Detection of TeV emission from poorly localized GRBs with ground based IACTs

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In collaboration with Banerjee B., Seglar-Arroyo M., Green J., Tiwari P., Miceli, D., Oganesyan G.

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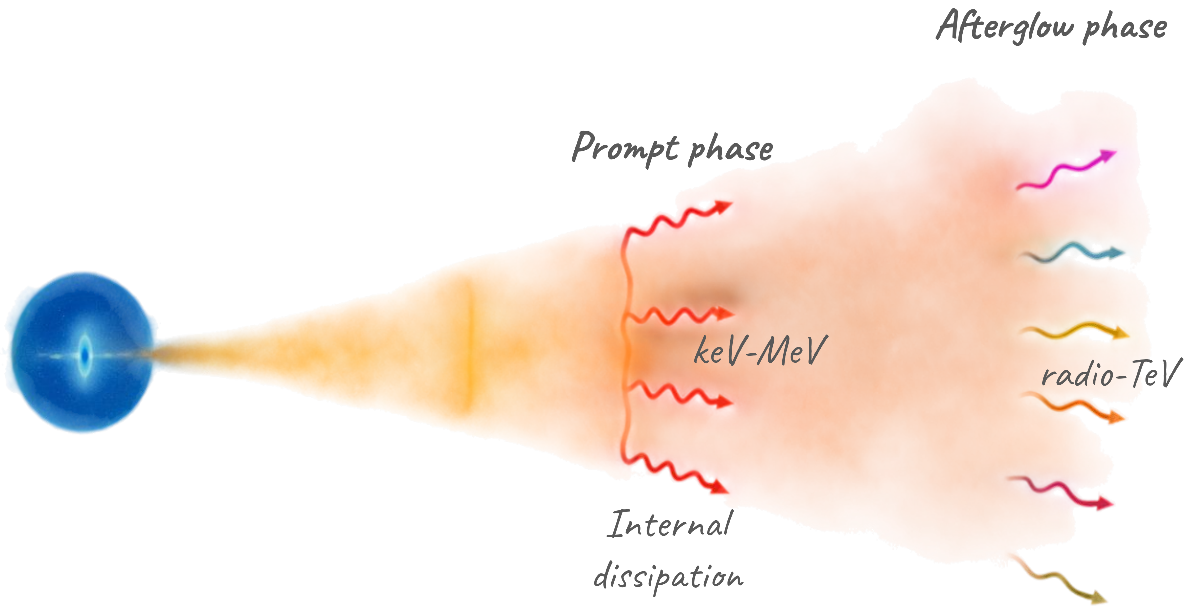
TeV Particle Astrophysics TeVPA Valencia 2025

GRB Phenomenology

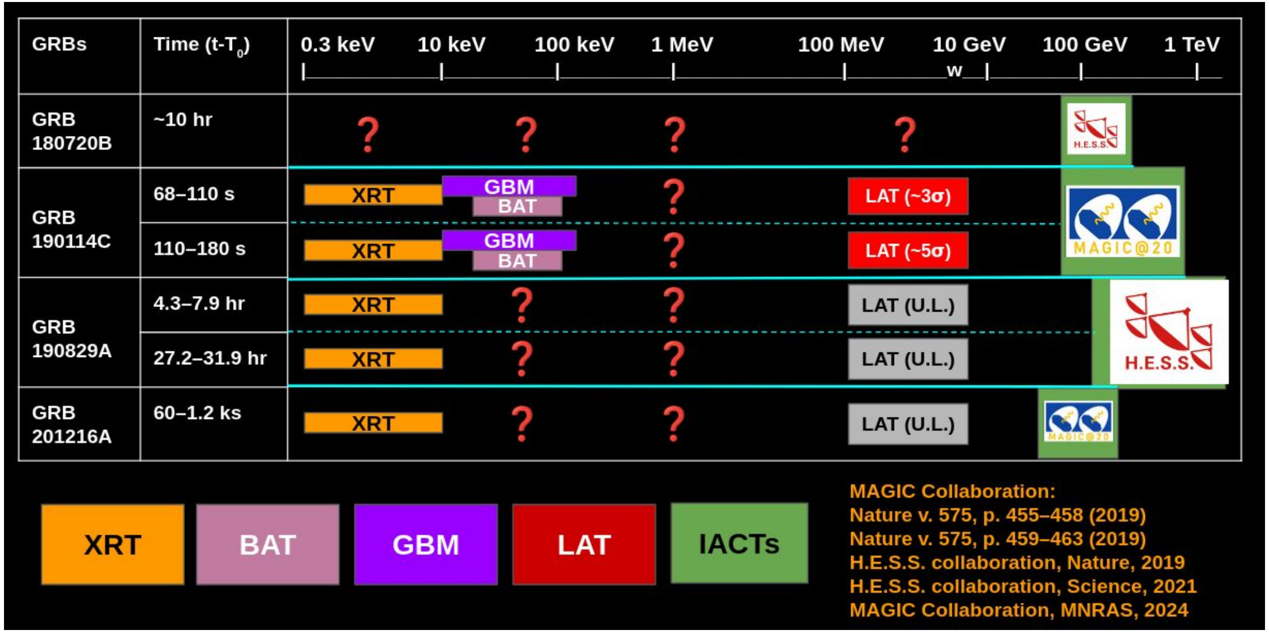


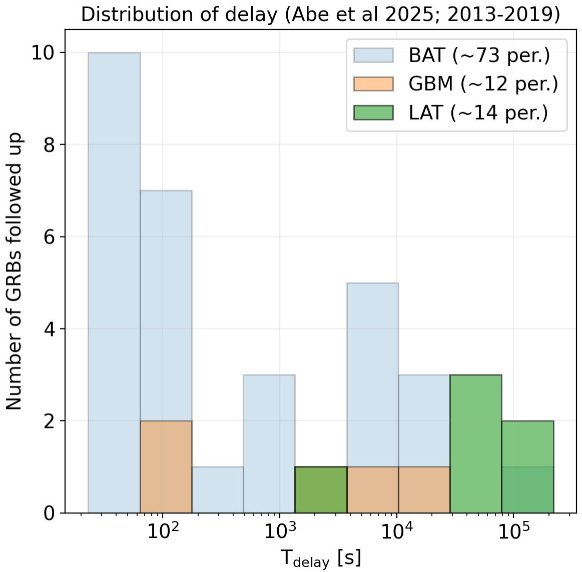
Afterglow emission

- ❖ Wide energy range (from radio to γ)
- ❖ Flux decays as a power law in time
- ❖ Can last from weeks to months
- ❖ External dissipation

Multiwavelength observations (radio-TeV) → unique probe of particle acceleration in relativistic shocks

GRBs detected in the Very High Energy (VHE, E > 100 GeV) domain with Cherenkov Telescopes



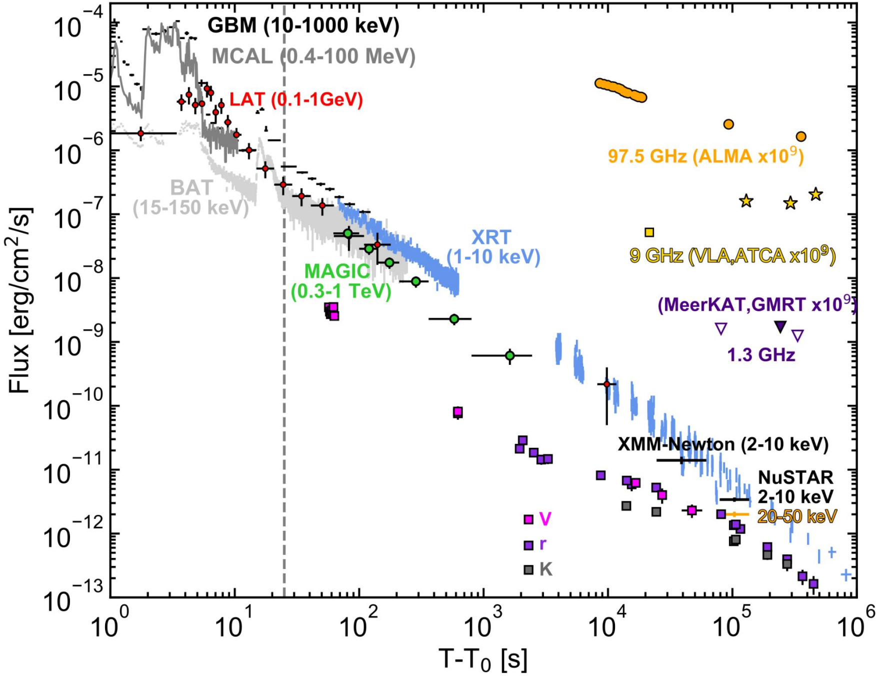


Extracted from Abe et al 2025
(see Miceli's talk)

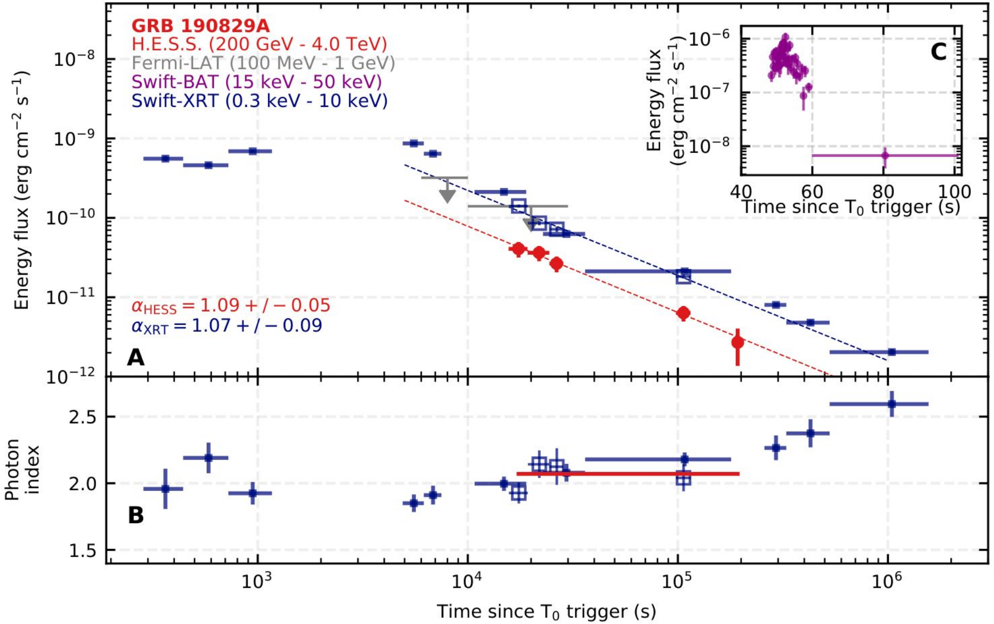
+ GRB 221009A detected by LHAASO
(**see Banerjee's talk**)

What we know: General Trends in GRBs Afterglow

GRB 190114C

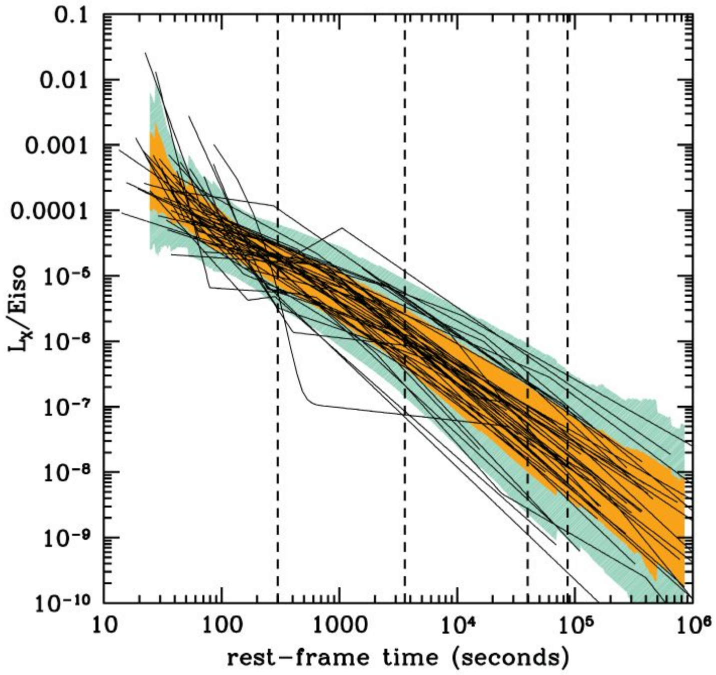


GRB 190829A



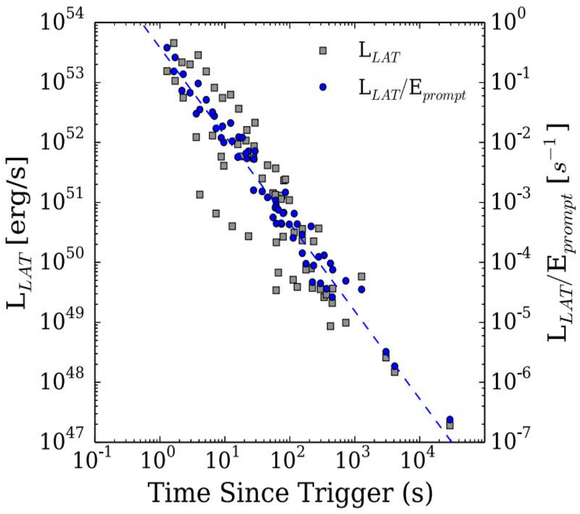
What we know: General Trends in GRBs Afterglow

X-rays (2-10 keV)

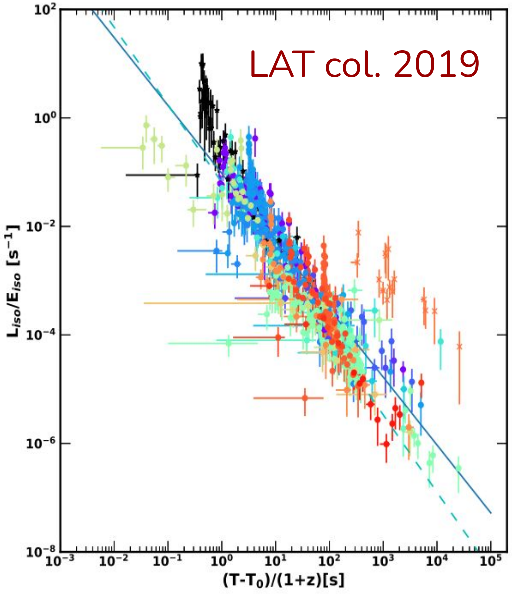


D'Avanzo et al 2012

HE gamma-rays

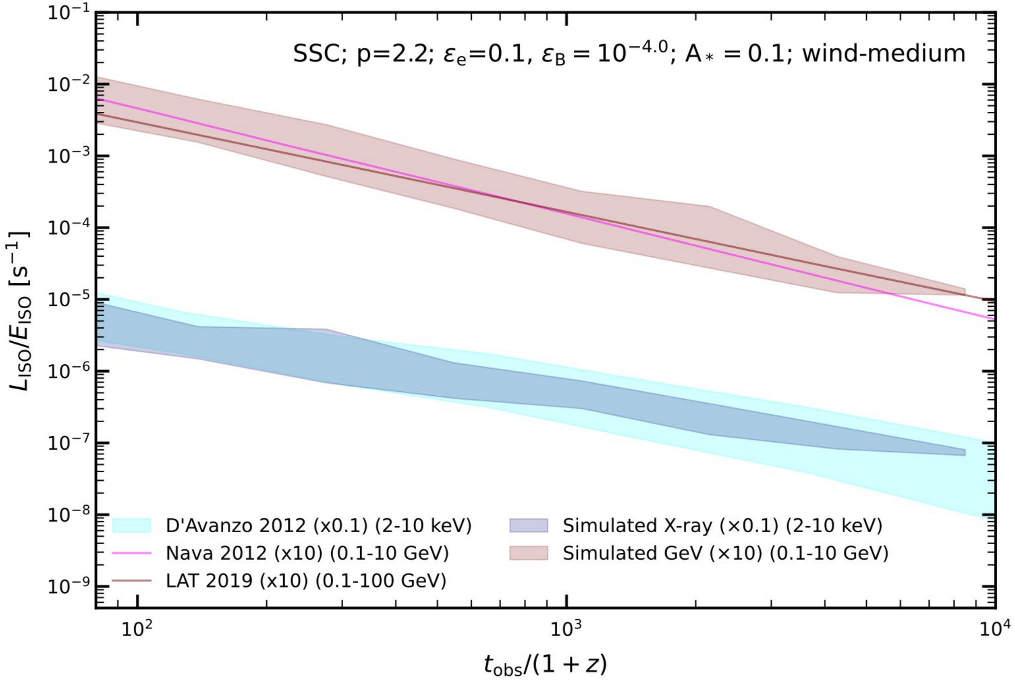


Nava et al. 2014



→ Strong correlation between E_{PROMPT} and afterglow luminosity in X-rays and GeV

What we derive: Afterglow model



Tiwari, P., …, MS et al, submitted to A&A

SSC in wind-medium with η=0.1, p=2.2, ϵ_e~ 0.1, ϵ_B~ 10^{-4}

Can explain:

1. **X-ray study noted in D'Avanzo 2012**
2. **GeV noted in Nava 2014, LAT 2019**

Inverse compton, lower density wind medium, ϵ_B~10^{-4}

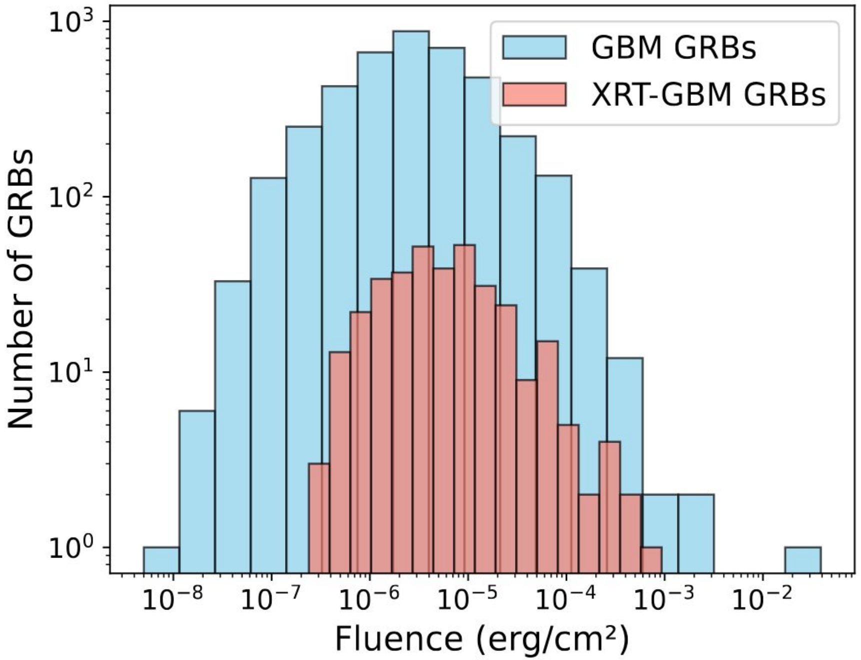
...How to increase the number of detected GRBs?

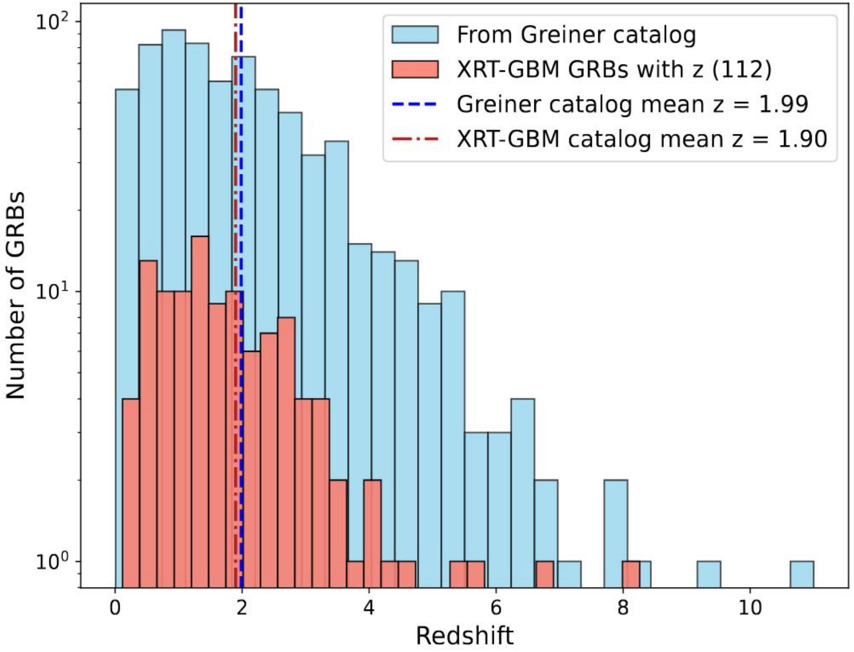
→ Follow-up also GRBs poorly localized by Fermi/GBM (or any similar detector) with an optimized observational strategy

Method

Collect GRBs detected by Swift/XRT and Fermi/GBM

- X-ray informations;
- Accurate sky-localization from XRT
- Sky-localization from GBM





Method

(Given the distribution of Fluence, z, E_{iso})

Collect GRBs detected by Swift/XRT and Fermi/GBM

Simulate one year of long GRBs (220 events = GBM detection rate)

Method

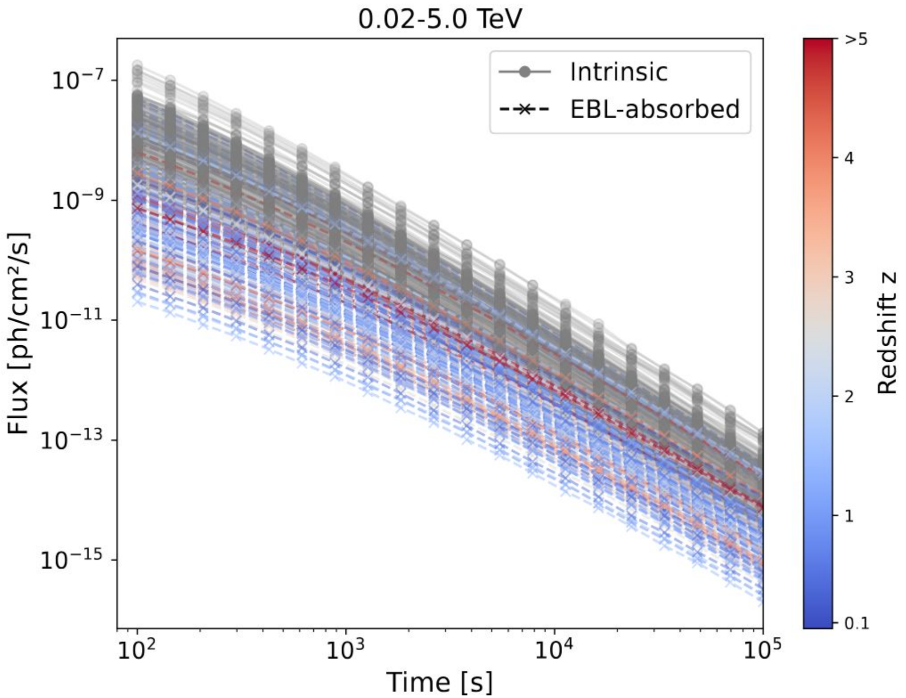
(Given the distribution of **Fluence, z, E_{iso}**)

Collect GRBs detected by Swift/XRT and Fermi/GBM

Simulate one year of long GRBs (220 events = GBM detection rate)

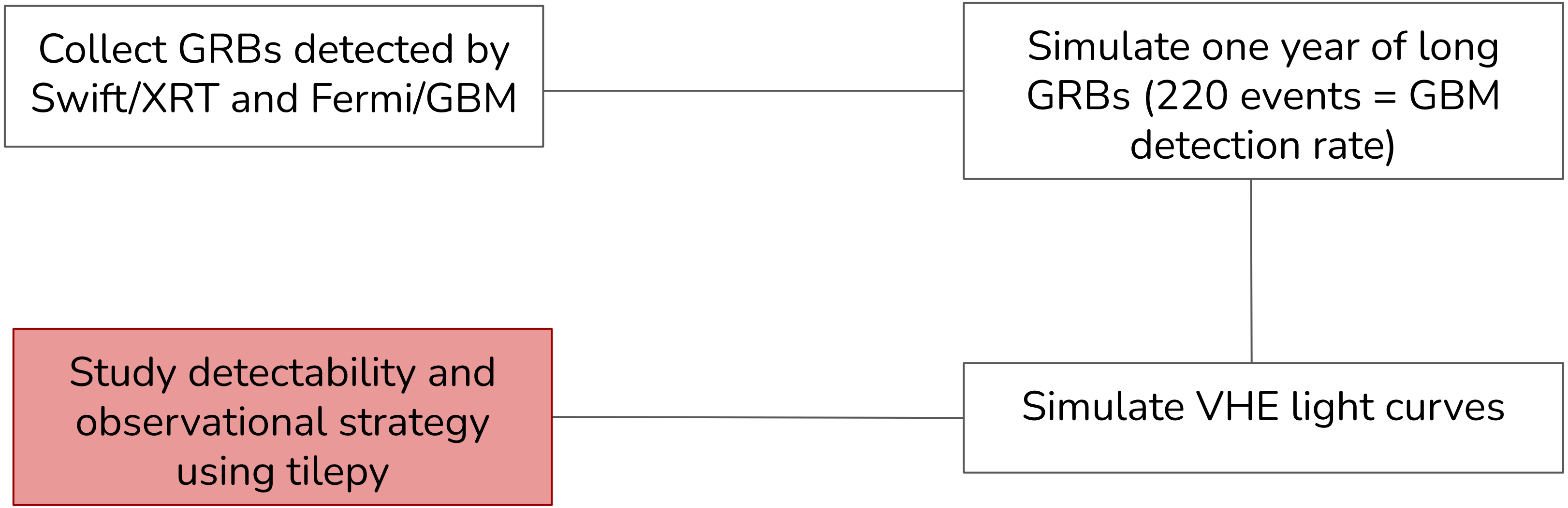
Simulate VHE light curves

EBL model by Dominguez et al 2011



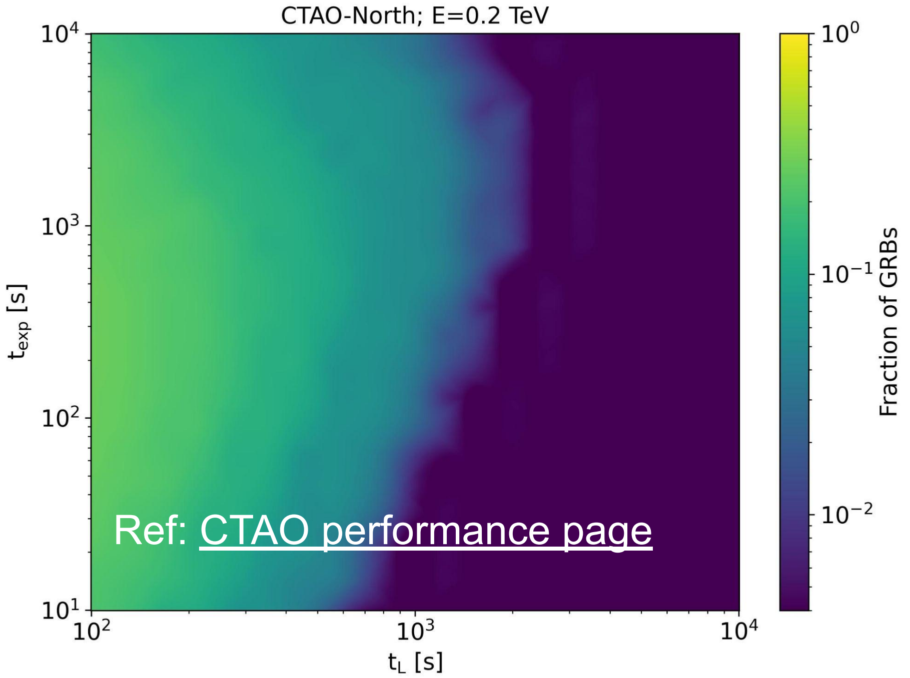
LeHaMoC:
leptohadronic modeling code
(Stathopoulos et al 2023)

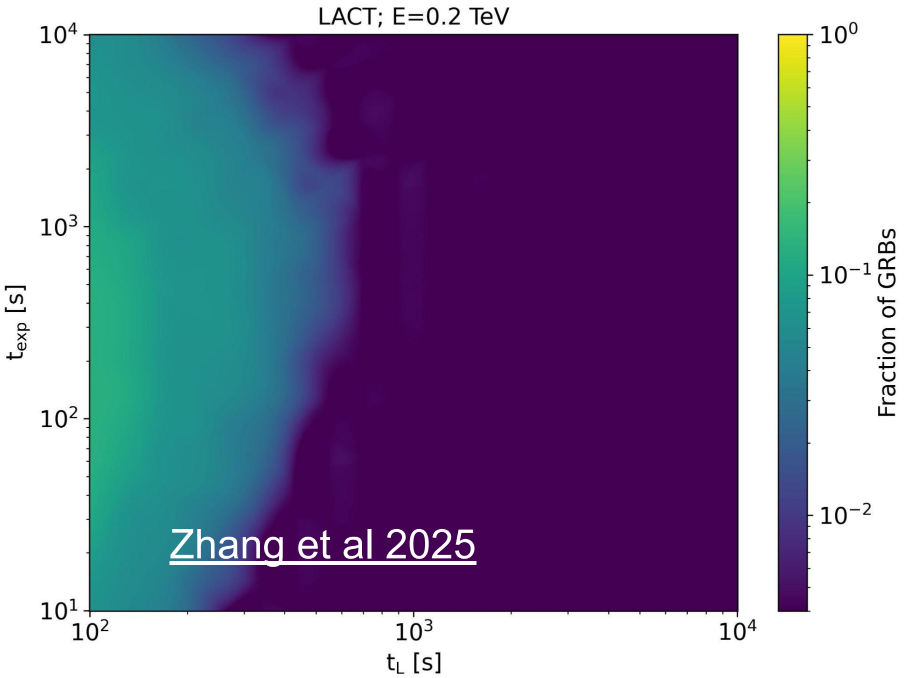
Method



How? → Use the produced **VHE light curves** + **sensitivity curves** or **IRFs** when available

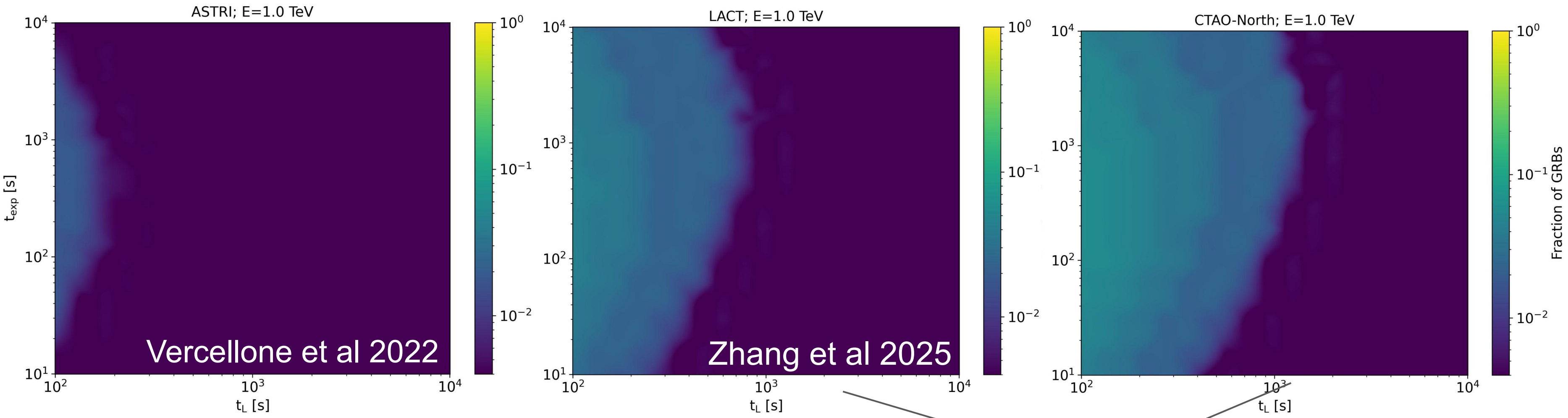
200 GeV Light Curves (applicable for low zenith)





- Promising for early follow-up
- Maximum latency ~ 30 minutes
- low t_{exp}
- ~40-50% of GRBs detectable

1 TeV Light Curves (from medium to high zenith)



- Wide FoV
- Single re-pointing suggested
- Maximum latency ~ 2 minutes
- 5% of GRBs can be followed-up

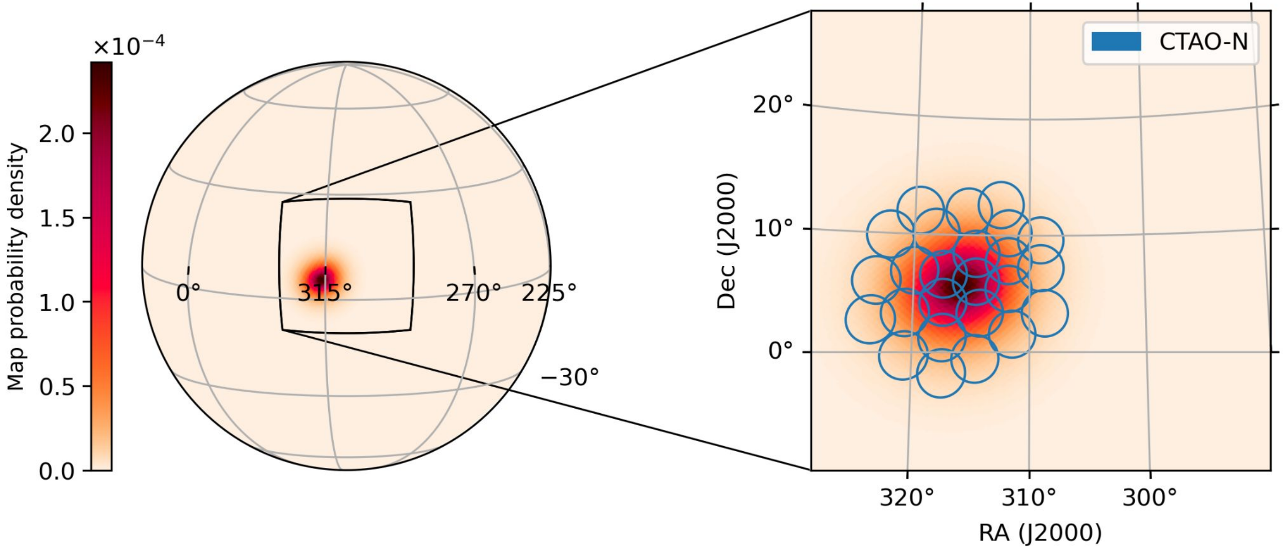
- Less GRBs detectable (mainly due to EBL absorption)
- Early follow-up suggested
- Maximum latency ~ 20-30 minutes
- low t_{exp}

Talk by **Carosi**

Scheduling strategy for Fermi-GBM GRBs

Next steps: Understanding the trade-off between exposure time, latency and detectability

With TILEPY
(Seglar-Arroyo 2024)



5’ exposure: 92% coverage

Conclusions

Follow-up of poorly localized GRBs (large sky-loc) → simulated sample of 1 year of observations

- ★ 200 GeV:
  - CTAO/LACT give promising results for early follow-up (max latency ~ 30 min)
  - 40-50% of GRBs detectable
- ★ 1 TeV:
  - Worse detectability, mainly due to strong EBL-absorption (caveat: no extra effects taken into account in our model)
  - CTAO/LACT: less detections, maximum latency ~ 20-30 minutes
  - ASTRI can see 5% of the events with single-repointing within ~ 2 min

→ <u>Early follow-up (up to 30-40 min) of Fermi/GBM (or similar detectors) GRBs could increase the number of detections</u>

→ Optimize observational strategies, i.e. optimize tilying, or divergent pointing (see **Ambrosini's talk**)... work in progress!

Thank you for your attention

Backup

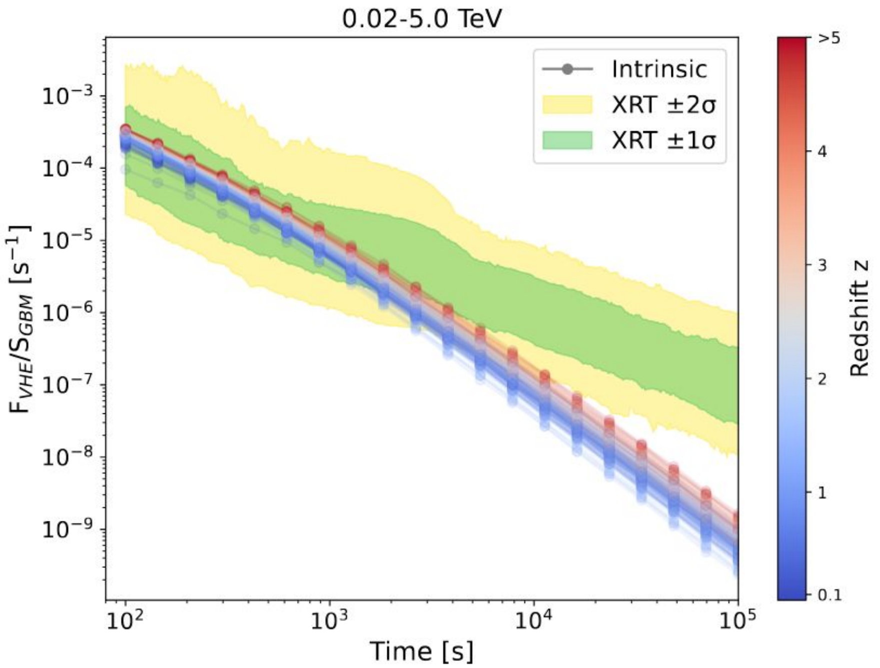
Method

(Given the distribution of Fluence, z, E_{iso})

Collect GRBs detected by Swift/XRT and Fermi/GBM

Simulate one year of long GRBs (220 events = GBM detection rate)

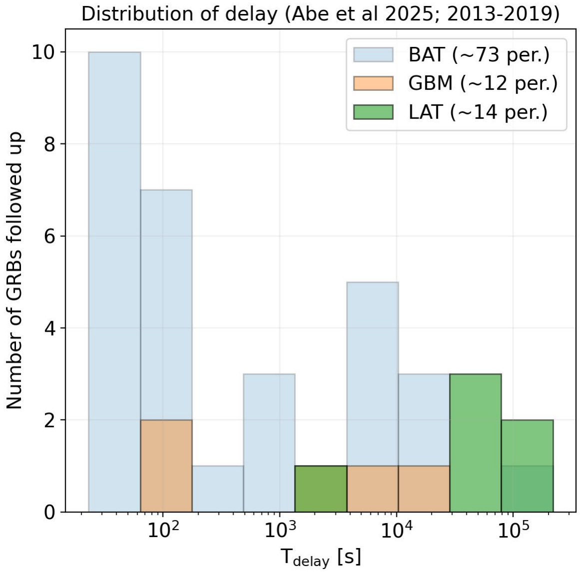
Simulate VHE light curves



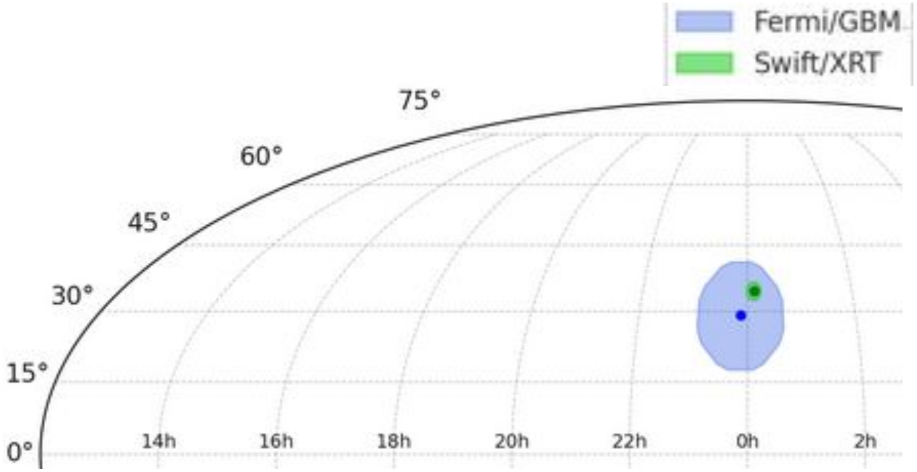
LeHaMoC:
leptohadronic modeling code
(Stathopoulos et al 2023)

Why so few? Challenge for Early Follow-up

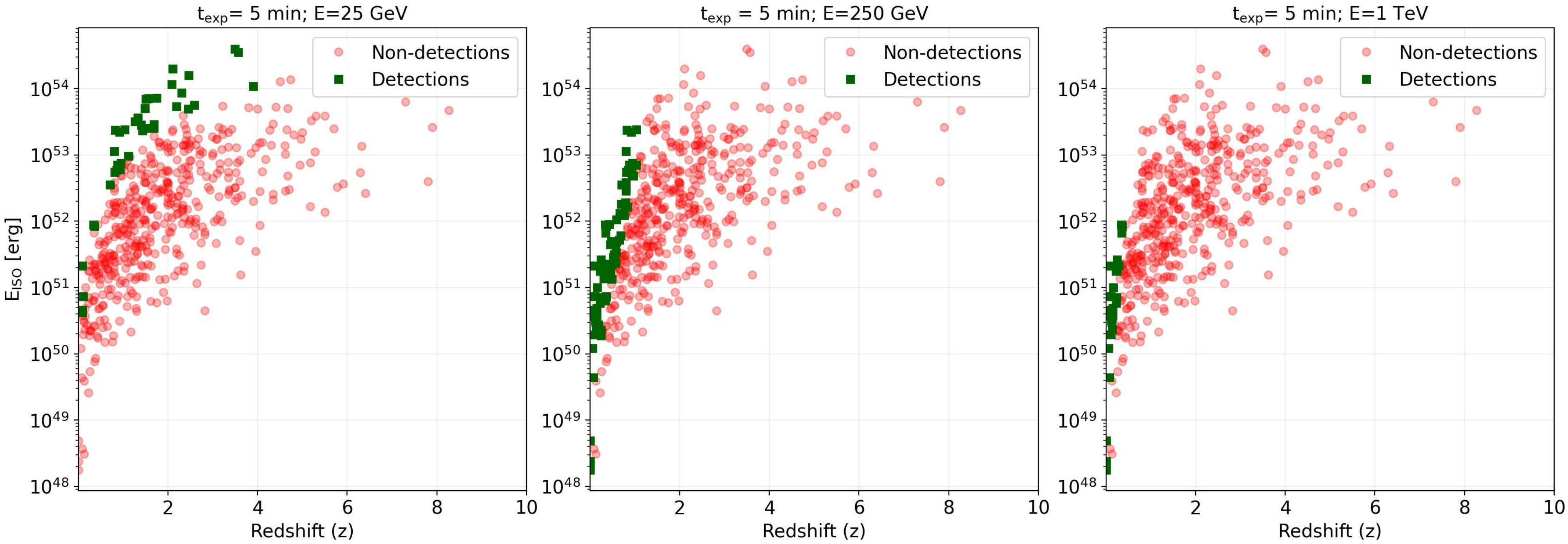
- Early follow-up depends on Fermi/GBM sky localization (via GCN notices)
- GBM provides large error regions → poorly localized GRBs
- Follow-up of only well localized GRBs: Swift/BAT GRBs, but less detections per year!



Extracted from Abe et al 2025

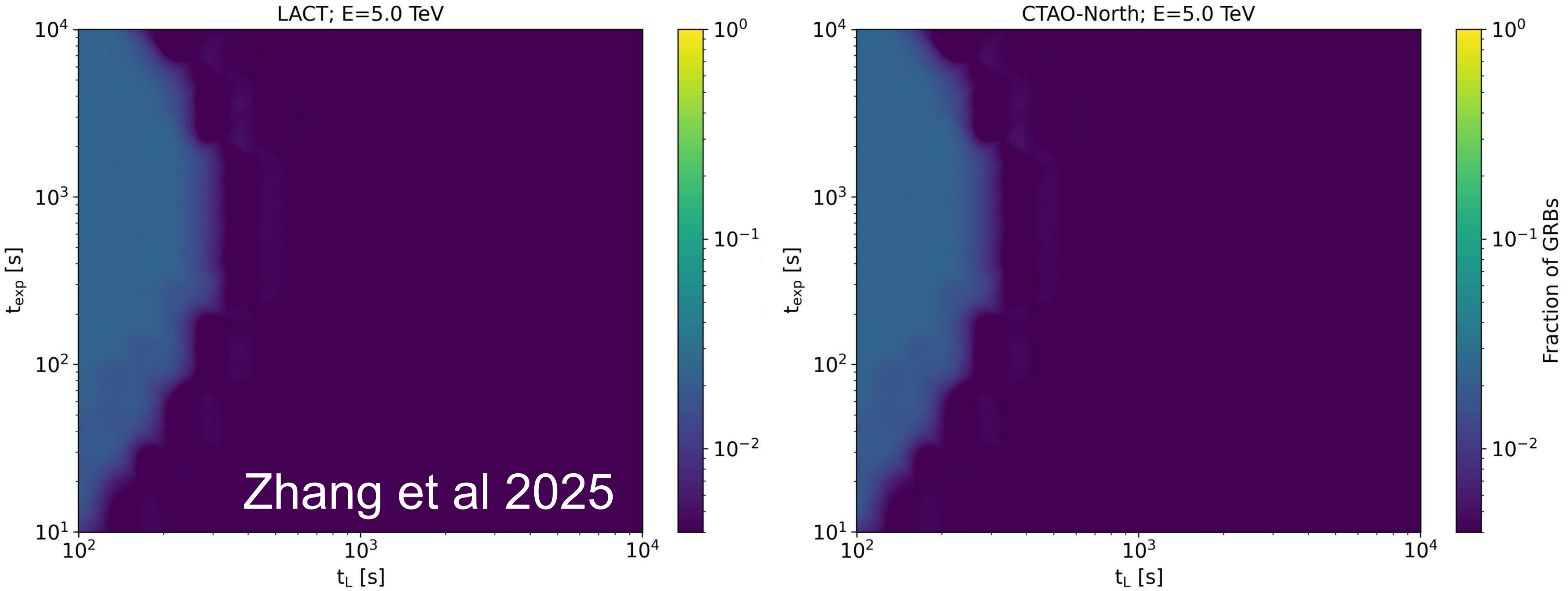


CTAO horizon:



*Given that all the sources are followed up starting from 100s from T_0 with an exposure of 5mins.

5 TeV Light Curves



Stronger EBL absorption, less detections

FoV of different instruments

Instrument		FoV	square deg
ASTRI		10°	→ 78.5
LACT		8°	→ 50.27
CTAO-North	**LST**	4.5°	→ 14.53
	MST	7.5°	→ 44.18

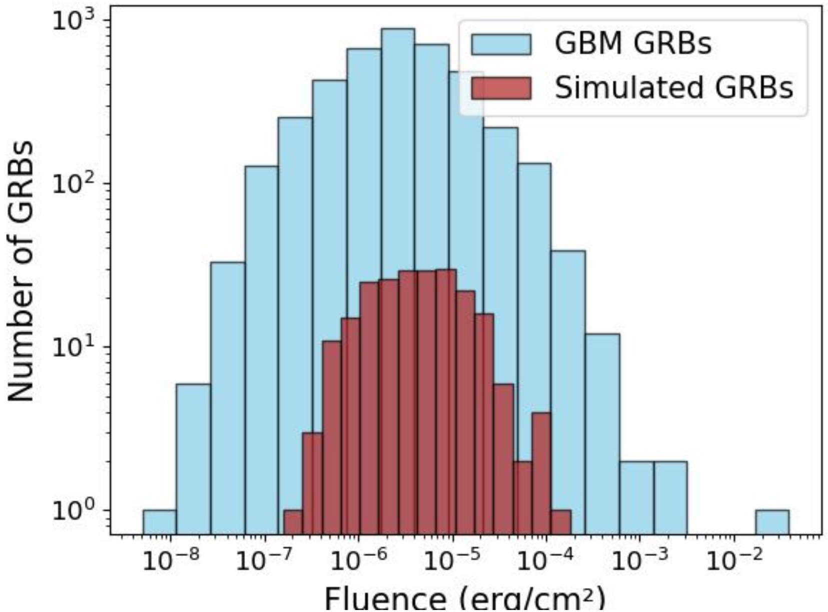
Fermi/GBM localization ~ 2-300 deg^2

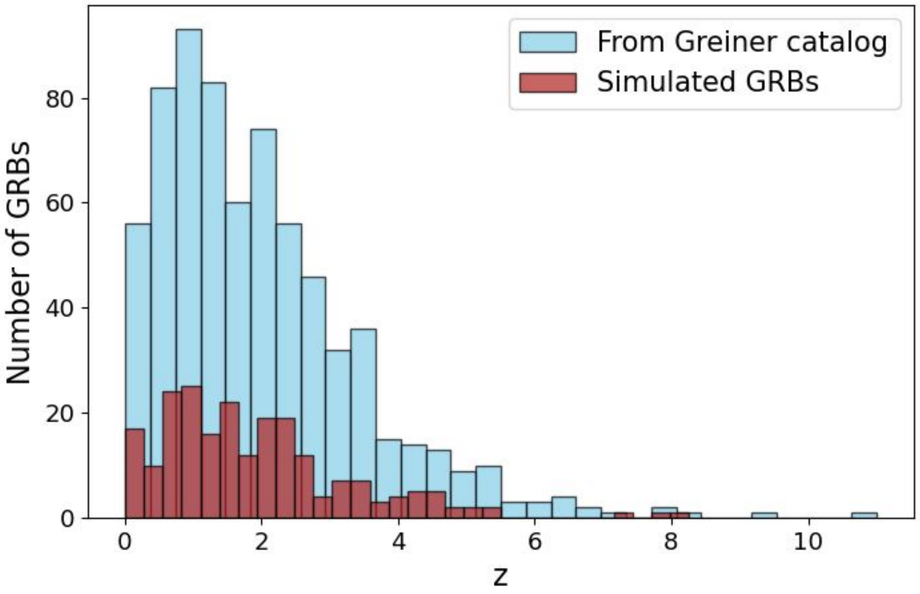
Swift/XRT localization ~ 0.16 deg^2

Method

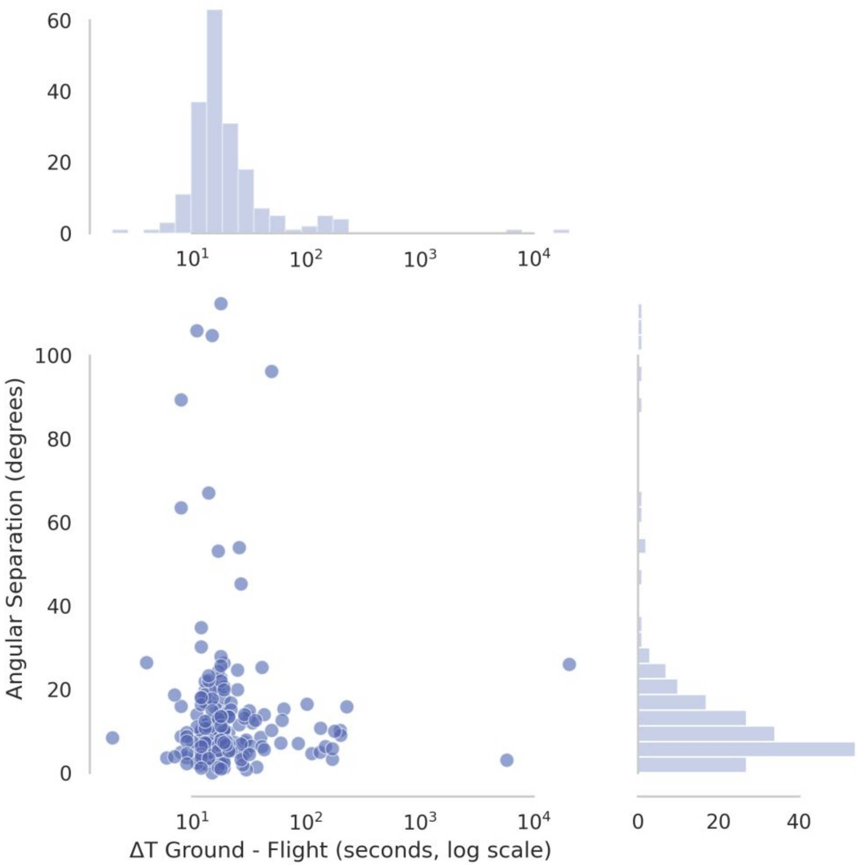
Collect GRBs detected by Swift/XRT and Fermi/GBM

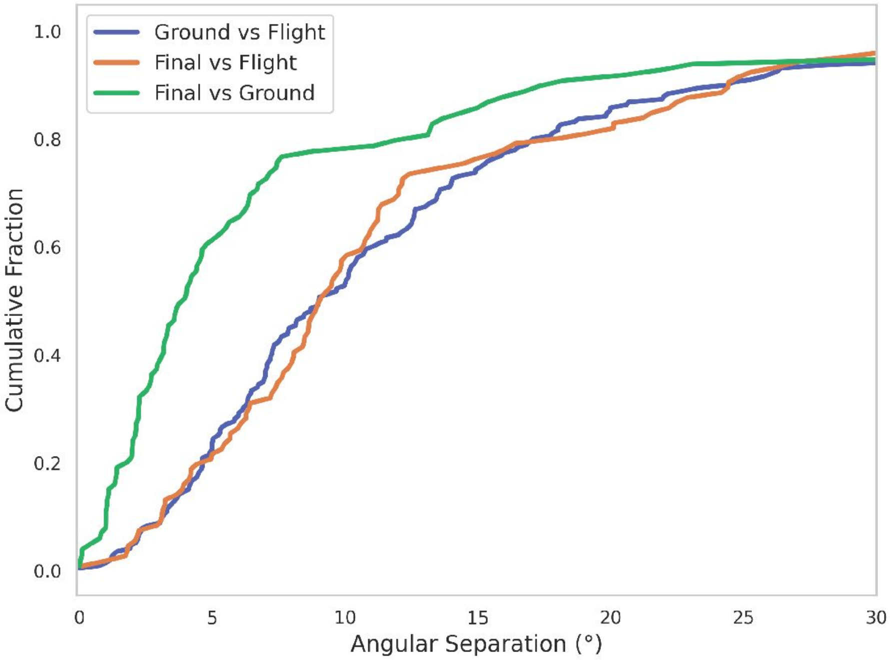
Simulate one year of long GRBs (220 events = GBM detection rate)





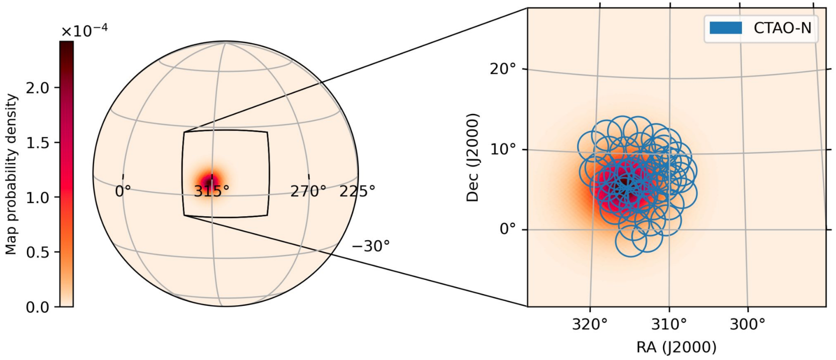
Angular separation between different GCN sky-loc



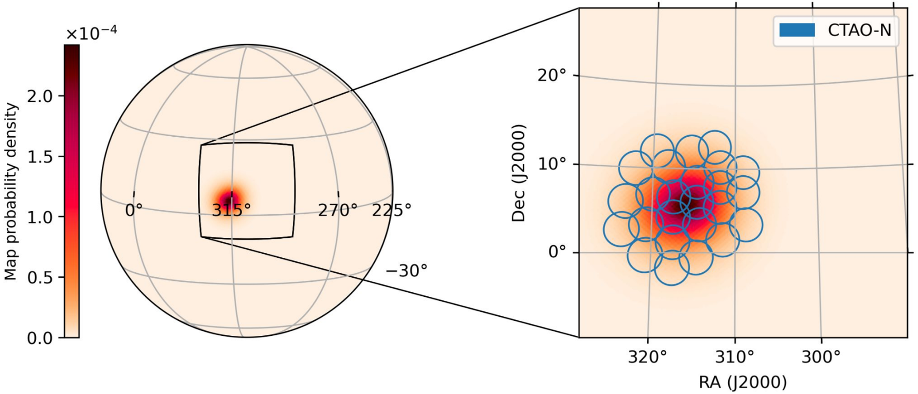


Scheduling strategy for Fermi-GBM GRBs

Next steps: Understanding the trade-off between duration, coverage and detectability



1’ exposure: 85% coverage, does not allow for the Earth to turn enough to access part of the region



5’ exposure: 92% coverage in way less observations!