electrons accelerated at an external shock



Ackermann *et al.* 2014 *Science* 343, 42

GRB 201015A

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TITLE: GCN CIRCULAR
NUMBER: 28659
SUBJECT: MAGIC observations of GRB 201015A: hint of very high energy gamma-ray signal
DATE: 20/10/16 16:48:37 GMT
FROM: Oscar Blanch at MAGIC Collaboration <blanch@ifae.es>

O.Blanch (IFAE-BIST Barcelona), M. Gaug (UAB Barcelona), K. Noda (ICRR University of Tokyo), A. Berti (INFN Torino), E. Moretti (IFAE-BIST Barcelona), D. Miceli (University of Udine and INFN Trieste), P. Gliwny (University of Lodz) S. Ubach (UAB Barcelona), B. Schleicher (University of Wuerzburg), M. Cerruti (University of Barcelona) and A. Stamerra (INAF Rome) on behalf of the MAGIC collaboration report:

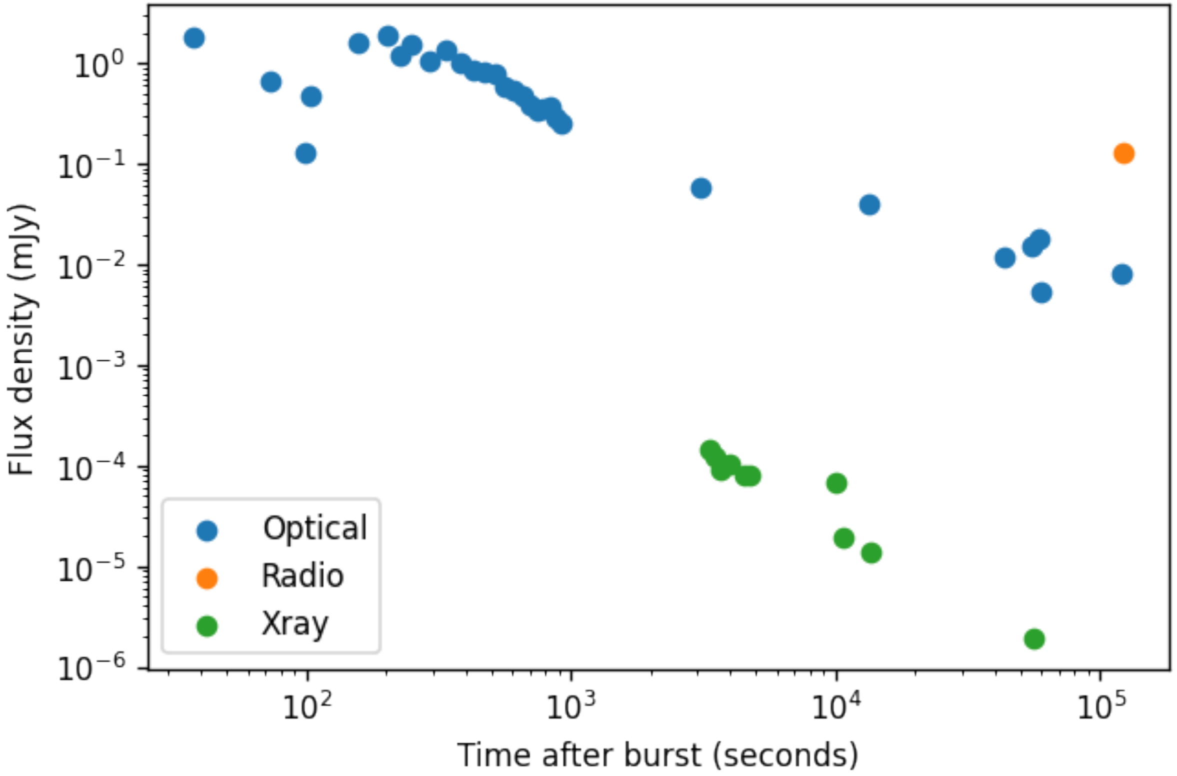
On October 15, 2020, the MAGIC telescopes observed GRB 201015A following the Swift-BAT trigger (Dâ€™Elia et al., GCN 28632). MAGIC started observations under good conditions about 40 seconds after the initial Swift trigger, revealing a hint of signal with significance >3 sigma in the very high energy band. Refined off-line analyses of the data are ongoing.

Further MAGIC observations on GRB 201015A are planned in the coming night. We strongly encourage follow-up observations by other instruments at all wavelengths.

The MAGIC point of contact for this burst is O. Blanch (blanch@ifae.es). Burst Advocate for this burst is M. Gaug (Markus.Gaug@uab.cat)

MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

- Subthreshold detection with Fermi-GBM
- Not reported detection with Fermi-LAT



Fermi LAT

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The Astrophysical Journal, 878:52 (61pp), 2019 June 10
https://doi.org/10.3847/1538-4357/ab1d4e

CrossMark

A Decade of Gamma-Ray Bursts Observed by *Fermi*-LAT: The Second GRB Catalog

M. Ajello[1], M. Arimoto[2], M. Axelsson[3,4], L. Baldini[5], G. Barbiellini[6,7], D. Bastieri[8,9], R. Bellazzini[10], P. N. Bhat[11], E. Bissaldi[12,13], R. D. Blandford[14], R. Bonino[15,16], J. Bonnell[17,18], E. Bottacini[14,19], J. Bregeon[20], P. Bruel[21], R. Buehler[22], R. A. Cameron[14], R. Caputo[23], P. A. Caraveo[24], E. Cavazzuti[25], S. Chen[8,19], C. C. Cheung[26], G. Chiaro[24], S. Ciprini[27,28],

The Large Area Telescope (LAT) aboard the *Fermi* spacecraft routinely observes high-energy emission from gamma-ray bursts (GRBs). Here we present the second catalog of LAT-detected GRBs, covering the first 10 yr of operations, from 2008 to 2018 August 4. A total of 186 GRBs are found; of these, 91 show emission in the range 30–100 MeV (17 of which are seen only in this band) and 169 are detected above 100 MeV. Most of these sources were discovered by other instruments (*Fermi*/GBM, *Swift*/BAT, AGILE, *INTEGRAL*) or reported by the Interplanetary Network (IPN); the LAT has independently triggered on four GRBs. This catalog presents the results for all 186 GRBs. We study onset, duration, and temporal properties of each GRB, as well as spectral characteristics in the 100 MeV–100 GeV energy range. Particular attention is given to the photons with the highest energy. Compared with the first LAT GRB catalog, our rate of detection is significantly improved. The results generally confirm the main findings of the first catalog: the LAT primarily detects the brightest GBM bursts, and the high-energy emission shows delayed onset as well as longer duration. However, in this work we find delays exceeding 1 ks and several GRBs with durations over 10 ks. Furthermore, the larger number of LAT detections shows that these GRBs not only cover the high-fluence range of GBM-detected GRBs but also sample lower fluences. In addition, the greater number of detected GRBs with redshift estimates allows us to study their properties in both the observer and rest frames. Comparison of the observational results with theoretical predictions reveals that no model is currently able to explain all results, highlighting the role of LAT observations in driving theoretical models.

Fermi LAT Coverage

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Can cover 13 sGRBs, 120 LGRBs in 10 years

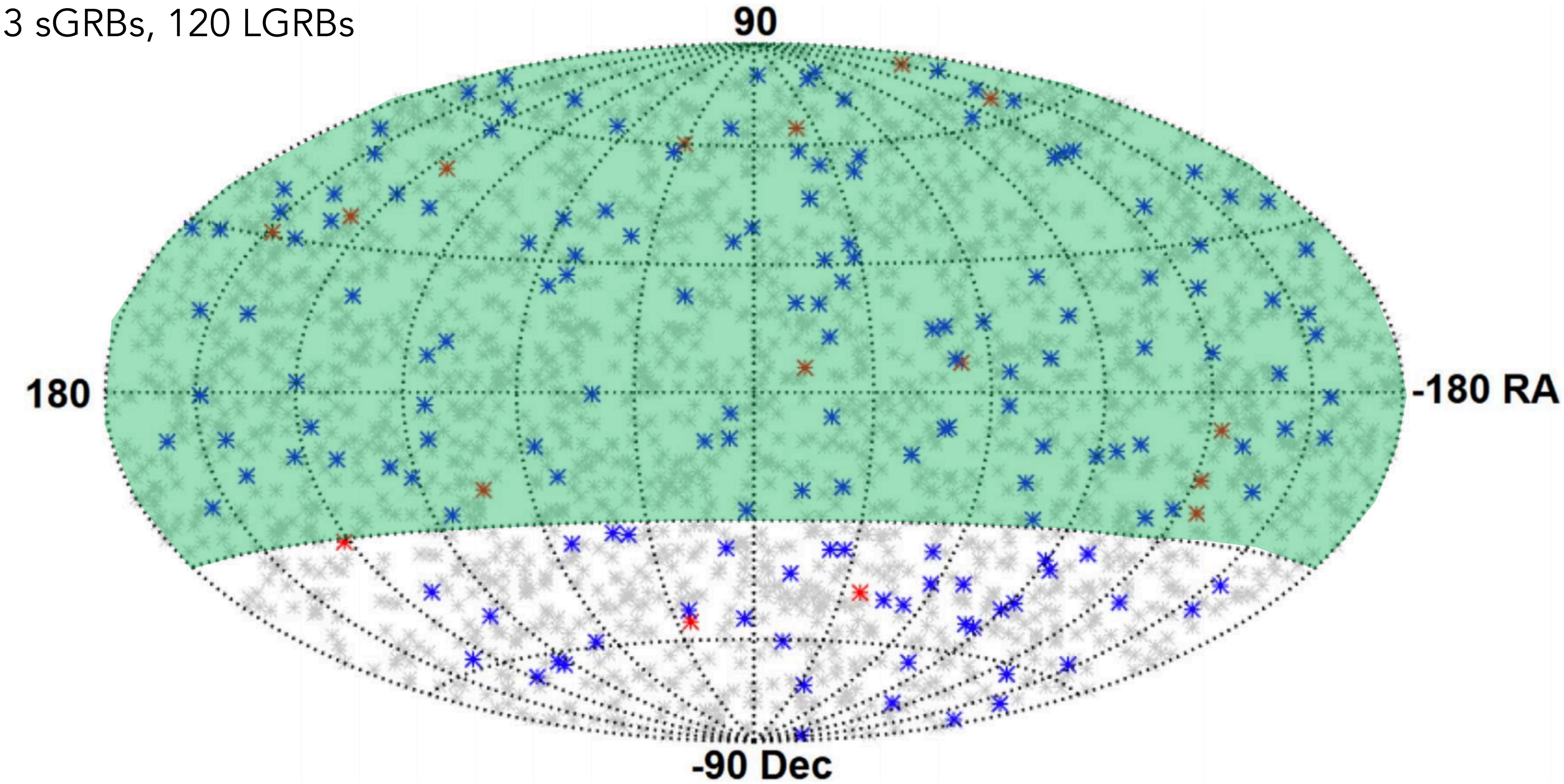
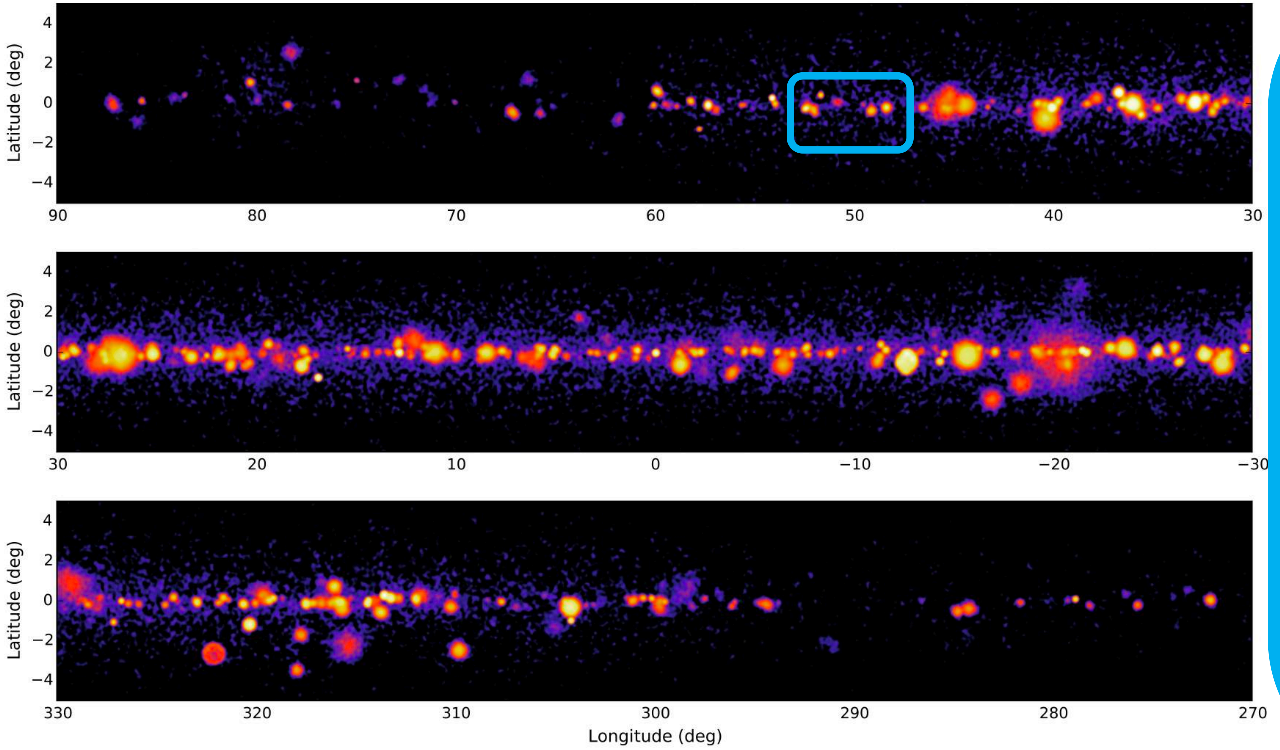
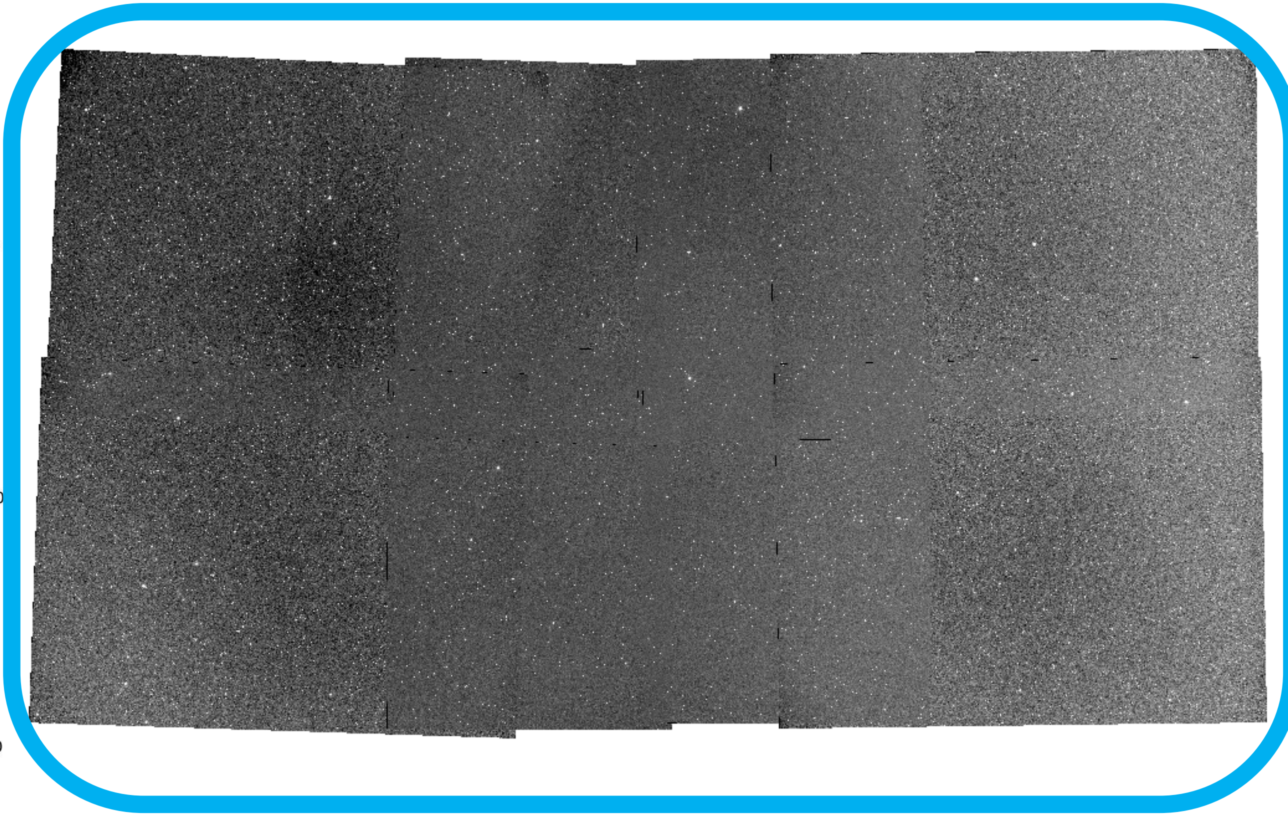


Figure 5. Sky distribution of 2357 GBM-triggered GRBs (from 2008 July 14 to 2018 July 31) in equatorial coordinates (gray asterisks). Blue (red) asterisks indicate 160 (16) long (short) LAT-detected GRBs included in the 2FLGC over the same time period.

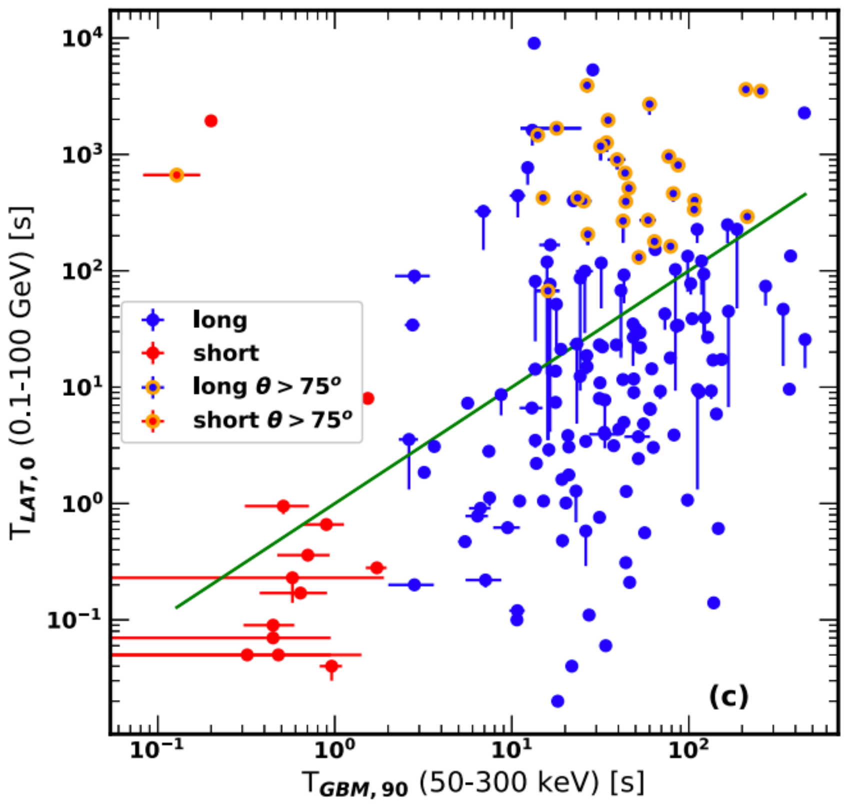
GOTO and LST-1 survey mode

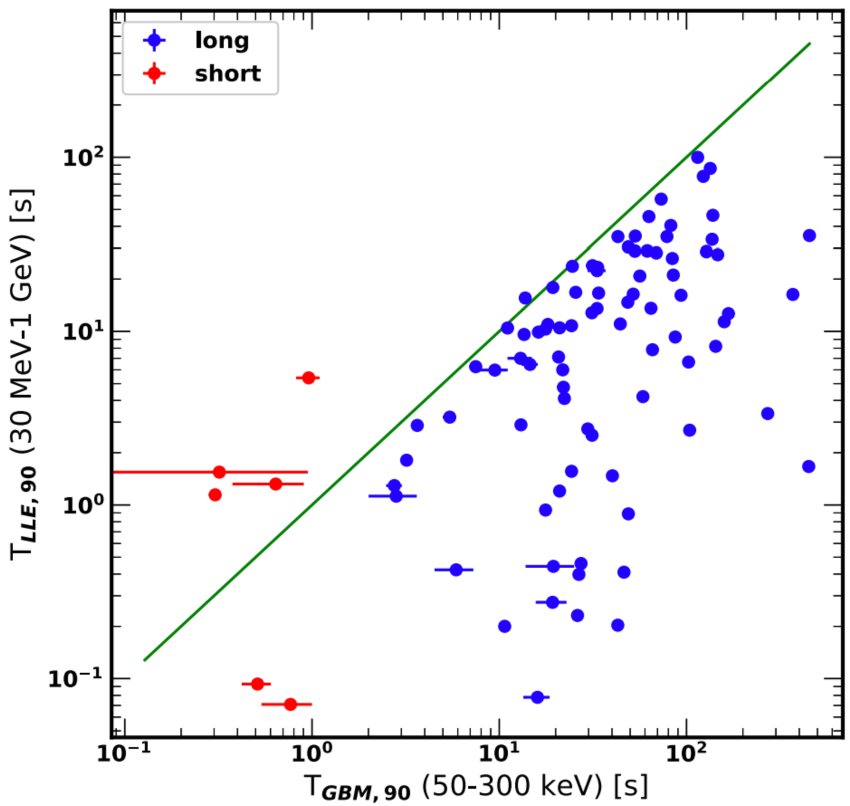
- Coverage over Galactic Plane can be highly contaminated in optical, but very clear in VHE gamma-rays





Fermi LAT population properties





- $T_{LAT,0}$ of majority of GRBs occurs before the prompt emission measured by the GBM is over
- Events outside the nominal LAT FoV (~75°) at time of GBM trigger are marked with thick orange contours.
- Onset of HE emission came after LE emission had faded → most such events are due to observational biases.
- When HE emission detected, starts during the prompt phase in >60% of cases.
- In simple SSC model, Compton emission can be delayed by at most the flux variability time scale, but >> 1s delay
- Instead, SSC emission from late internal shocks with longer variability time at GeV

Fermi LAT population properties

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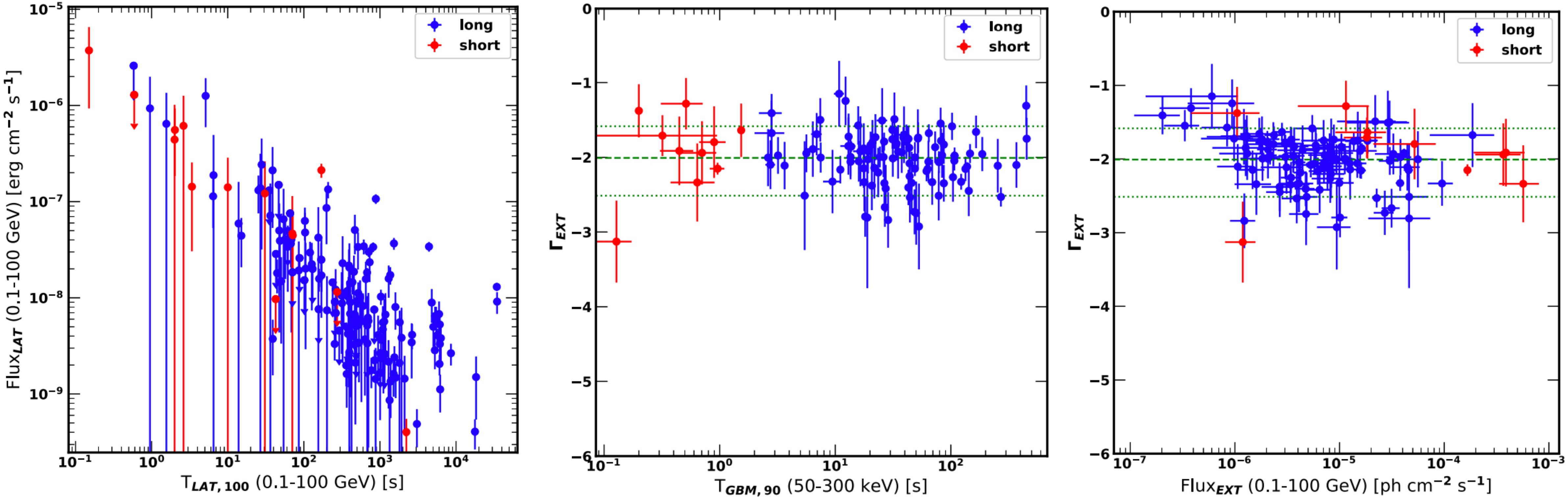


- long and short GRBs show no clear separation in the "LAT" or "EXT" duration window
- photon index shows no sign of correlation with either GBM duration or flux in either time window; similar for long/short GRBs
- may indicate that emission in this window is dominated by afterglow and process is similar regardless of progenitor

Fermi LAT

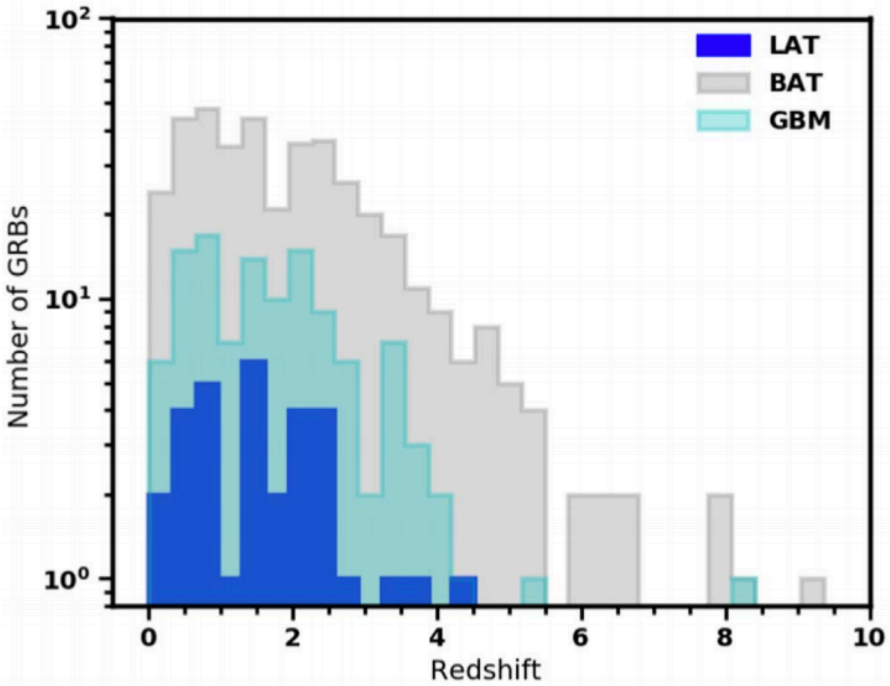


Figure 17. Redshift distribution of 34 GRBs detected by LAT (blue histogram), 405 GRBs detected by *Swift*-BAT (gray histogram), and 116 GRBs detected by GBM (cyan histogram).

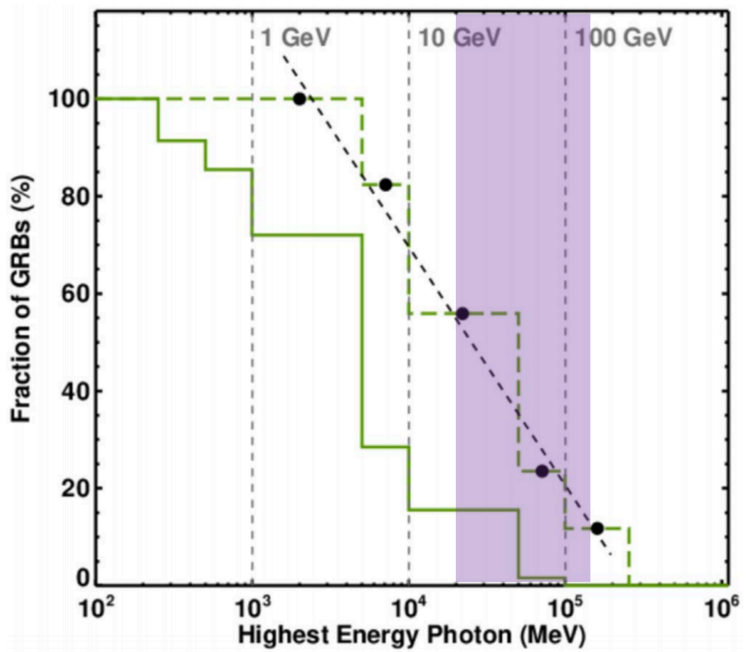
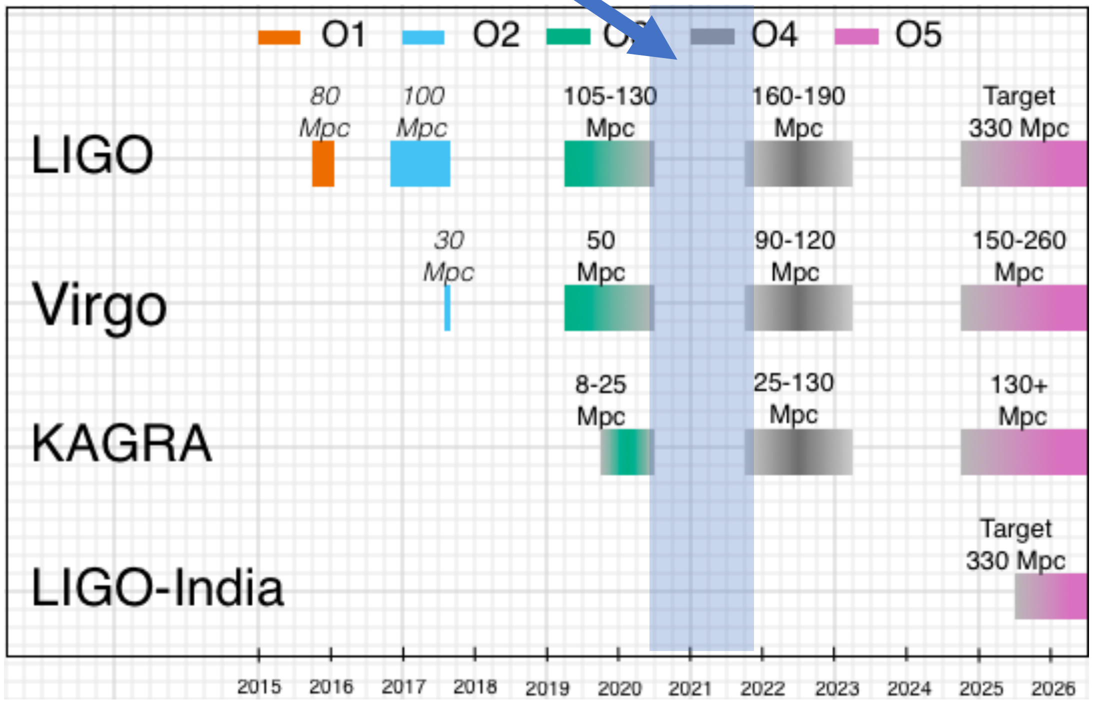


Figure 24. Fraction of GRBs with the highest-energy photon detected above selected threshold energies (250 MeV, 500 MeV, 1 GeV, 5 GeV, 10 GeV, 50 GeV; green solid line). The distribution of the source-frame-corrected energies for the redshift sample is indicated with the dashed green line. The dashed black line denotes a linear fit to the values corresponding to the center of each bin.

- Before launch: estimated that the LAT would detect 10–12 GRBs per year above 100 MeV.
- The results from first GRB catalog show 28 GRBs detected in the first 3 years of the mission (below expectations)
- In second catalog, LAT has exceeded this: 169 GRBs detected above 100 MeV in 10 years

Timescales

- GOTO is currently fully observing
- LIGO-Virgo O3b Run suspended on 24 March; O4 expected in ~2022.
  - Great time to progress on secondary science cases
- Target all Fermi-LAT triggers
- Target Fermi-GBM sGRB triggers with Fermi-LAT detection



M13 on 1-year anniversary

Summary

- GOTO is optimized for and primarily dedicated to GW-EM searches (even poorly localized/lower FAR events). The robotic capability, speed and flexibility of the instrument is great for collaboration with external groups (CTA, …)

- Early identification of candidates (GW counterpart & other notable/fast transient) – have a recent comparison image available

- All 8UTs installed in North giving >50 sq. deg
- Complements longitude/latitude and strategy of other facilities

- Feeder facility for follow-up

- Future: Instruments in the North (~80 sq. deg) and South (~50 sq. deg) for complementary science cases.

www.goto-observatory.org