Perspectives of observing prompt very-high-energy gamma emission from binary neutron star mergers

- Biswajit Banerjee

Gamma-2022, Barcelona

GSSI GW team

Motivation

- Detection of GRBs in very high energy gamma-rays (VHE) by MAGIC and HESS.
- New window for GRB physics
- Possible to detect prompt emission in VHE?

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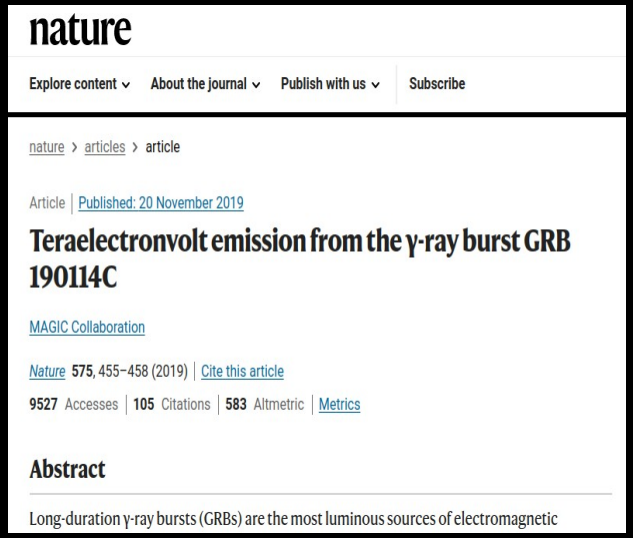

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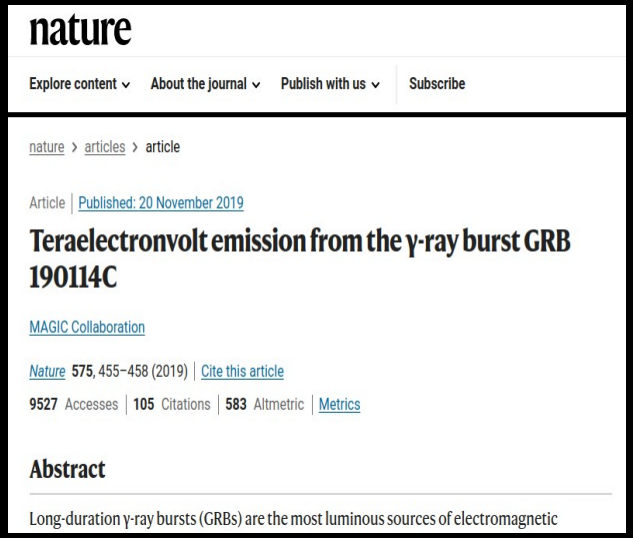
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Teraelectronvolt emission from the γ-ray burst GRB 190114C

MAGIC Collaboration

Nature **575**, 455–458 (2019) | Cite this article

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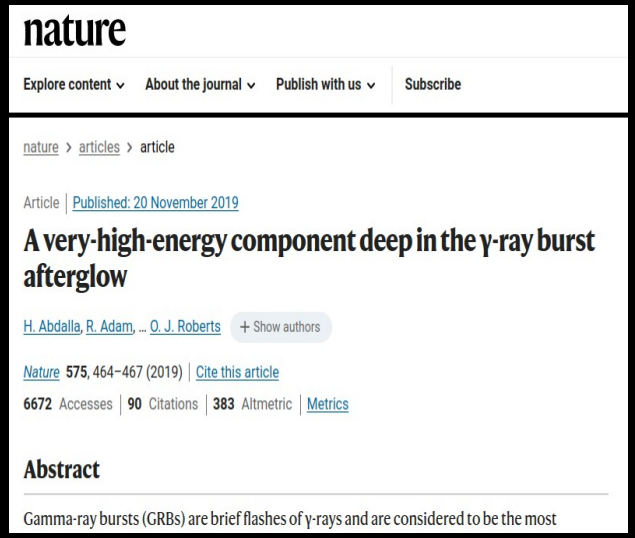
Abstract

Long-duration γ-ray bursts (GRBs) are the most luminous sources of electromagnetic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Article | Published: 20 November 2019

A very-high-energy component deep in the γ-ray burst afterglow

H. Abdalla, R. Adam, ... O. J. Roberts + Show authors

Nature **575**, 464–467 (2019) | Cite this article

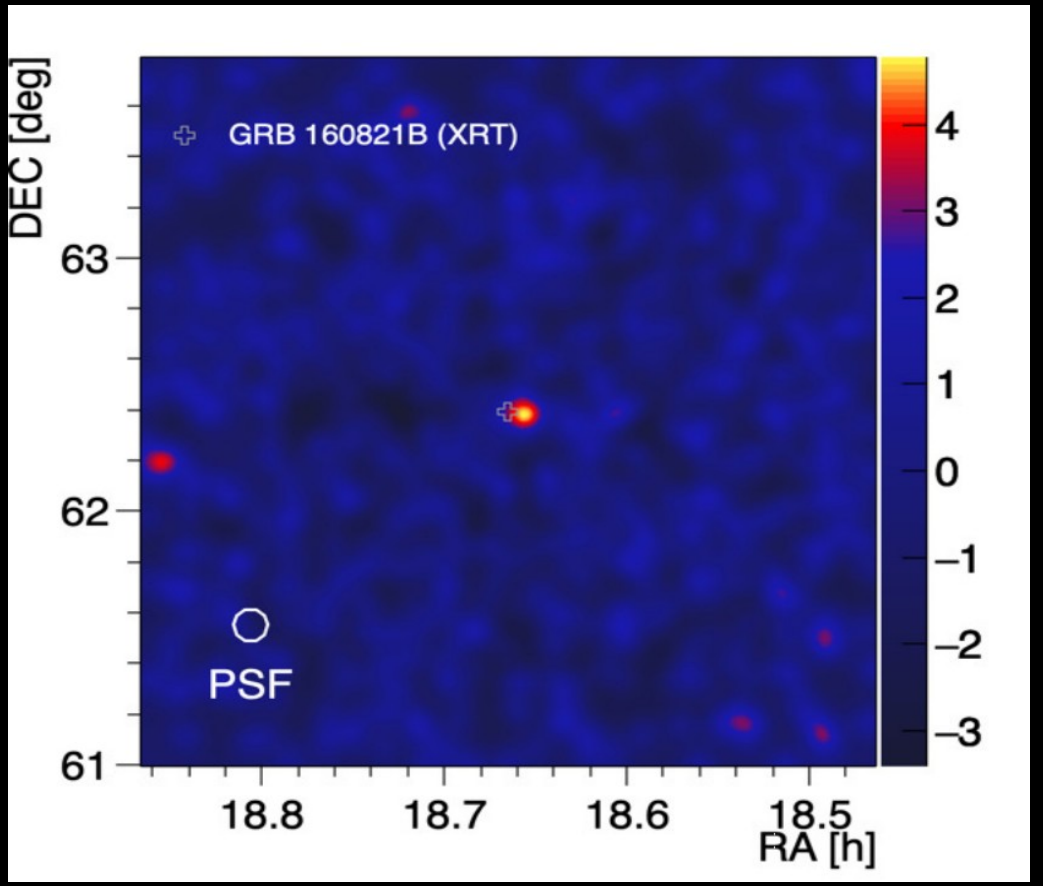
6672 Accesses | **90** Citations | **383** Altmetric | Metrics

Abstract

Gamma-ray bursts (GRBs) are brief flashes of γ-rays and are considered to be the most

Short-GRB in VHE: GRB 160821B

- Excess of TeV photons (~3σ); E > 0.5 TeV
- Results in an upper limit- helps to constrain emission models.
- After 20s: shortest response time so far.



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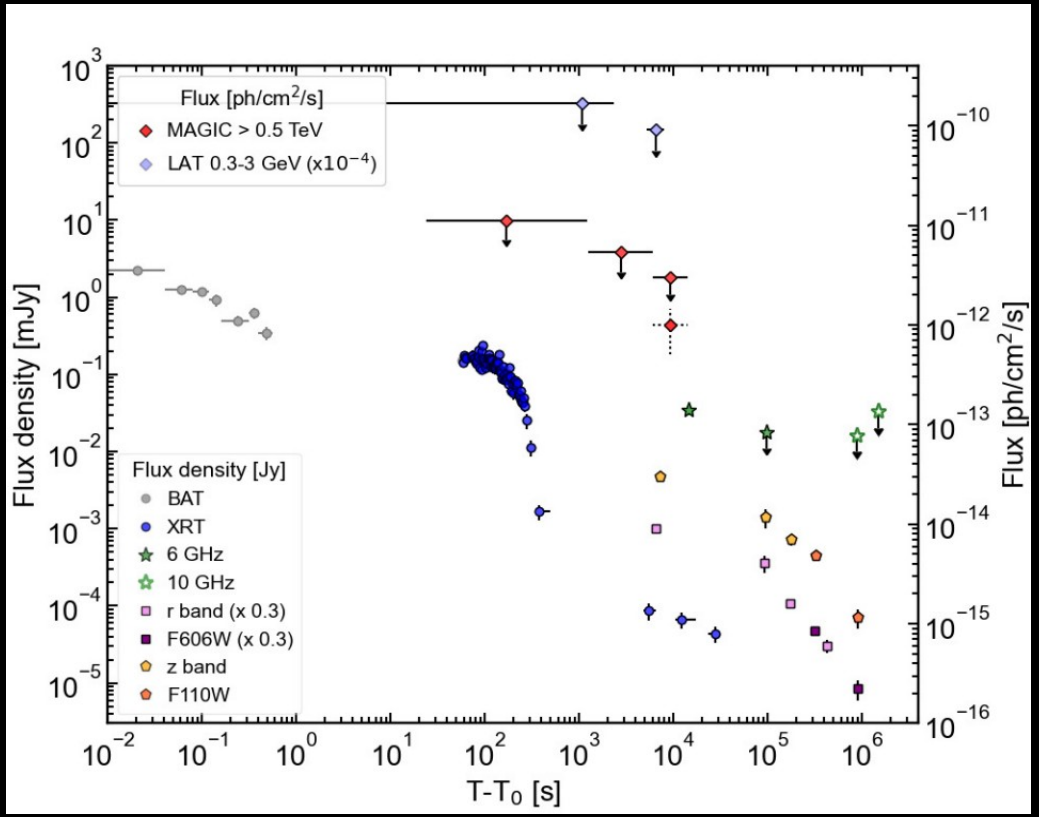
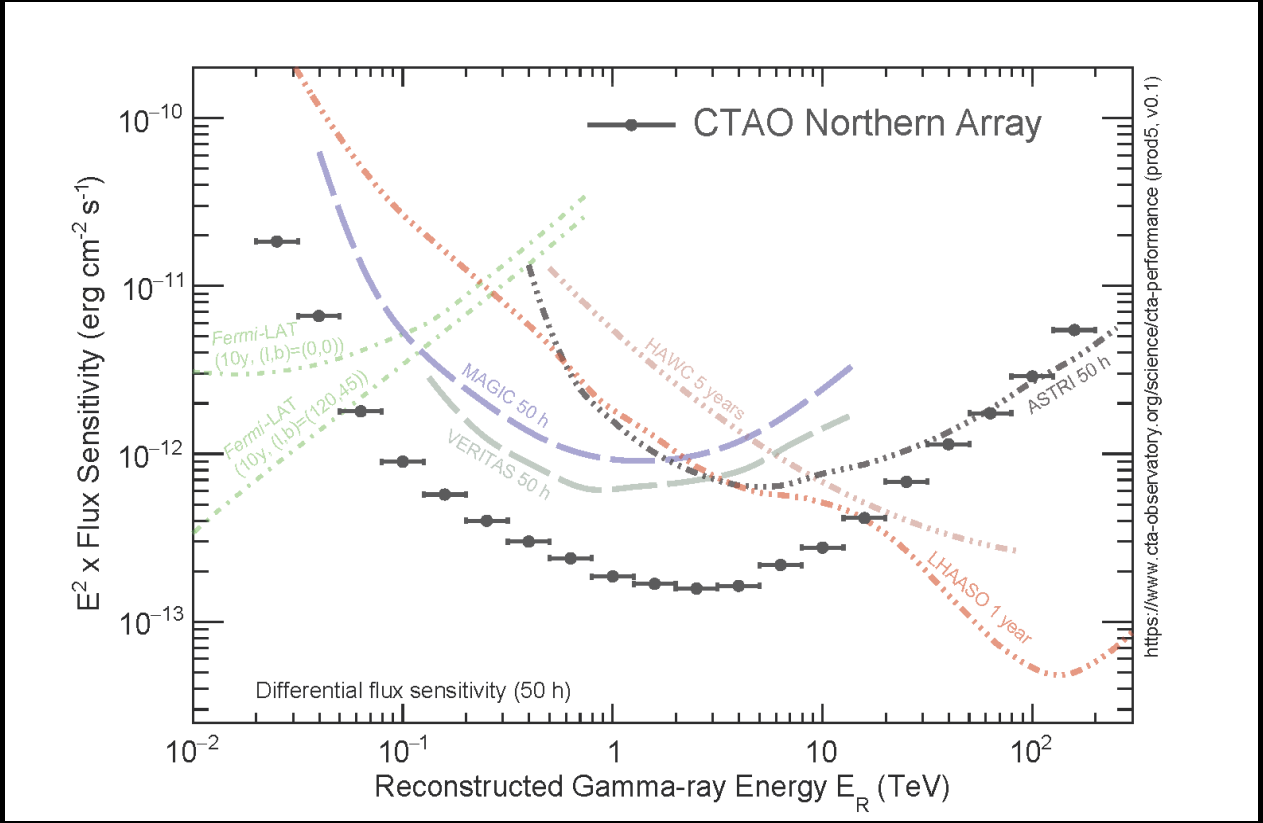


Cherenkov Telescope Array (CTA)

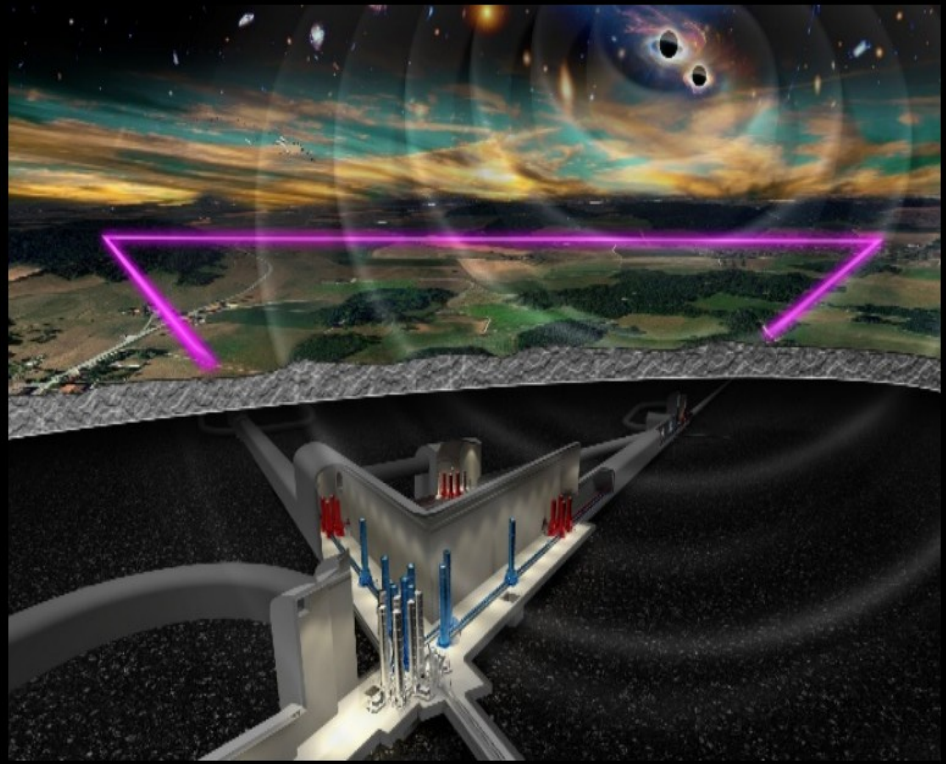
- Largest IACT facility (100+ IACTs)
- Sites: La Palma, Spain and Chile.
- 10x better sensitivity
- Energy: 0.01- 100 TeV
- FoV ~50 sq. deg.
- Response time of ~20s



Einstein Telescope & Cosmic Explorer

Credit: Google-map

- Triangular detector
- Arm length of 10 km
- Underground Locations (selection by 2025)
- Sardinia, Italy/ Netherlands



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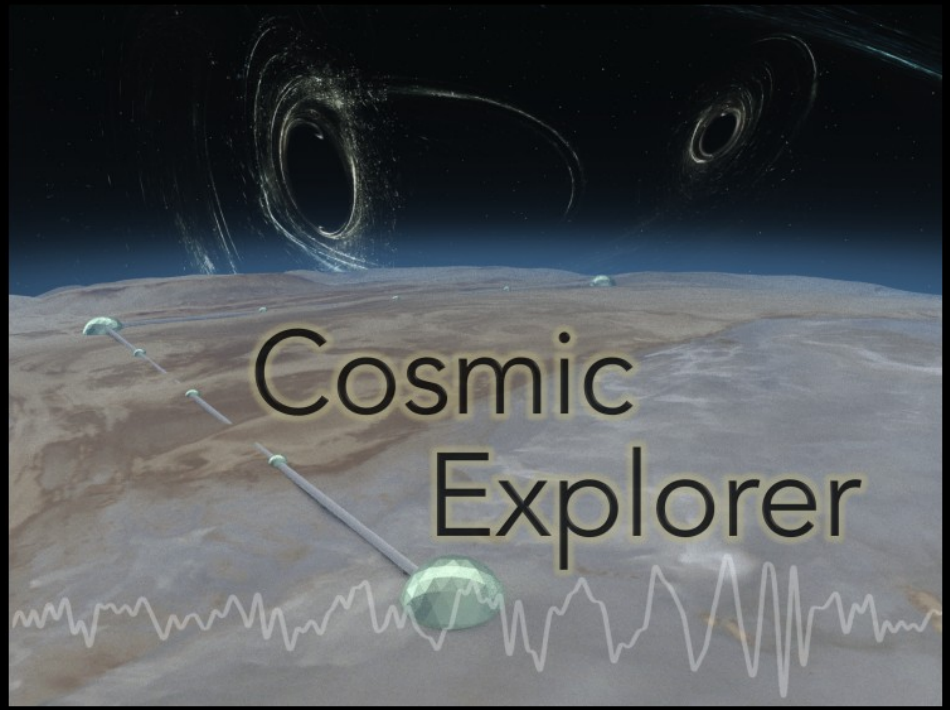
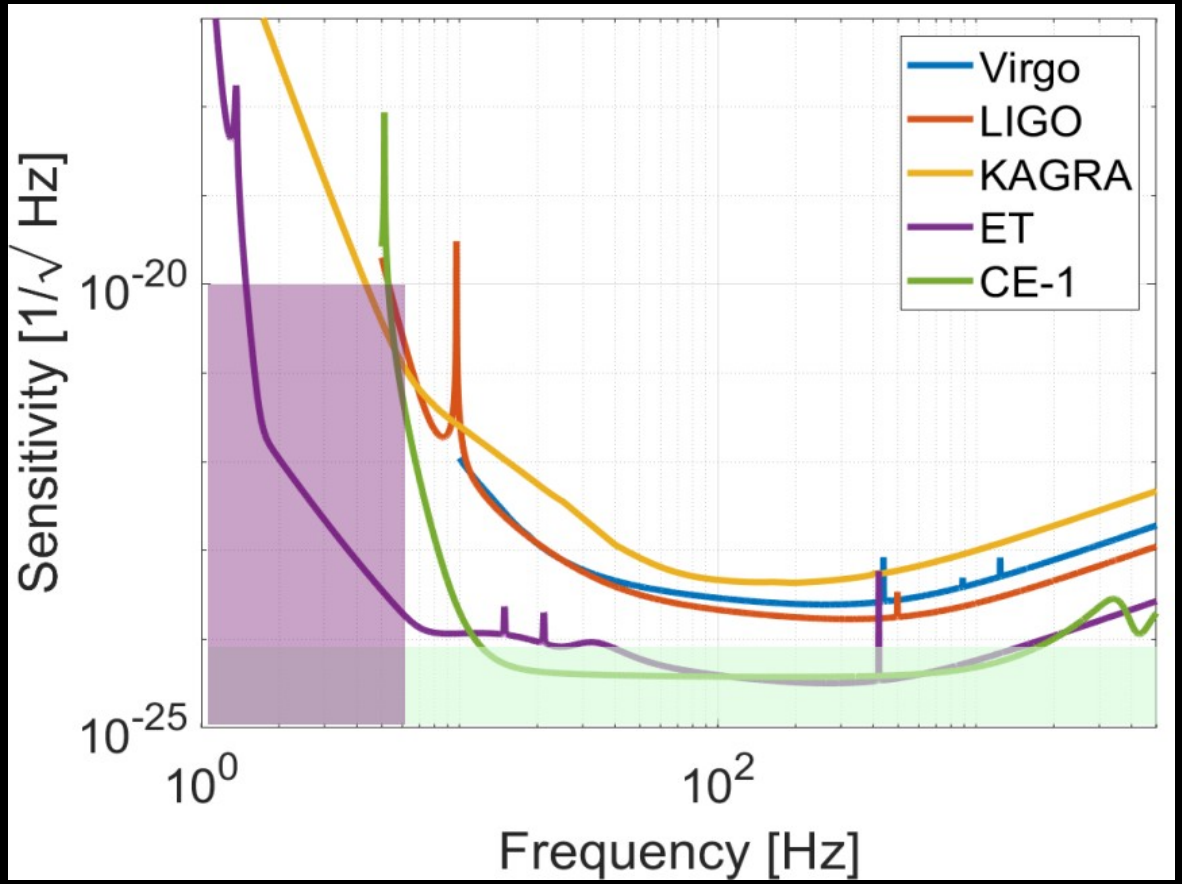


- Surface L-shaped detectors
- Arm length of 40 km
- Location: USA and Australia

Einstein Telescope & Cosmic Explorer

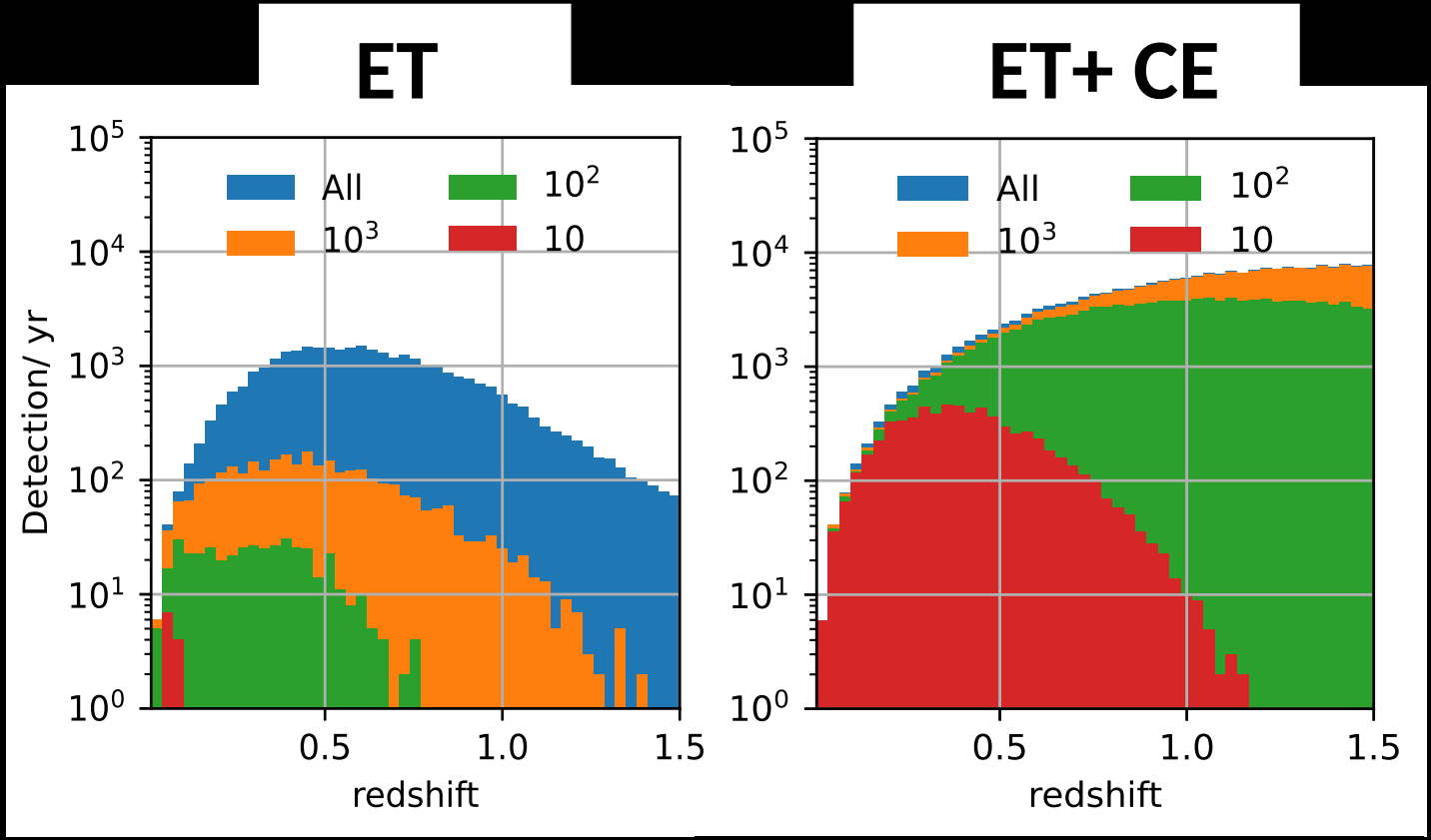


ET/ CE sky-localization capabilities:

GWFISH

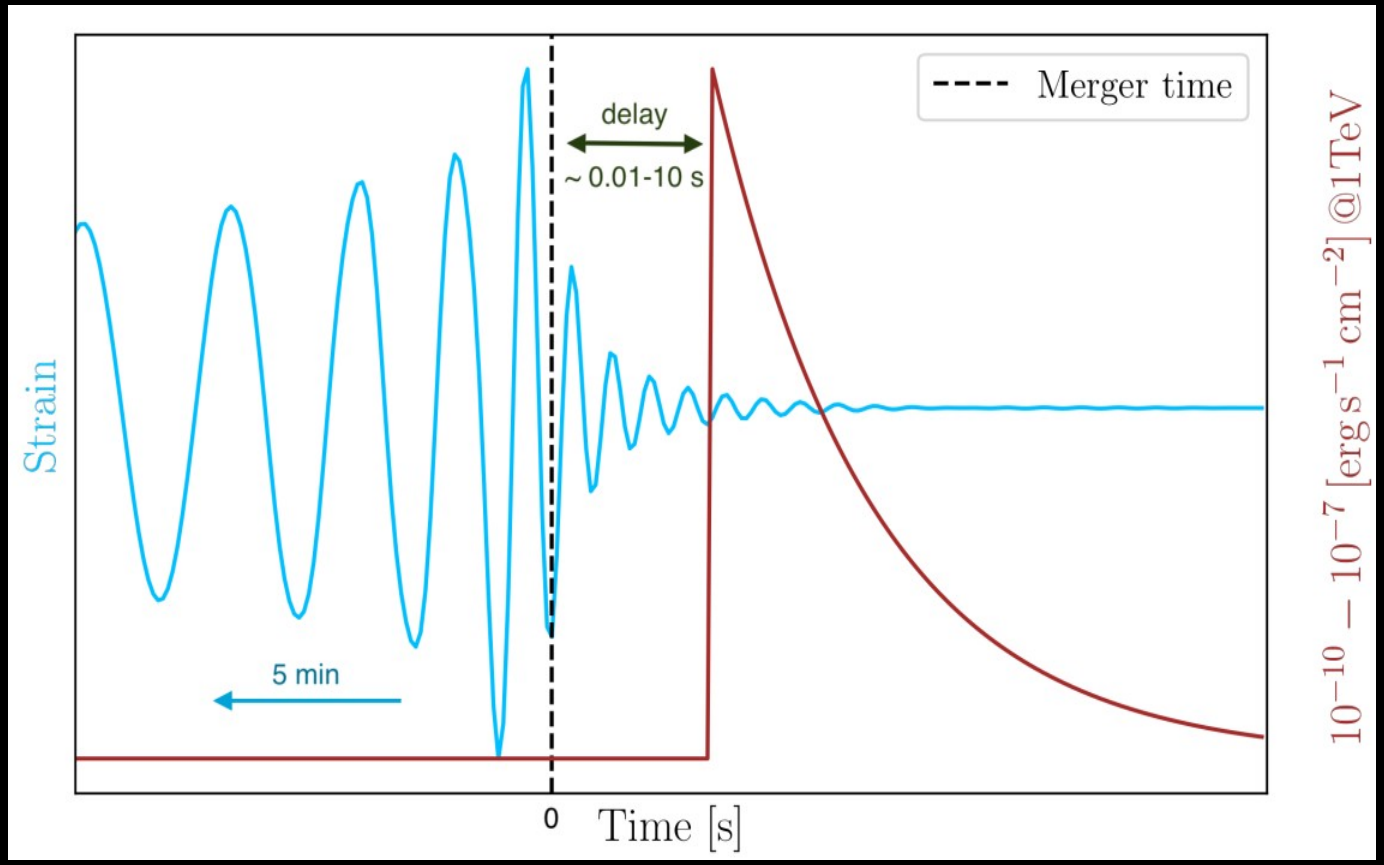
Harms et al. ‘2022

- Injection: 10^5/ yr
- Mass: 1-2.5 M_s
- CosmoRate
(Santoliquido et al. 2020)



github.com/janosch314/GWFish

Concept of Pre-alert:



- Low-frequency coverage

- Pre-alerts, detection and sky-localization before the merger

Sky-Localization Pre-mergers:

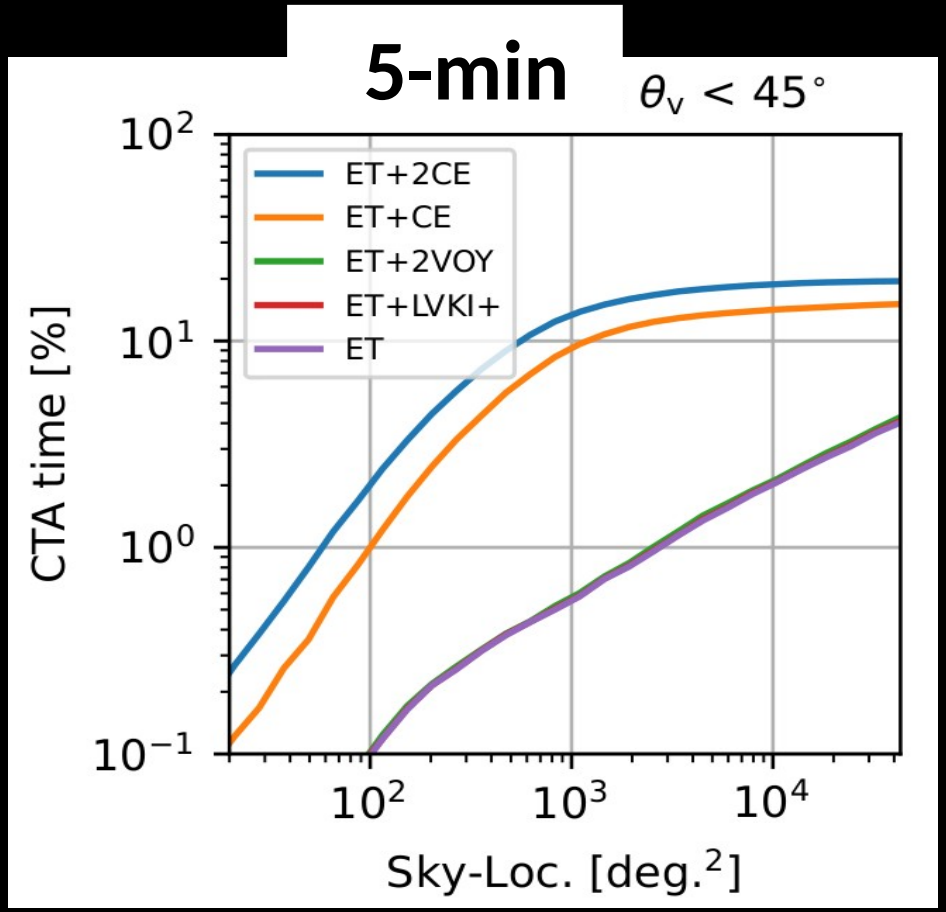
Detector	Ω[deg.^{2}]	All Orientations			
		15 min	5 min	1 min	0 min
ET+CE	10	21	51	185	6656
	100	442	1325	5075	123303
ET	10	5	5	8	14
	100	90	130	208	436

Detector	Ω [deg.^{2}]	Viewing angle $< 10°$			
		15 min	5 min	1 min	0 min
ET+CE	10	3	5	17	397
	100	21	71	314	3376
ET	10	1	1	2	2
	100	3	6	13	40

Follow-up by CTA

- One-shot observation:

  follow-up every BNS alert.
- Exhaust 1-2% CTA time to follow events < 100 deg^2
- Events with 5-min pre-alert
- Duty cycle of CTA ~ 15%



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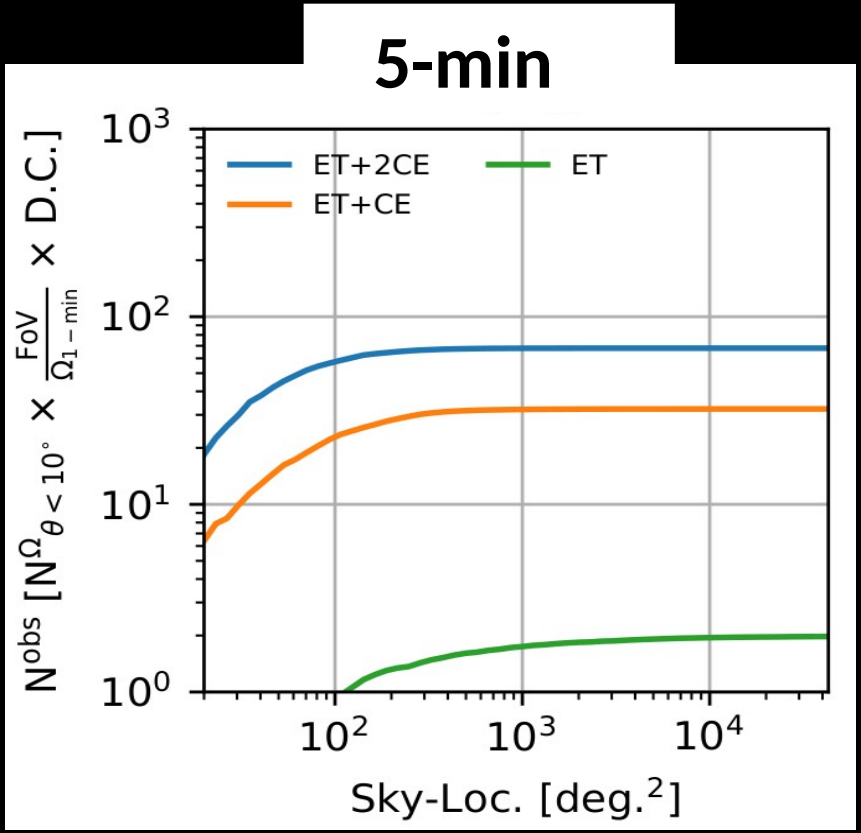
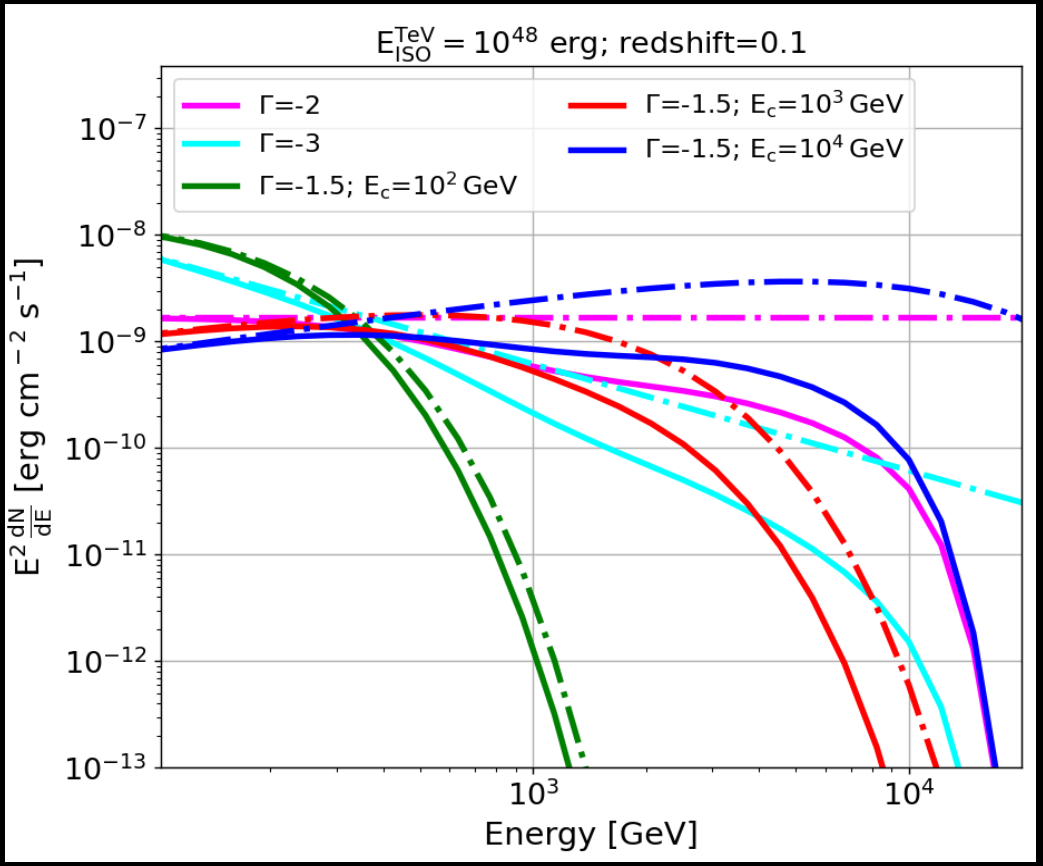


- Potentially detectable sources
- Followed sources within 100 deg^2
- Single shot-observation covering

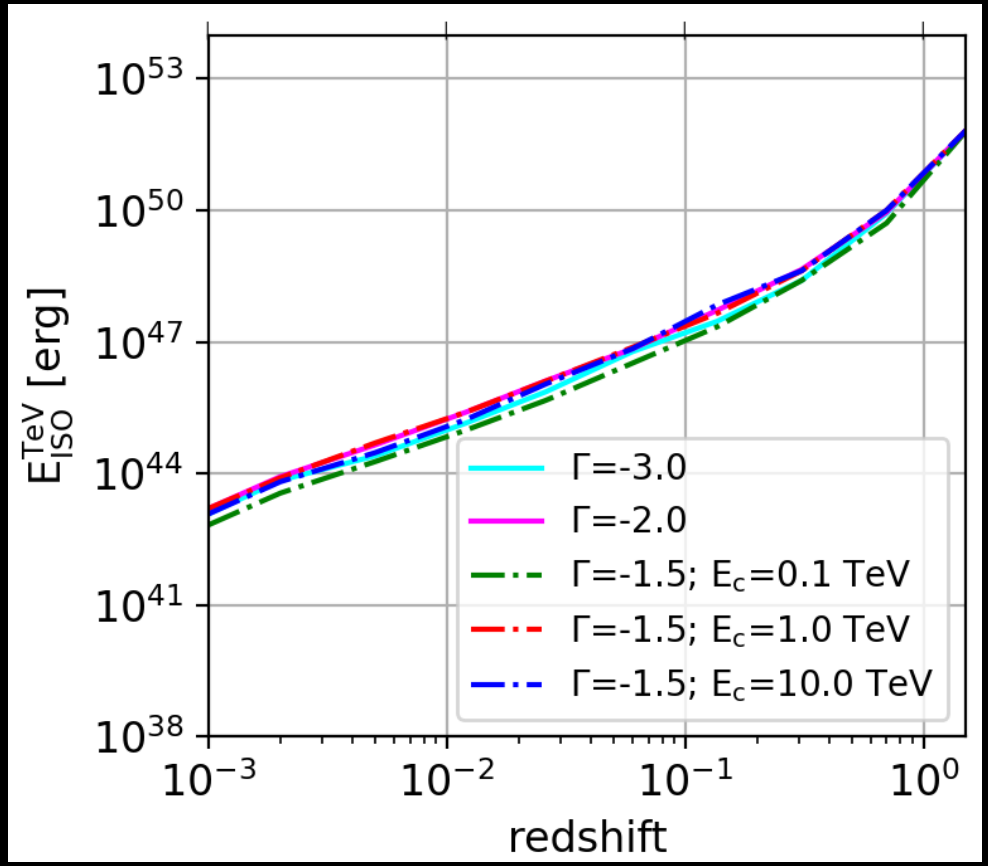
  ~ 20 deg^2 → CTA FoV
- Viewing angle < 10 deg.
- Parameters updated 1 min before merger
- Expected detection 20-60/ yr

Assumed models

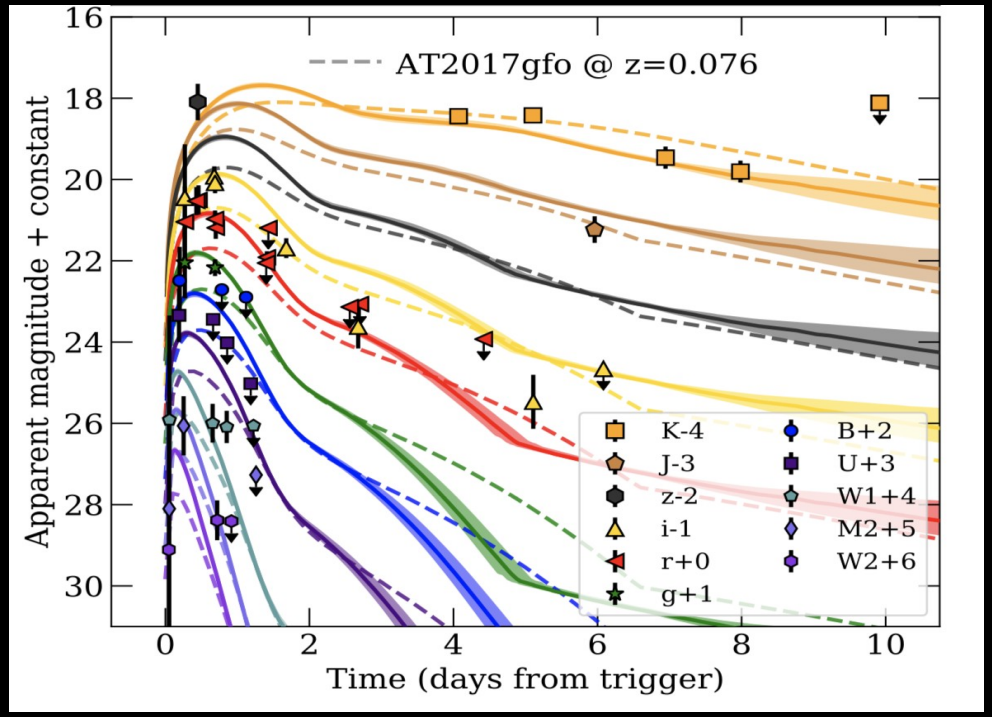


Detectability of VHE emission by CTA

5-sigma detection
with
10 s exposure



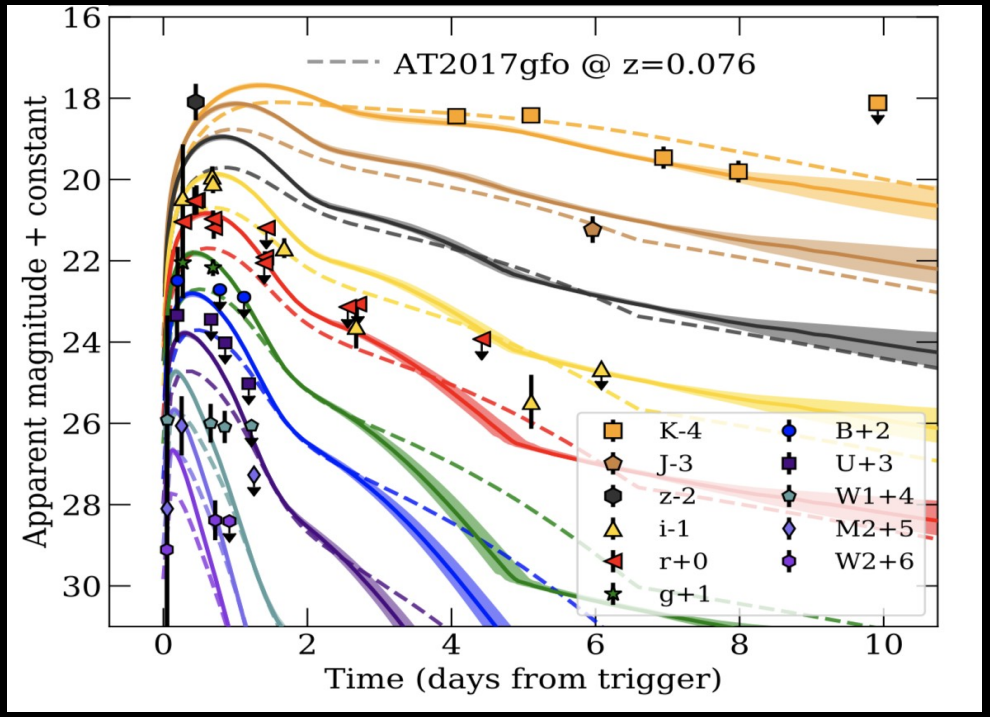
GRB 211211A: GRB/KILONOVA



Rastinejad, J. C. et al. arXiv:2204.10864

See also Xiao, S. et al. arXiv:2205.02186 for γ-ray precursor showing signatures of quasi-periodic oscillations

GRB 211211A: GeV emission



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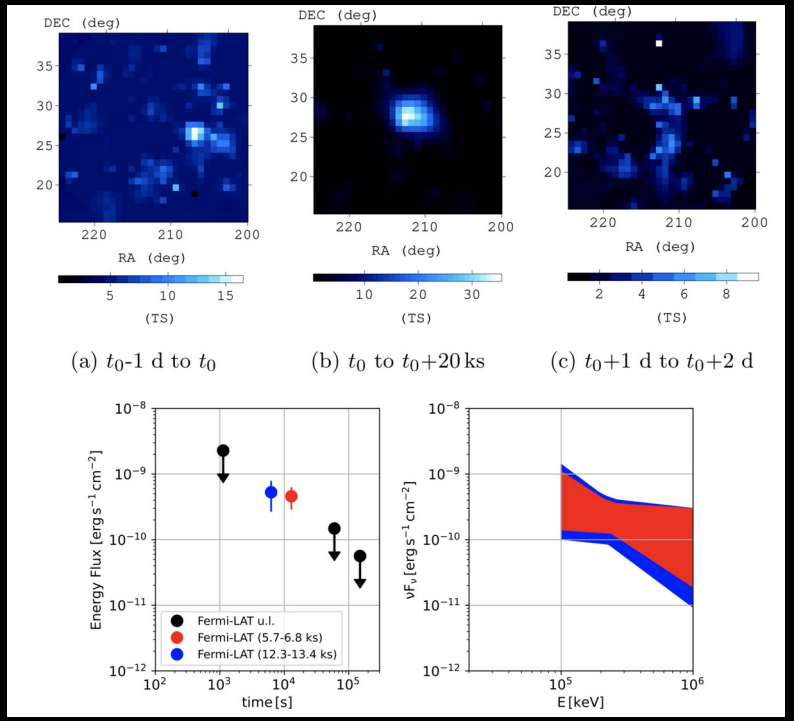

Mei, Banerjee, Oganesyan, .. Branchesi et al. 2022; arXiv:2205.08566

See Talk of M. Branchesi on 7th July

See also Xiao, S. et al. arXiv:2205.02186 for γ-ray precursor showing signatures of quasi-periodic oscillations

Conclusions:

- ET and CE will send 10^5 BNS alers per year
- Prompt emission can be detectable with the pre-alert
- 2030-2040: Timely joint operation of ET, CE and CTA
- Detecton of 20-50 sources following pre-alert of 5min by ET and CE following localization better than 100 sq. deg, with 2% of CTA time.
- Observation of GRBs in VHE will put stringent bounds on Lorentz invariant violation.

Backup

SKY-LOCALIZATION PRE-MERGERS

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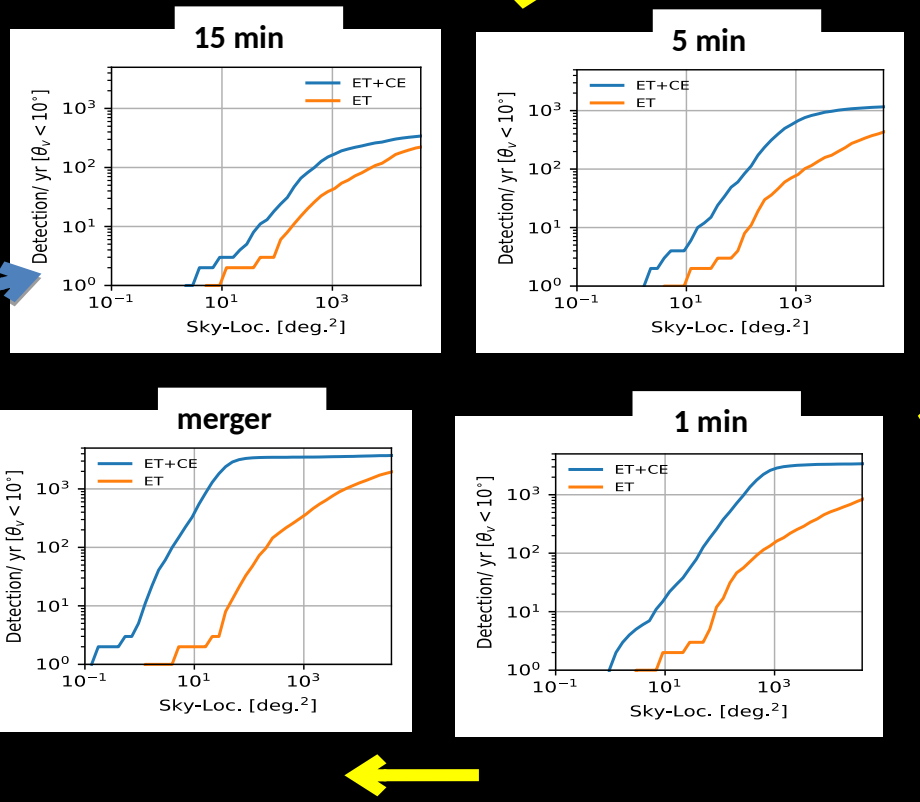

Banerjee et al. 2022, in prep.

Precursor, way to detect long-GRB prompt

GRB Precursor Catalog

Emission times of precursors published in PhysRevD.102.103014

Description

We have developed a fully automated search to identify precursors in the light curves of Gamma-Ray Bursts (GRBs). Applying our selection to more than 11 years of Fermi-GBM data, we identified 217 GRBs (9% of the total) in which the prompt emission was preceded by a precursor flash. The emission times and the light curves of the 244 identified precursor episodes are given in the table below. Our selection contains both long and short bursts, though short GRBs are observed to be ~ 10 times less likely to produce a precursor than long GRBs. A noteworthy long burst for which two precursors have been observed is the ultra-bright GRB 190114C.

For more details about this precursor selection, see https://doi.org/10.1103/PhysRevD.102.103014 / arXiv:2004.03246.

Viewing angle dependence:

ET+CE

ET+2CE