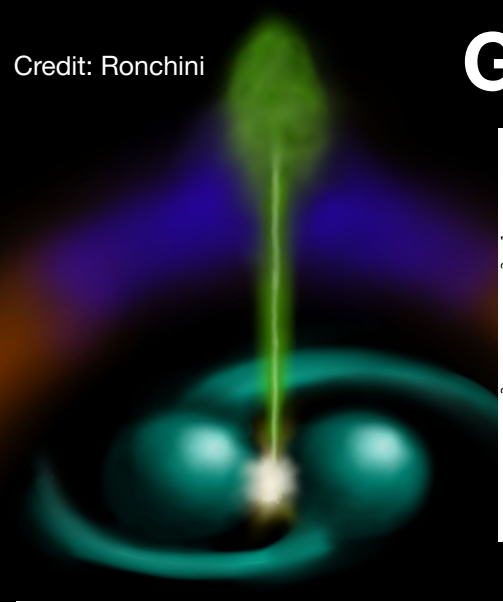
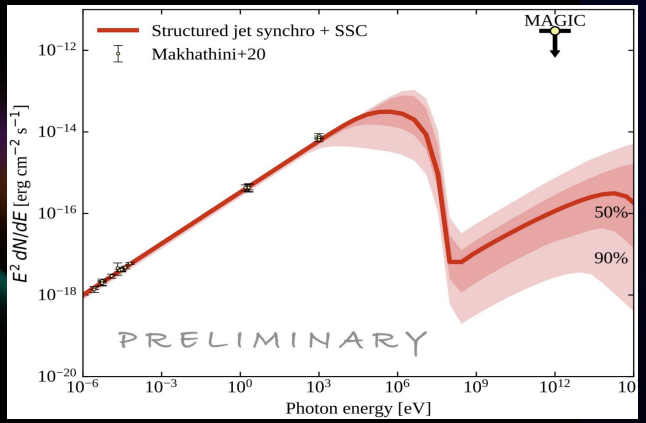
What can we learn from VHE transients and *how to detect them?*

- Biswajit Banerjee

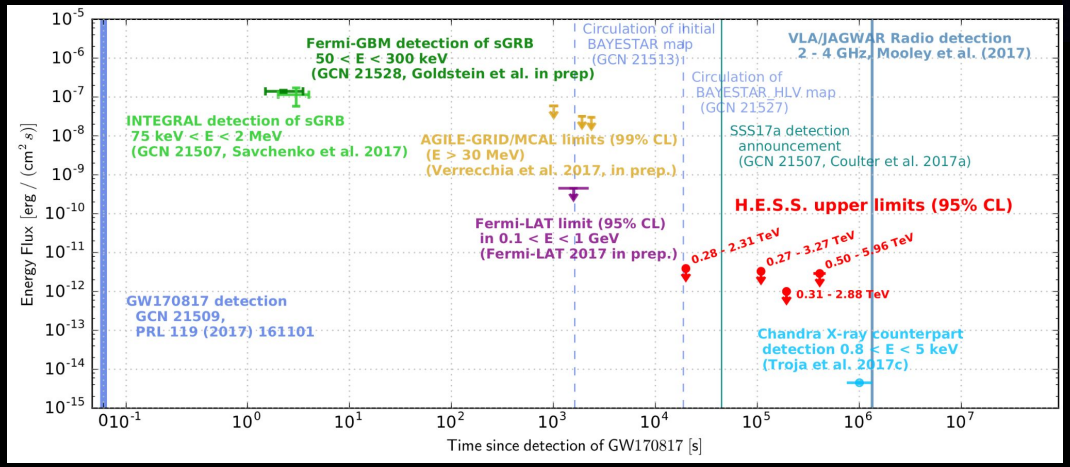
GW 170817/ GRB 170817A

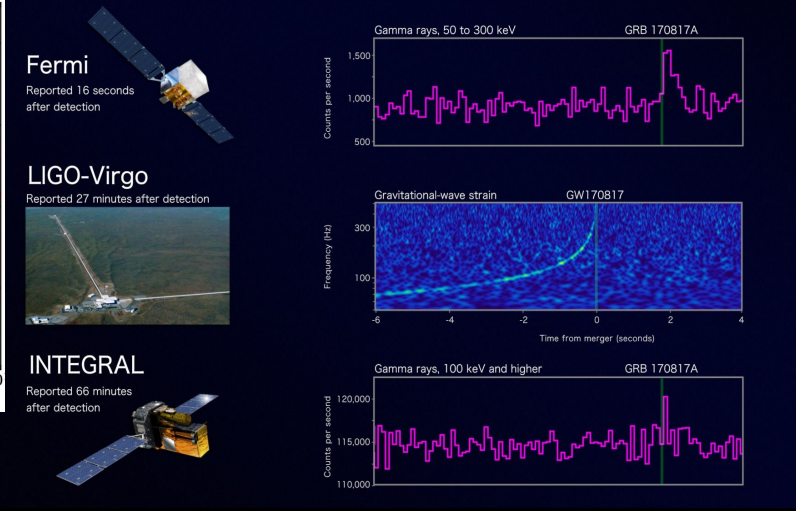
Credit: Ronchini

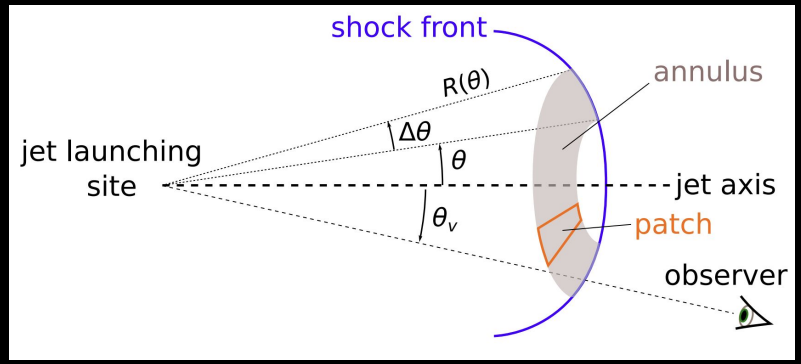




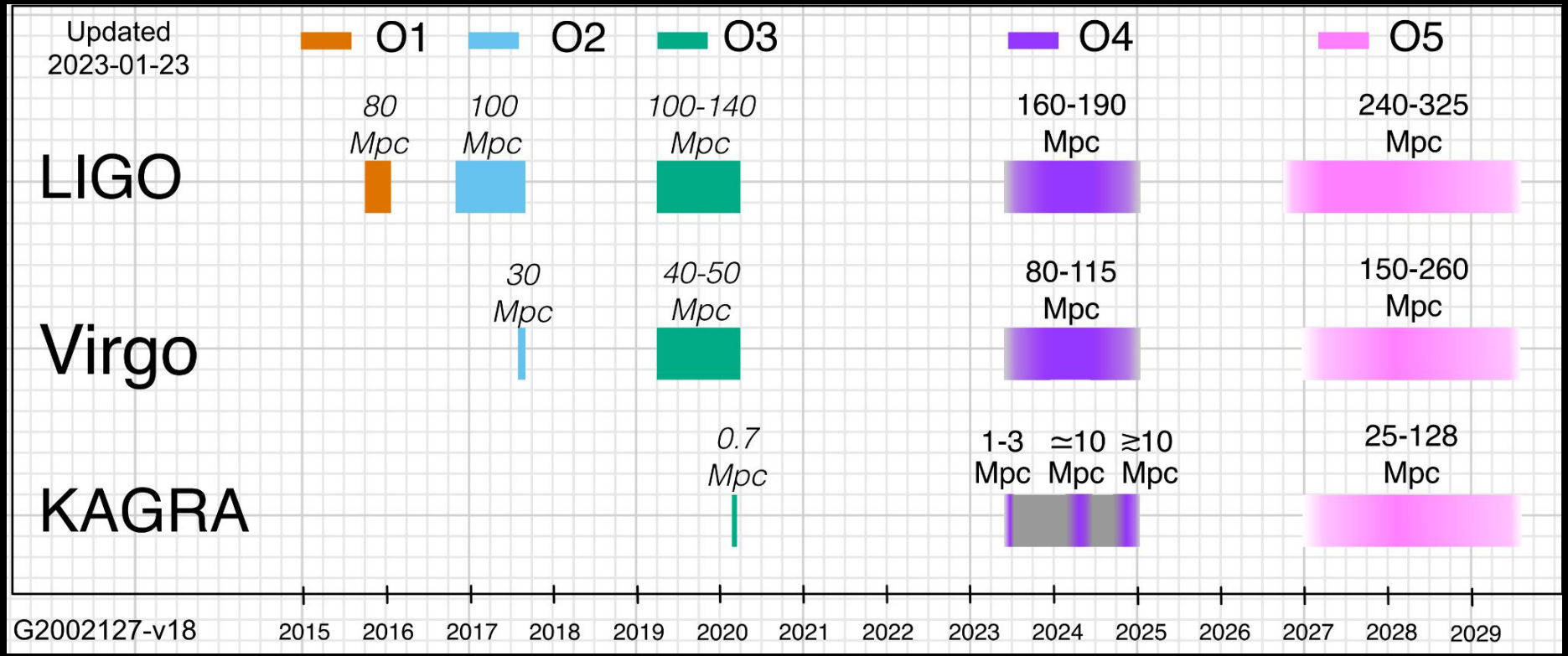
Stamerra, Salafia et al 2021







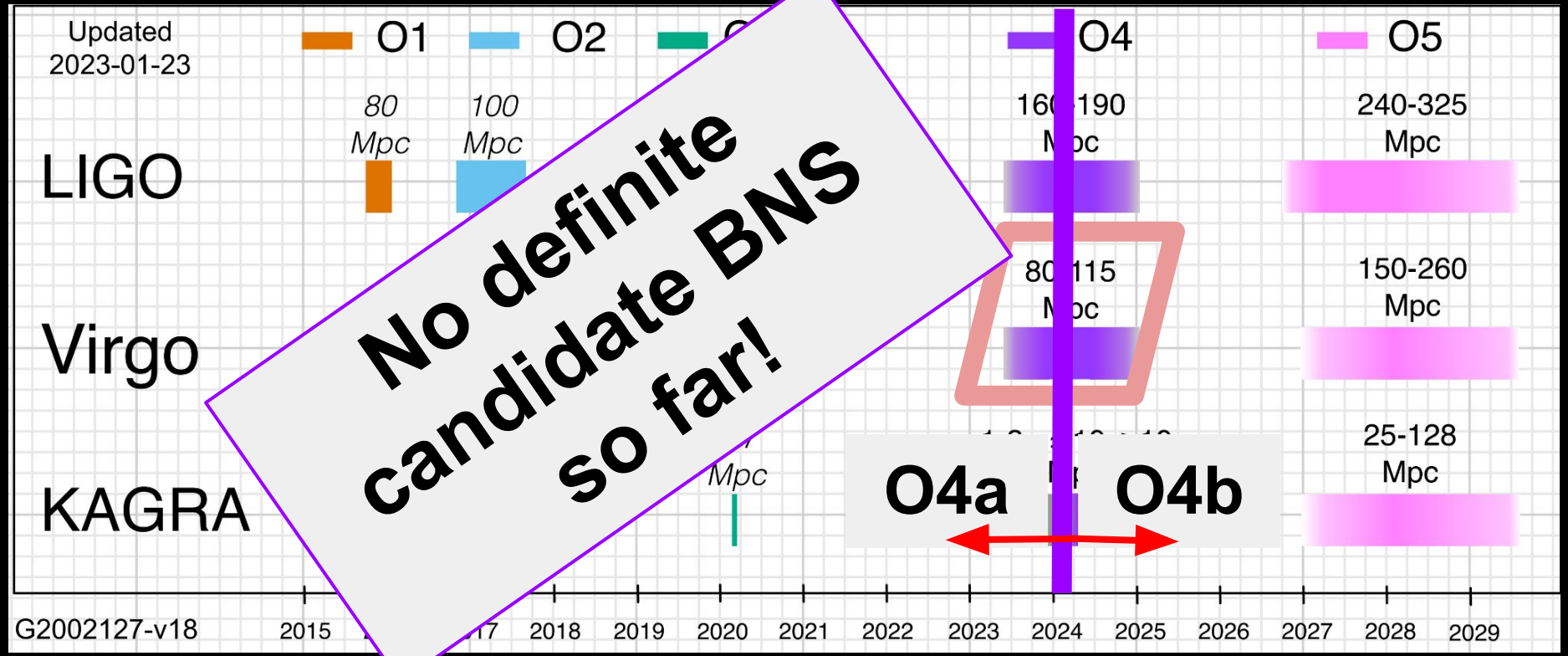
Ongoing observation run of LVK: O4



Abbott et al. 2020, LRR

O4 volume ~ 3*O3 volume
O5 volume ~10*O3 volume

Ongoing observation run of LVK: O4

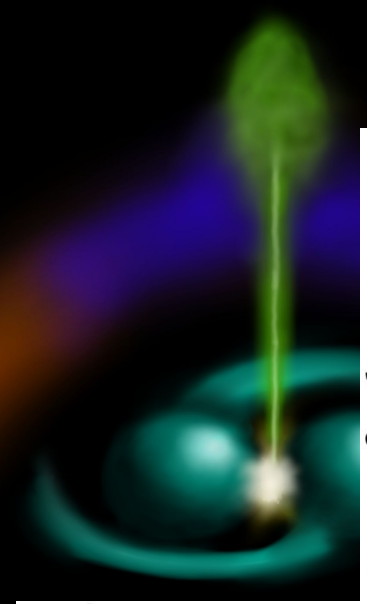


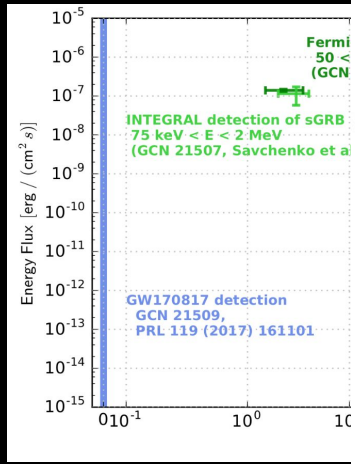
No definite candidate BNS so far!

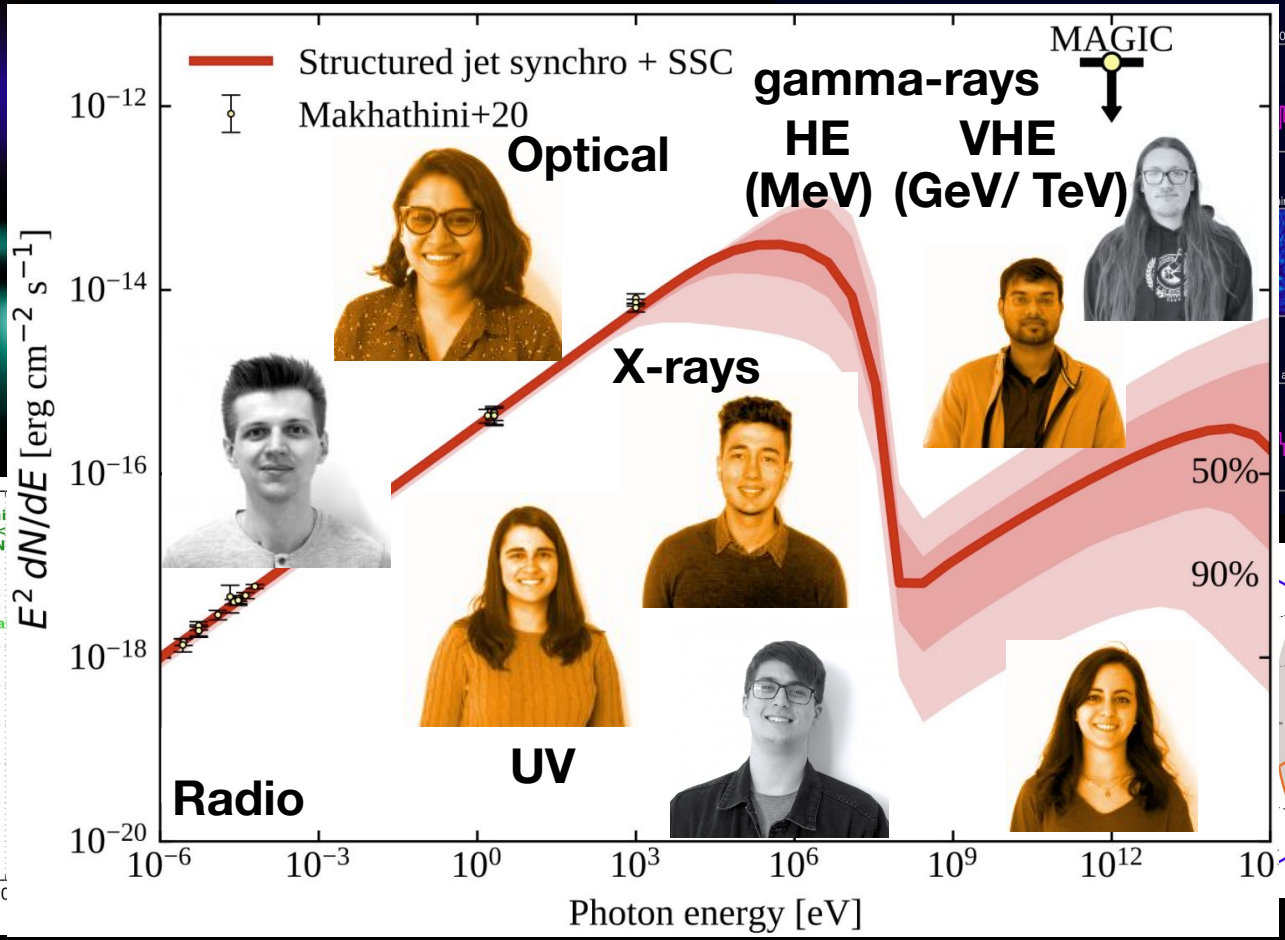
Abbott et al. 2020, LRR

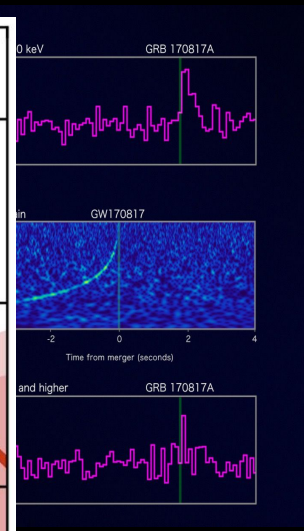
O4 volume ~ 3*O3 volume
O5 volume ~10*O3 volume

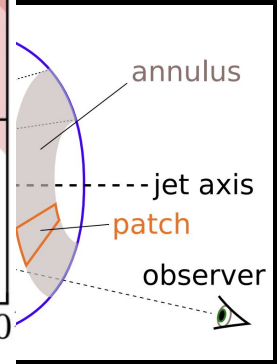
GW 170817/ GRB 170817A











What are we *Really* looking for

Time-scales

Early emission (~ 10 s)

LIV - EBL

(Violent prompt emission/ high variability)

Late emission (~minutes)

EBL - IGMF

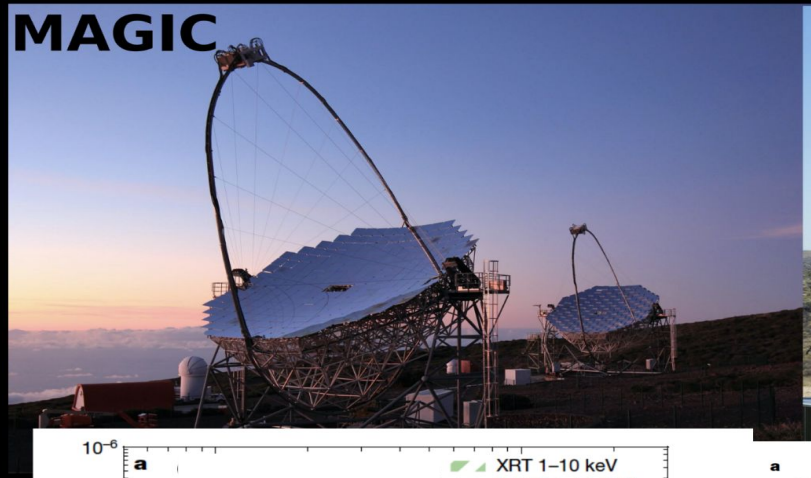
1. Pre-alert Mergers
2. Pre-cursors collapsars

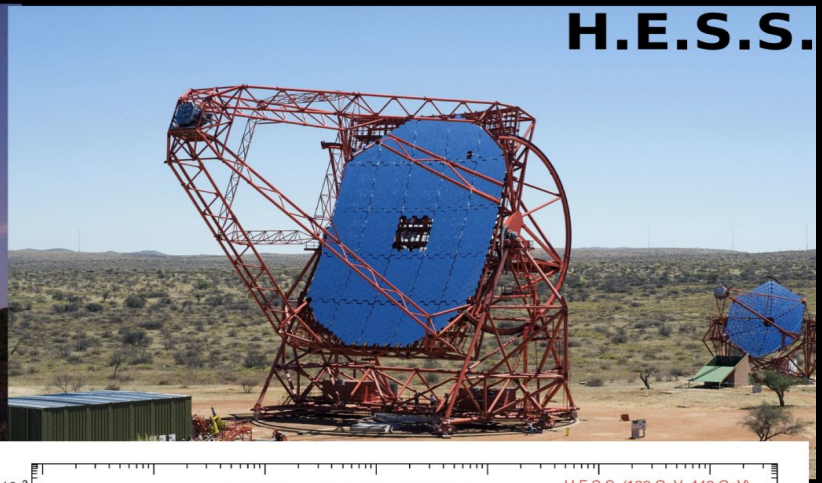
Regular GRB hunting with MAGIC, H.E.S.S., CTA-LST

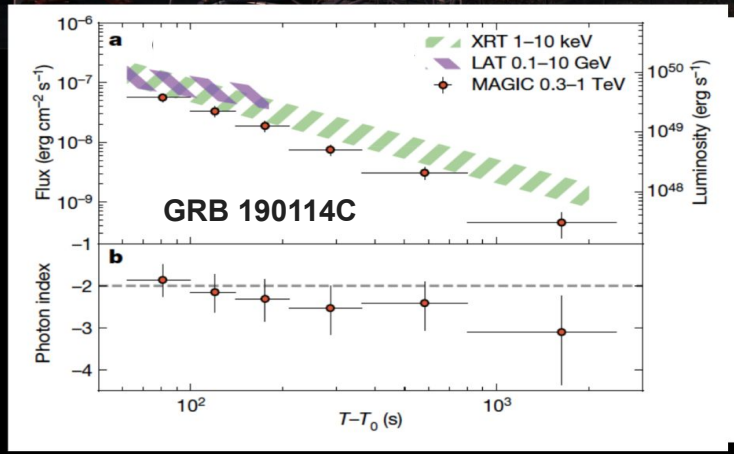
GRB hunting
MAGIC, H.E.S.S, LHAASO

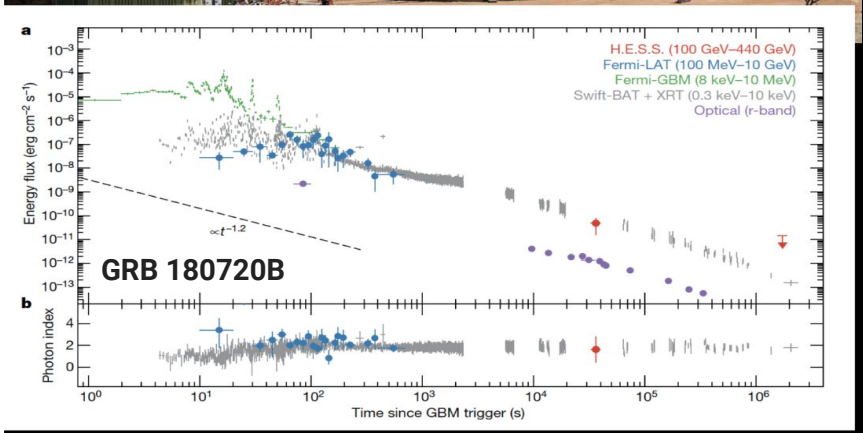
EBL - IGMF

GRBs in VHE gamma-rays





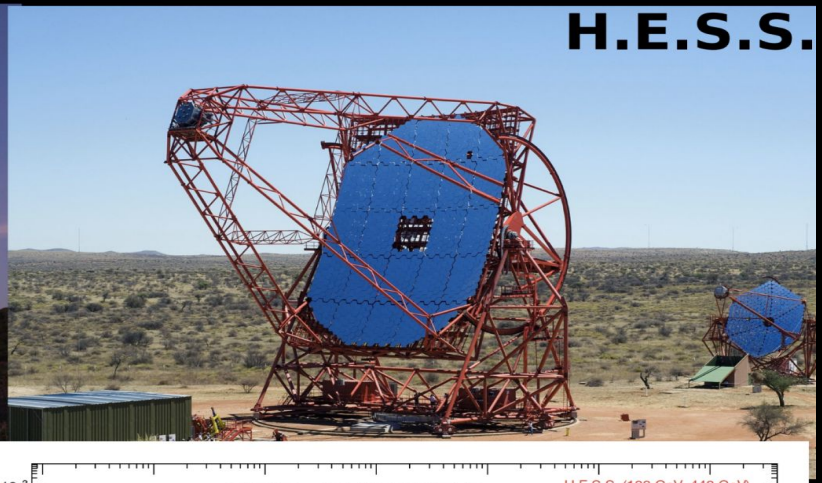


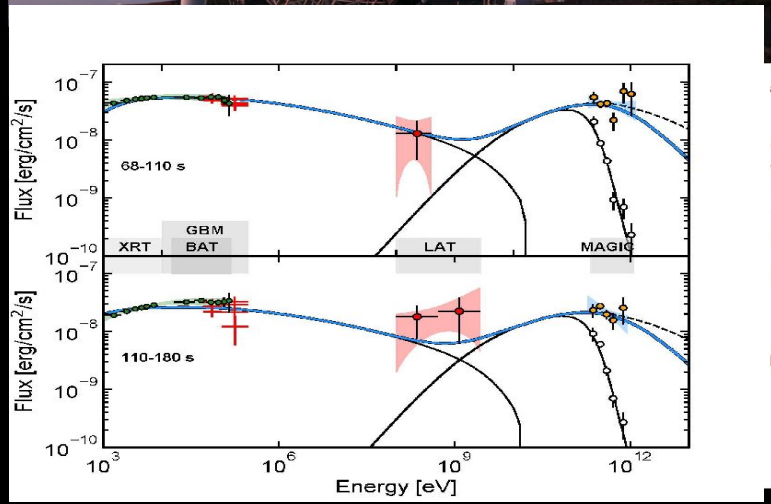


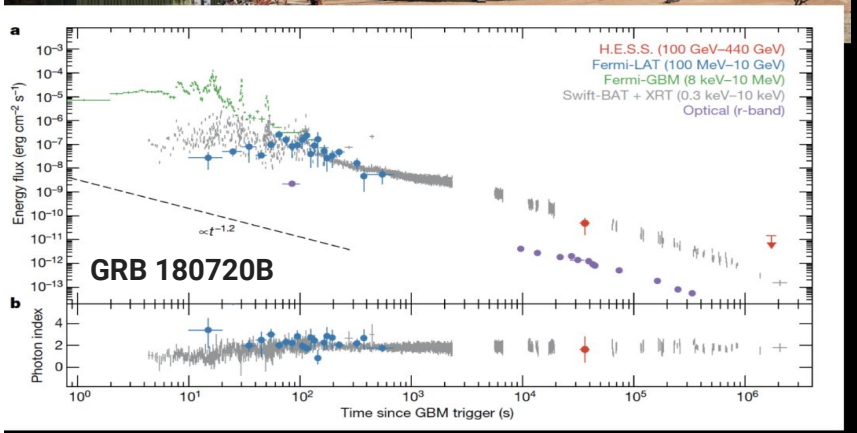
Acciari et al 2019, Nature

Abdalla et al 2019, Nature

GRBs in VHE gamma-rays



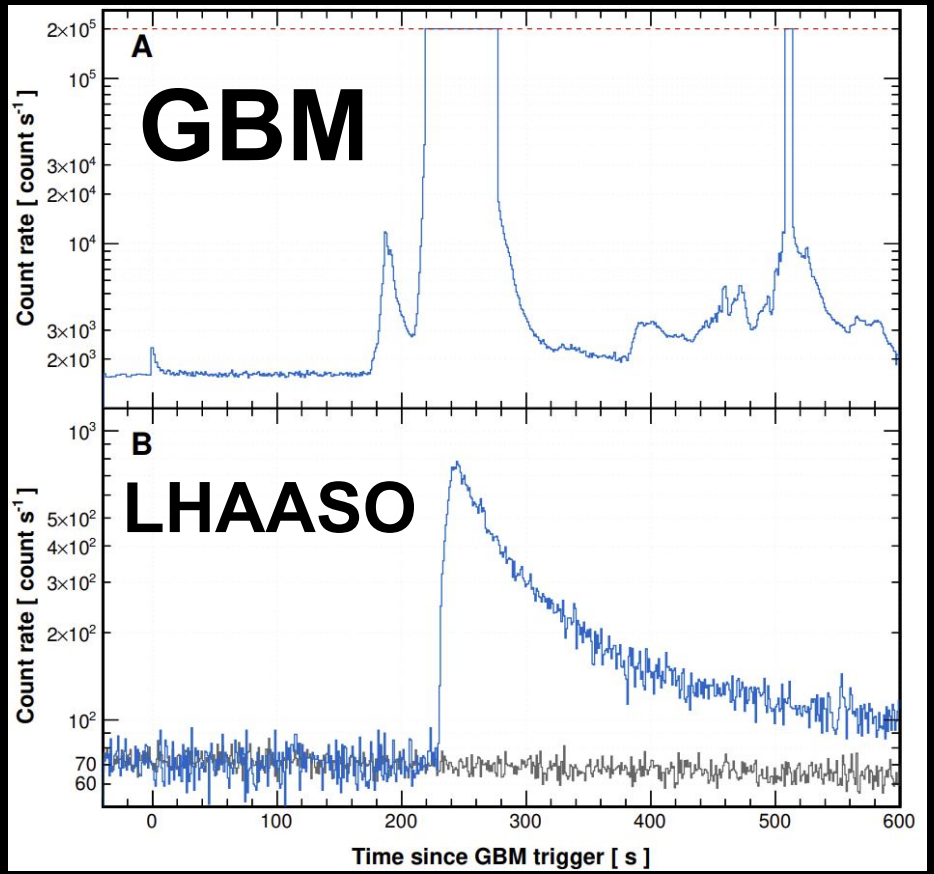


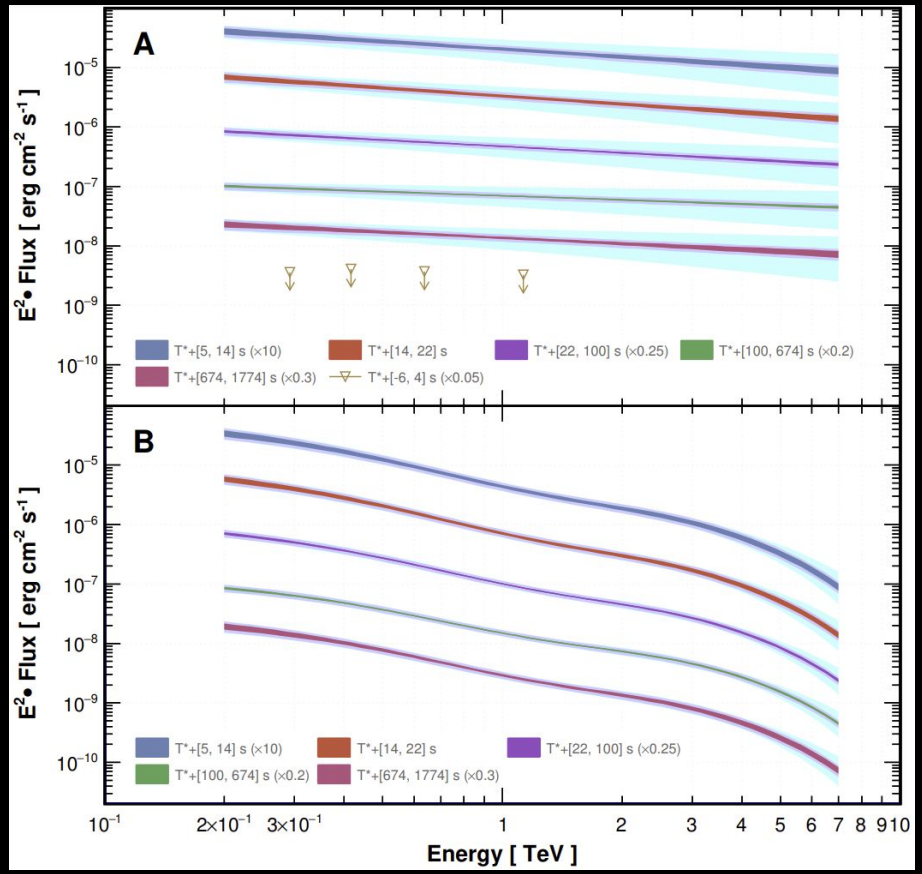


[Acciari et al 2019](), Nature

[Abdalla et al 2019](), Nature

GRB 221009A: LHAASO





LHAASO Collaboration, Science 380, 1390-1396

Notes:

- There are VHE gamma-ray transients!

  Thanks to MAGIC/ H.E.S.S.

- Second spectral (second hump) component due to Inverse Compton
- VHE emission during prompt is not highly variable!
- Stringent LIV constraints from GRB 221009A

Short GRB: Synergy between Einstein telescope and CTA

Pre-alert Mergers

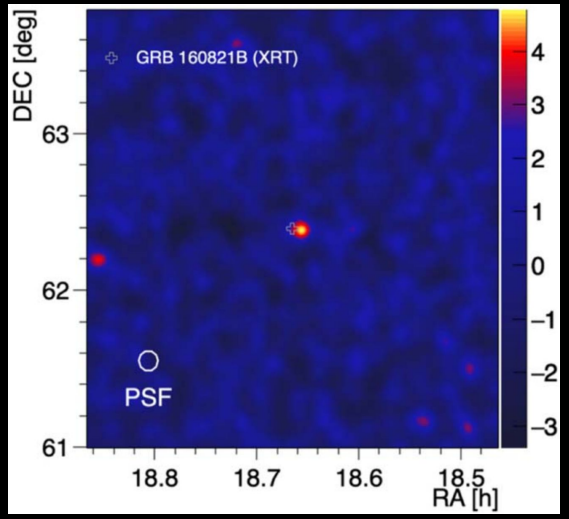
LIV - EBL

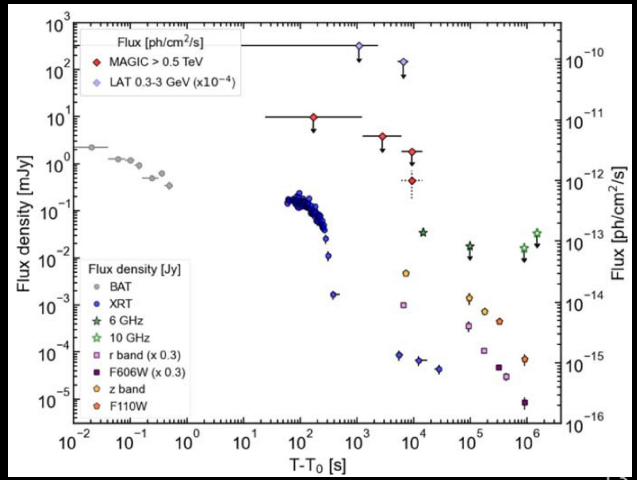
Hunting sGRB in VHE

The curious case of **GRB 160821B**

- Observation started at ~T0+20s, **shortest response time** for any IACT so far.
- Excess of TeV photons detected ~4σ in the energy range > 0.5 TeV co-located at XRT detection of GRB 160821B
- Results in an upper limit for VHE flux

Fastest slew, ever by any IACT!

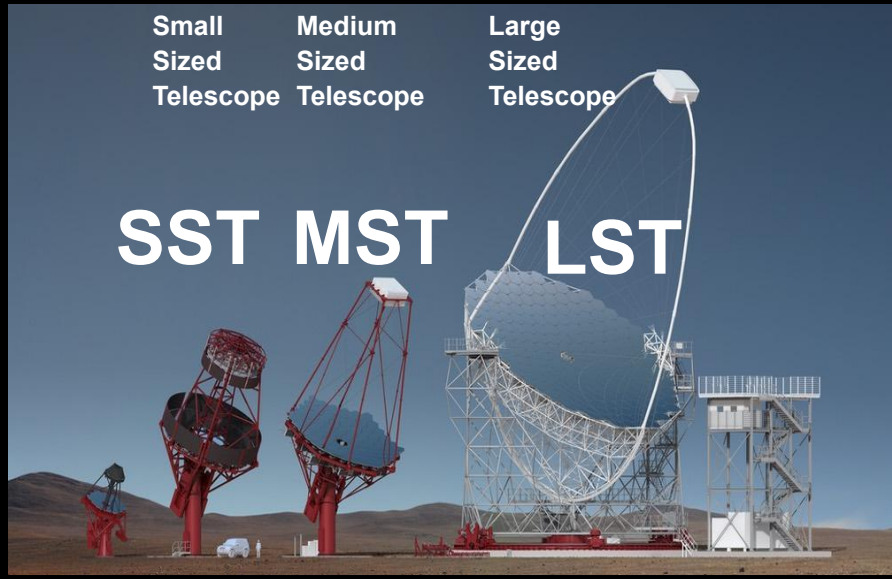




Acciari et al 2020

Cherenkov Telescope Array (CTA)

1. Largest ground-based Cherenkov telescope facility, more than 100 IACT with two proposed sites: La Palma, Spain and Chile.
2. 10X sensitivity than MAGIC, HESS.
3. Operational energy range **<u>VHE gamma-rays~0.01-100 TeV</u>**
4. Field of view up to ~50 sq. deg.
5. Response time of ~20 seconds.



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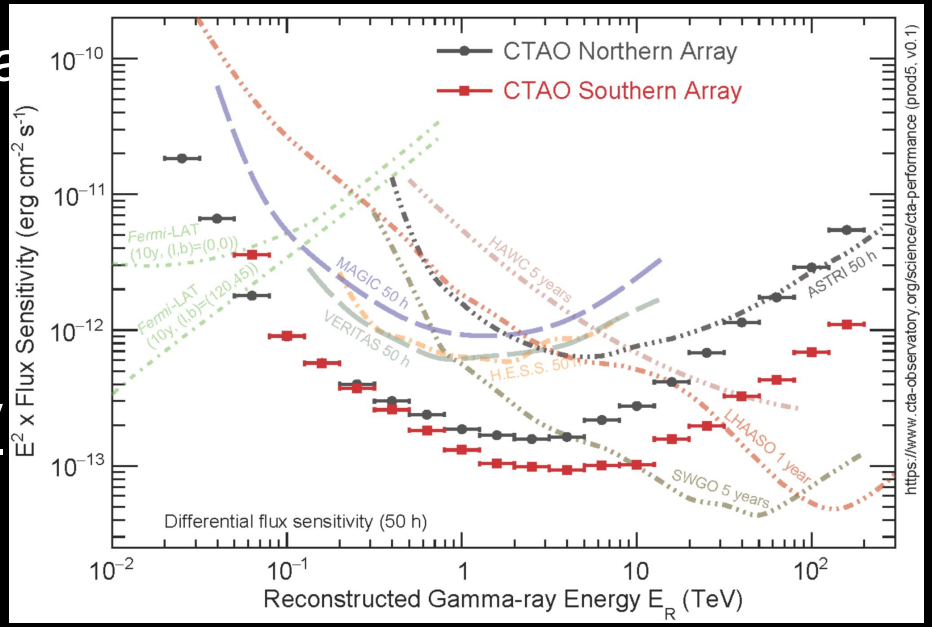
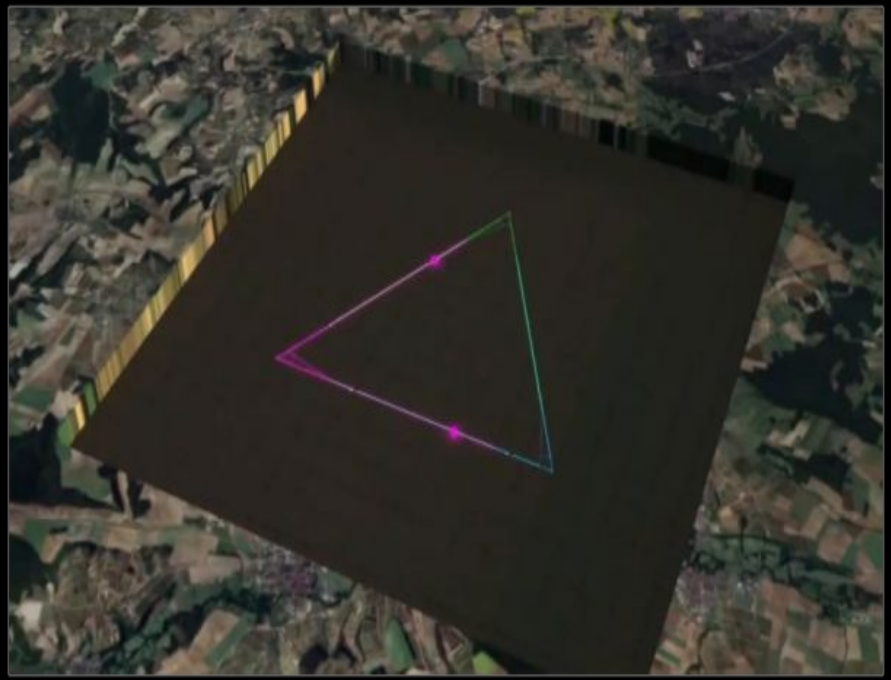
LST+MST+SST



A bit of help from Gravitational waves

ET: European 3G Interferometer:



- Delta/ 2L shape
- Length: 10 km (!)
- Underground
- Cryogenic, Increase laser power
- **Branchesi & Maggiore 23** On science cases of ET

Italy to support Sardinian site

ET ITALY
Einstein Telescope

3G effort worldwide: Cosmic Explorer (CE)

- 2L design; 40 km
- Two sites:
  USA
  Australia

Gupta et al 2024

ET sensitivity: Branchesi, Maggiore et al 2023

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Science with the Einstein Telescope: a comparison of different designs

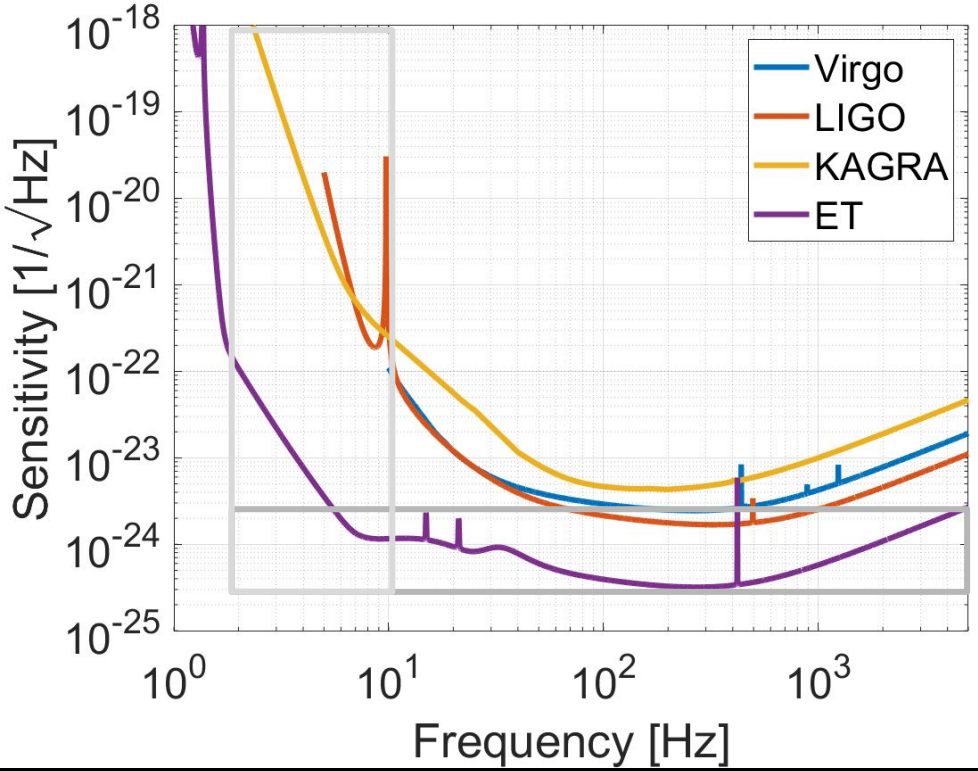
Marica Branchesi,[1,2,*] Michele Maggiore,[3,4,*] David Alonso,[5] Charles Badger,[6] Biswajit Banerjee,[1,2] Freija Beirnaert,[7] Enis Belgacem,[3,4] Swetha Bhagwat,[8,9] Guillaume Boileau,[10,11] Ssohrab Borhanian,[12] Daniel David Brown,[13] Man Leong Chan,[14] Giulia Cusin,[15,3,4] Stefan L. Danilishin,[16,17] Jerome Degallaix,[18] Valerio De Luca,[19] Arnab Dhani,[20] Tim Dietrich,[21,22] Ulyana Dupletsa,[1,2] Stefano Foffa,[3,4] Gabriele Franciolini,[8] Andreas Freise,[23,16] Gianluca Gemme,[24] Boris Goncharov,[1,2] Archisman Ghosh,[7] Francesca Gulminelli,[25] Ish Gupta,[20] Pawan Kumar Gupta,[16,26] Jan Harms,[1,2] Nandini Hazra,[1,2,27] Stefan Hild,[16,17] Tanja Hinderer,[28] Ik Siong Heng,[29] Francesco Iacovelli,[3,4] Justin Janquart,[16,26] Kamiel Janssens,[10,11] Alexander C. Jenkins,[30] Chinmay Kalaghatgi,[16,26,31] Xhesika Koroveshi,[32,33] Tjonnie G.F. Li,[34,35] Yufeng Li,[36] Eleonora Loffredo,[1,2] Elisa Maggio,[22] Michele Mancarella,[3,4,37,38] Michela Mapelli,[39,40,41] Katarina Martinovic,[6] Andrea Maselli,[1,2] Patrick Meyers,[42] Andrew L. Miller,[43,16,26] Chiranjib Mondal,[25] Niccolò Muttoni,[3,4] Harsh Narola,[16,26] Micaela Oertel,[44] Gor Oganesyan,[1,2] Costantino Pacilio,[8,37,38] Cristiano Palomba,[45] Paolo Pani,[8] Antonio Pasqualetti,[46] Albino Perego,[47,48] Carole Périgois,[39,40,41] Mauro Pieroni,[49,50] Ornella Juliana Piccinni,[51] Anna Puecher,[16,26] Paola Puppo,[45] Angelo Ricciardone,[52,39,40] Antonio Riotto,[3,4] Samuele Ronchini,[1,2] Mairi Sakellariadou,[6] Anuradha Samajdar,[21] Filippo Santoliquido,[39,40,41] B.S. Sathyaprakash,[20,53,54] Jessica Steinlechner,[16,17] Sebastian Steinlechner,[16,17] Andrei Utina,[16,17] Chris Van Den Broeck[16,26] and Teng Zhang[9,17]

[1]Gran Sasso Science Institute (GSSI), I-67100 L'Aquila, Italy
[2]INFN, Laboratori Nazionali del Gran Sasso, I-67100 Assergi, Italy

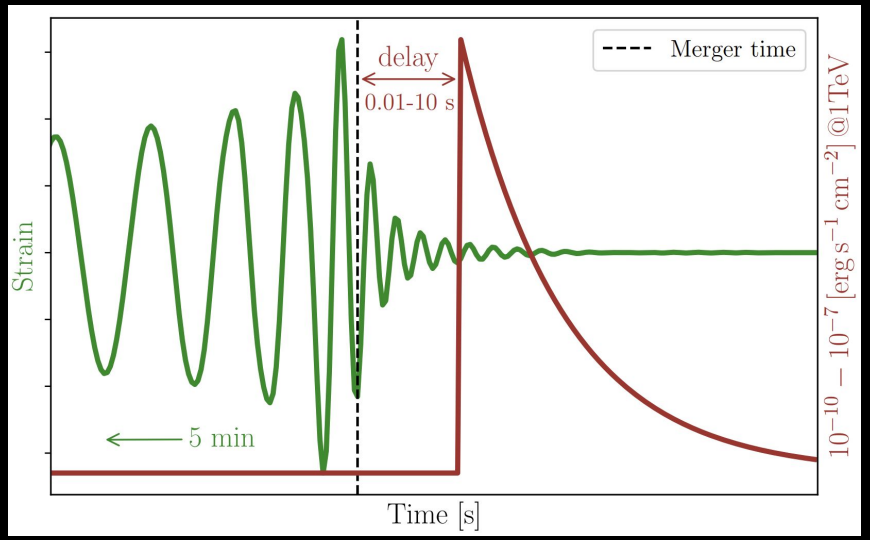
*Corresponding author.

https://doi.org/10.1088/1475-7516/2023/07/068

JCAP07(2023)068

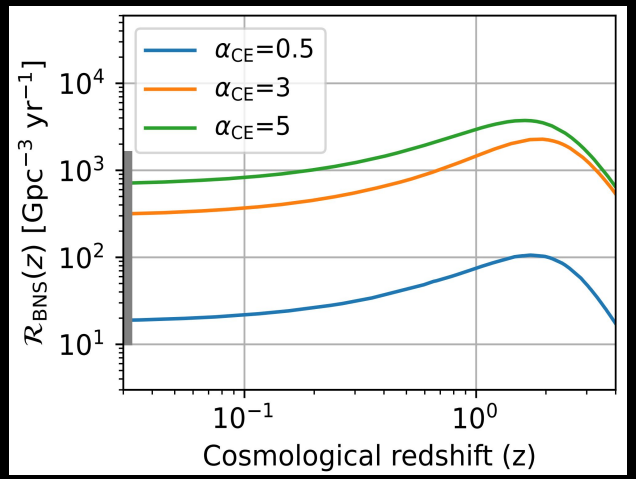


Analysis tools:



1. Detection of BNS during inspiral?
2. Sky-localization?
3. Pre-alert time?

Dupletsa, Harms, *BB* et al 2023



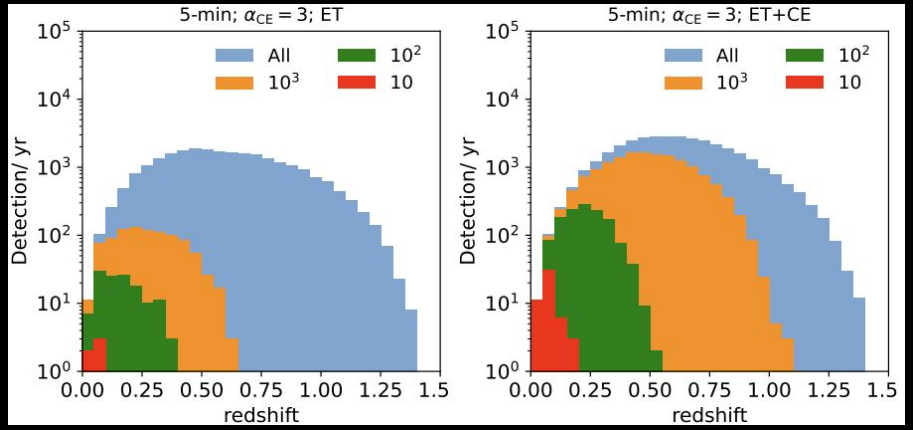
Santoliquido et al 2021

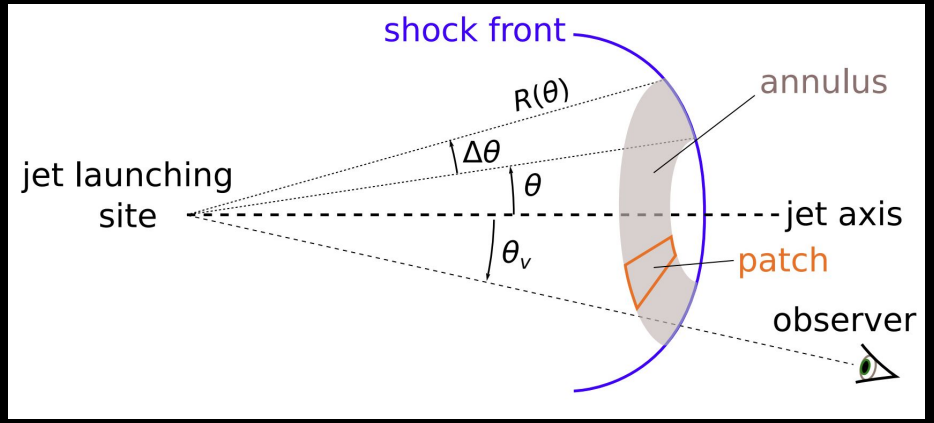
GWFISH

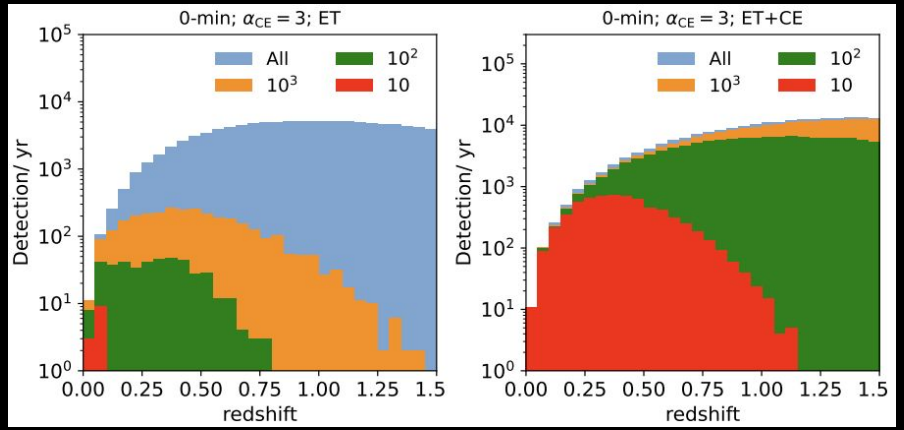
Publicly Available

- Three different populations
- Flat BNS mass ~1.0-2.5 Ms
- ET-D (Sardinia)/ CE (US)/ CE(Australia)
- Lower freq. down to 2 Hz

Sky-localization capability:

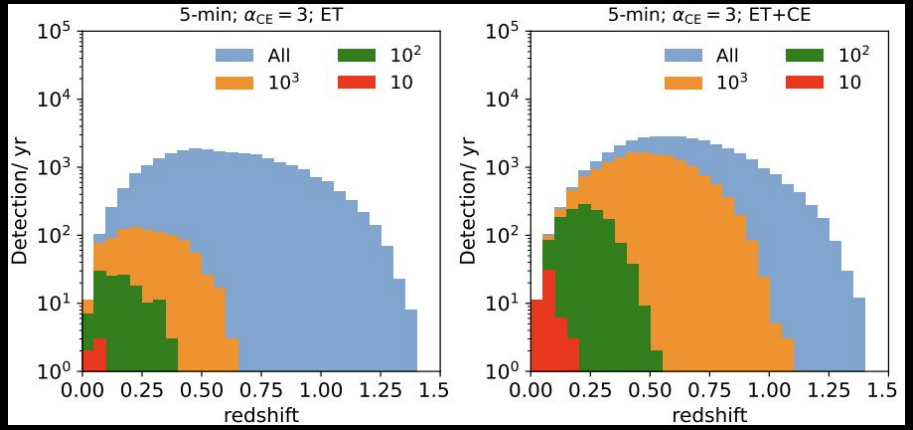


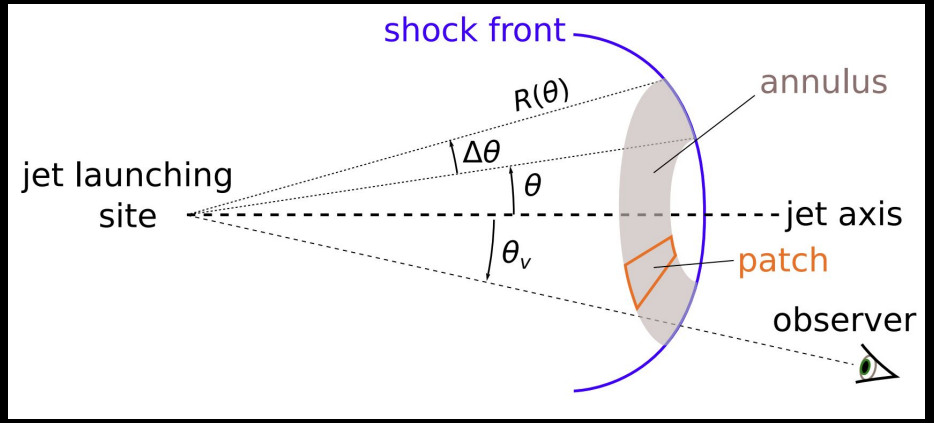


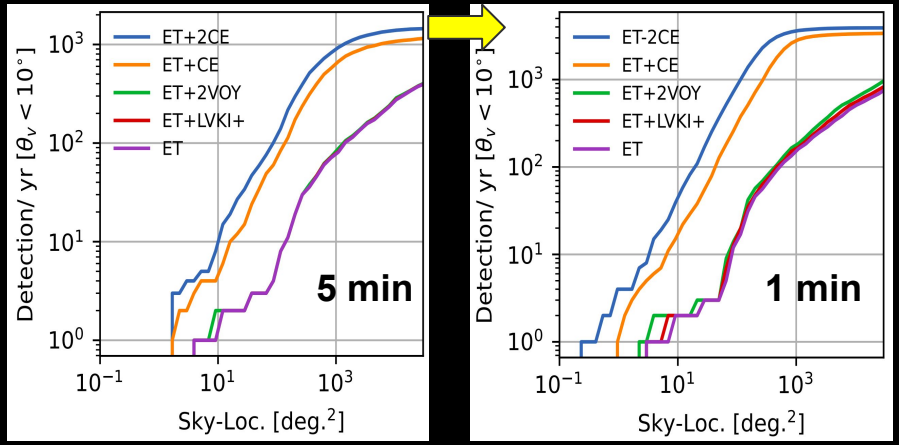


Detector	Ω [deg^2]	Viewing angle (<10^0)			
		15 min	5 min	1 min	0 min
ET + CE	**100**	**21**	**71**	**314**	**3376**
ET	**100**	**3**	**6**	**13**	**40**

Sky-localization capability:







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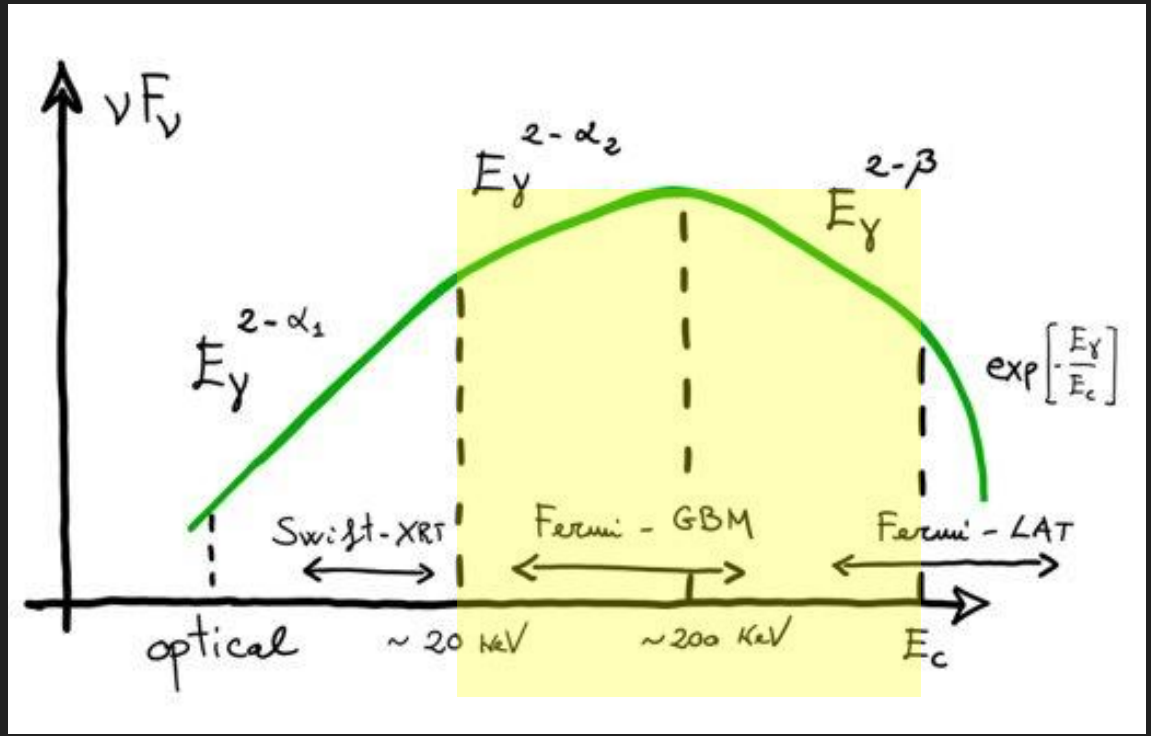
Study of the prompt emission Spectrum

Extension to higher energies

+

Physical model for the prompt

Slide credit: Samanta Macera

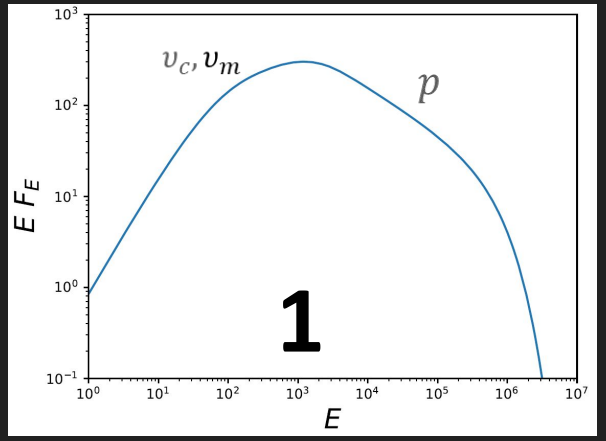


Macera et al 2024 in prep.

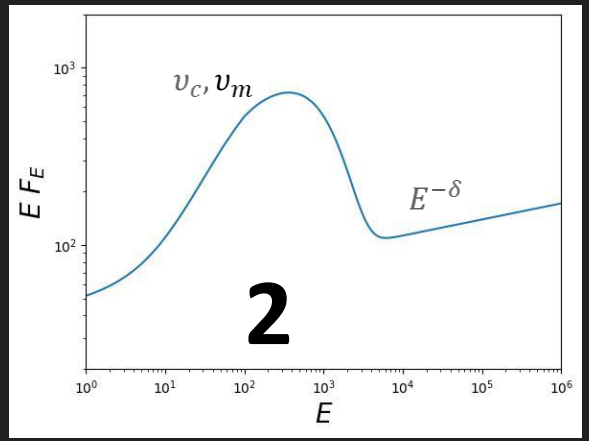
Tested Models

Slide credit: Samanta Macera

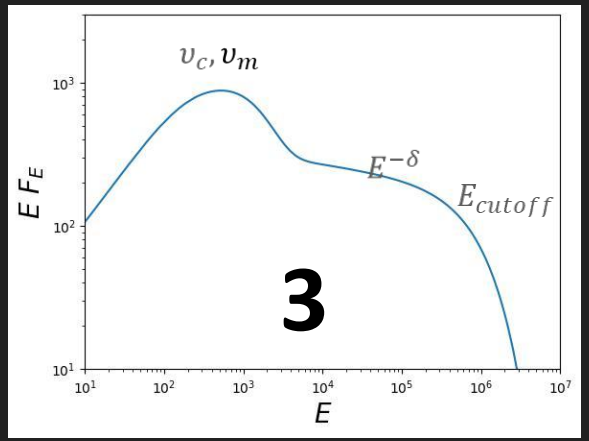
Synchrotron*HE cutoff

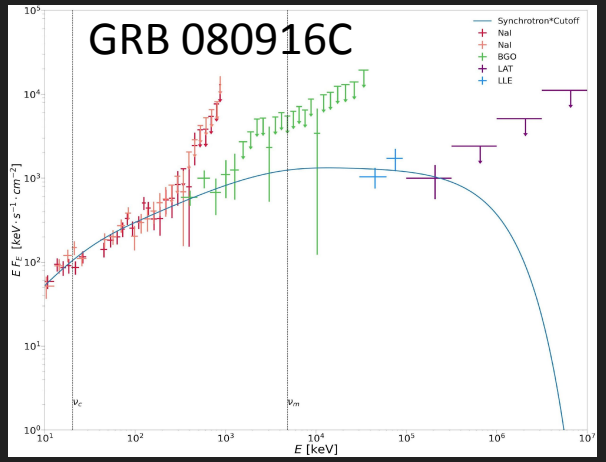


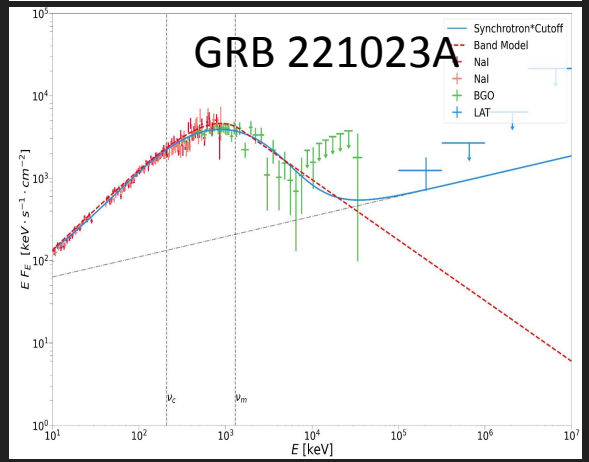
Synchrotron + Power Law



Synchrotron + Cutoff Power Law

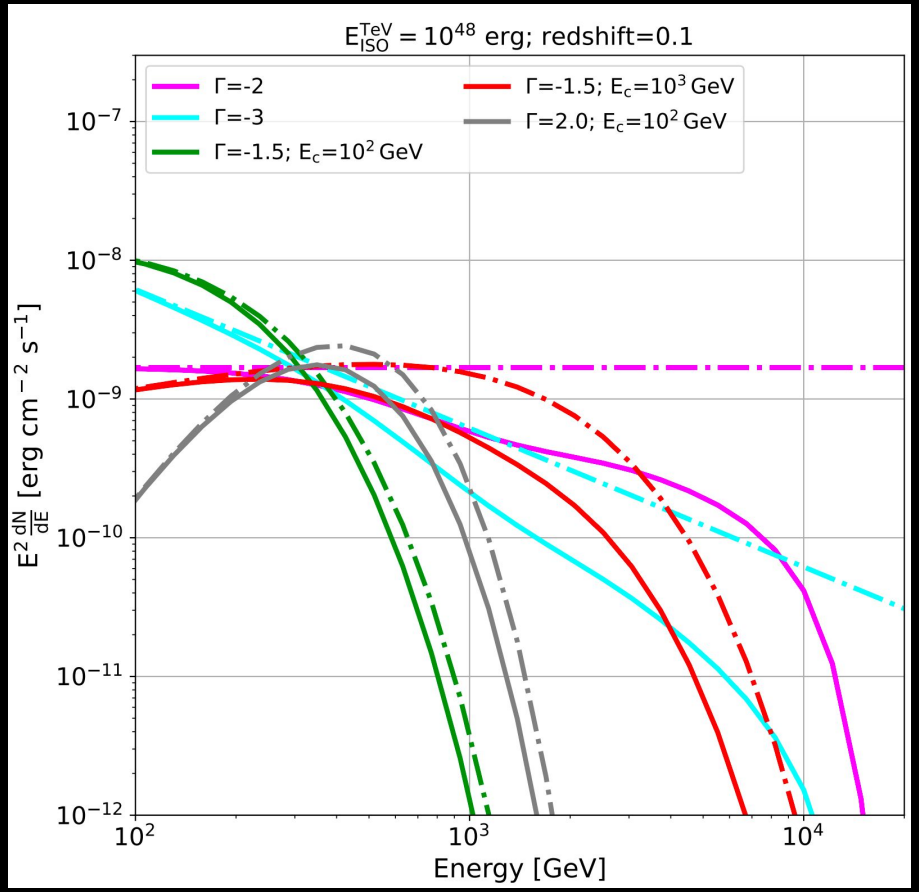


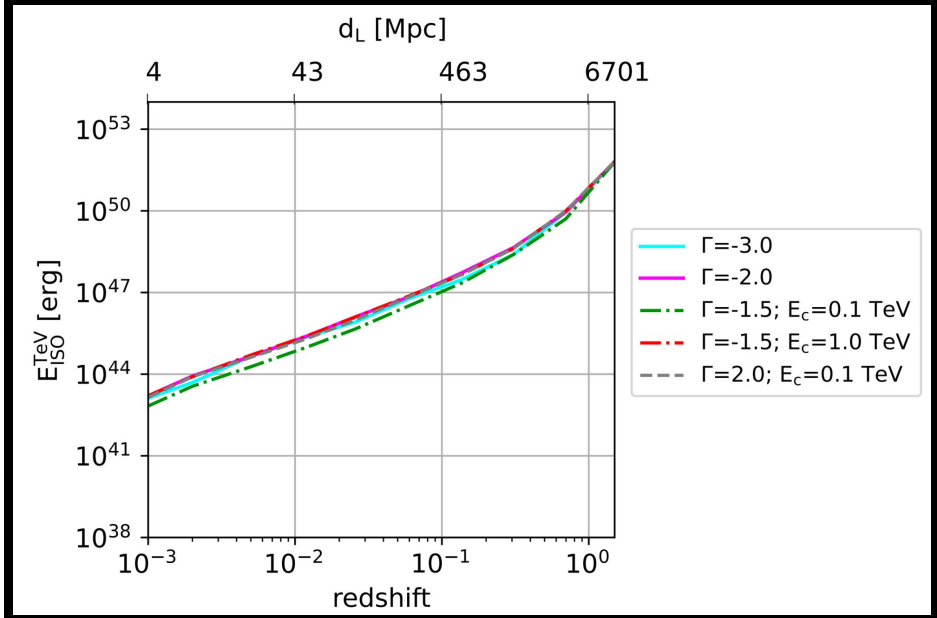




Samanta's presentation

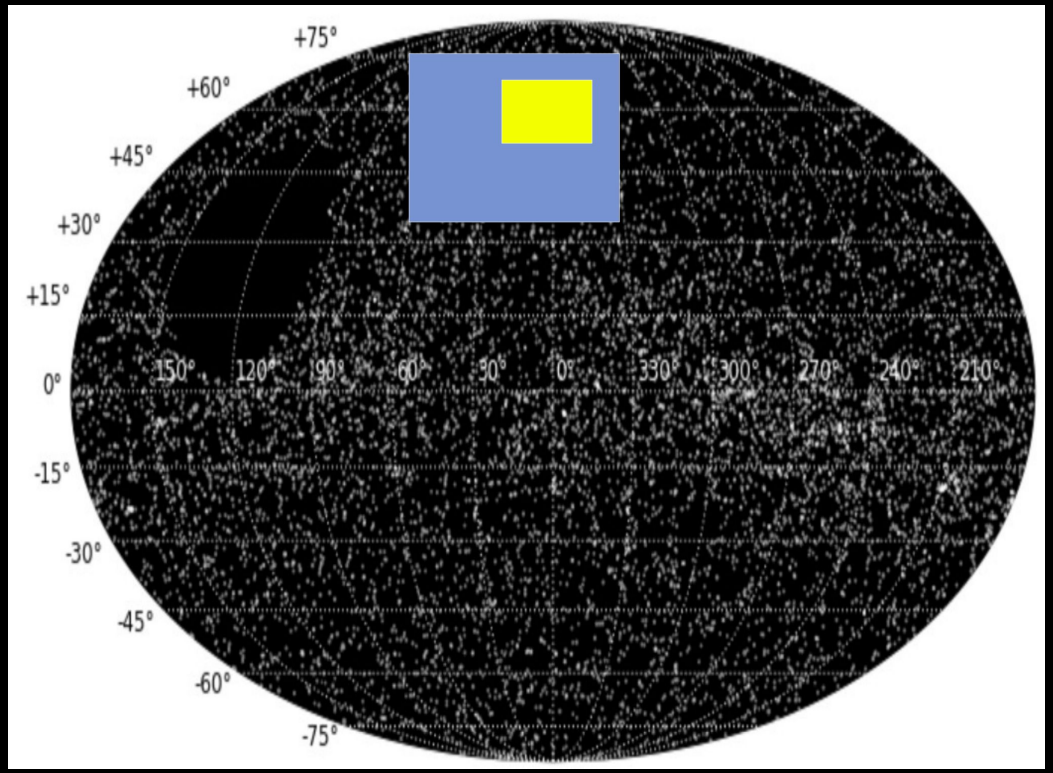
Detectability of VHE emission:





5-sigma in 20s

Observation strategy:

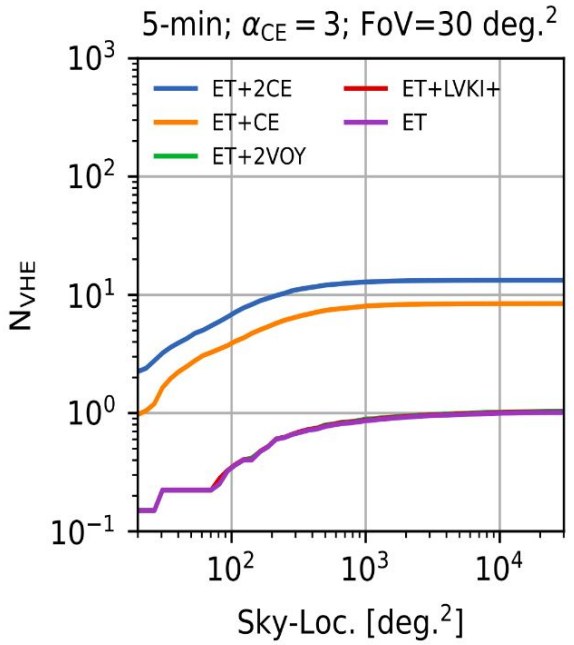


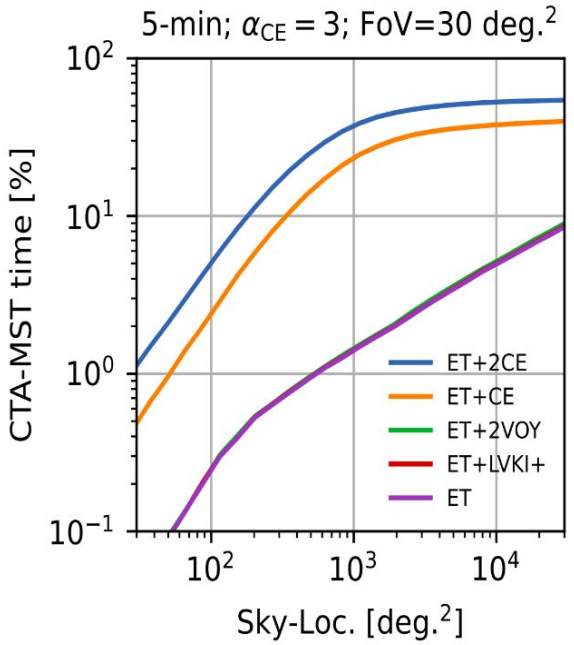
- Follow prealert
- FoV of CTA
  (~10/ 30 sq. deg.)

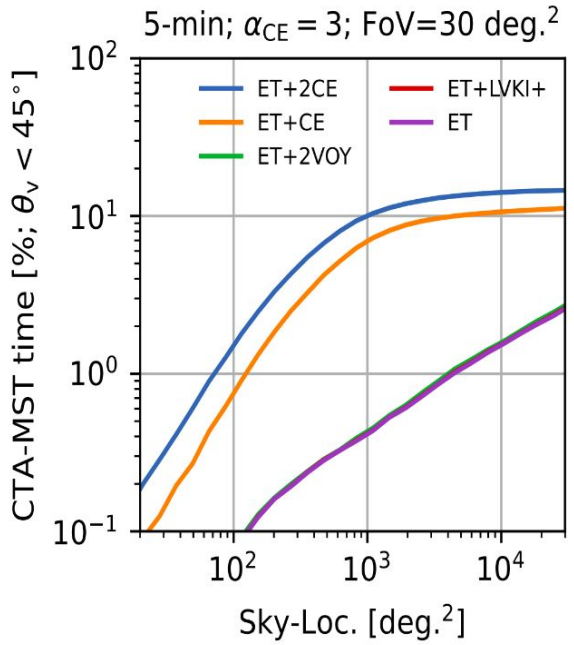
$$N_{VHE} = \sum_{i=1}^{N_{\theta<10^\circ}(<\Omega)} \frac{FoV}{\Omega_i} \times D.C. \times CTA_{vis}$$

$$CTAtime(\%) = \frac{N(<\Omega) \times t_{obs} \times CTA_{vis}}{CTA_{TOT}}$$

Observation strategy: MST







t_{alert}= 30s; t_{slew}= **90s**; t_{rep}= 10s; t_{exp}= 20 s

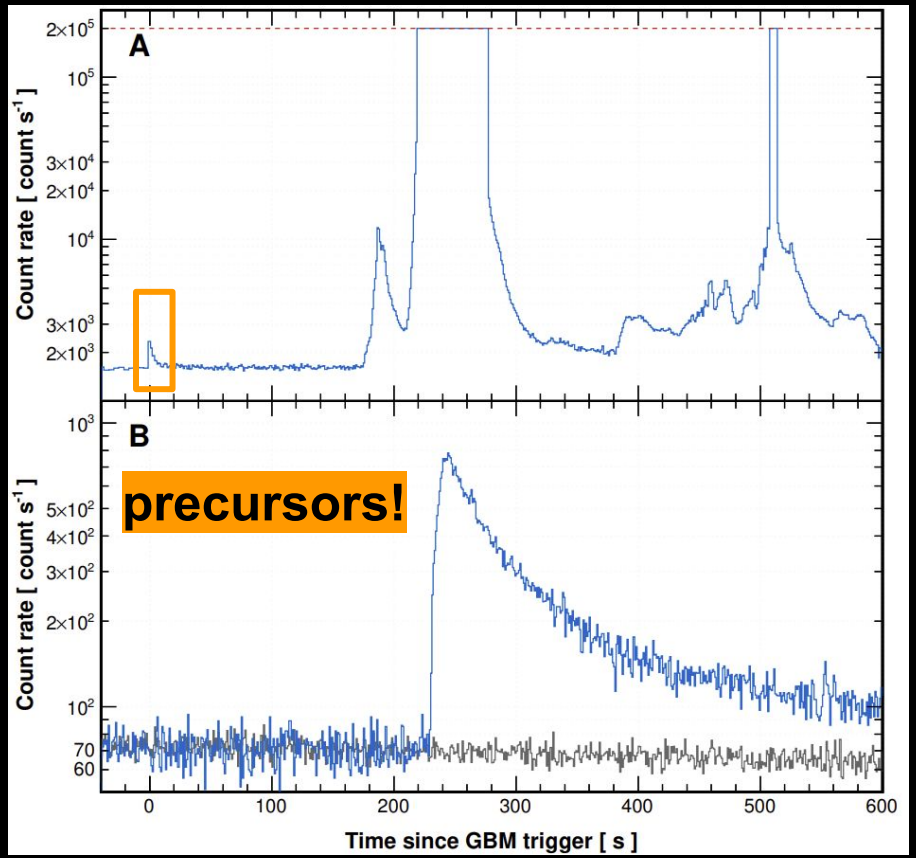
Long GRB: New observational strategy

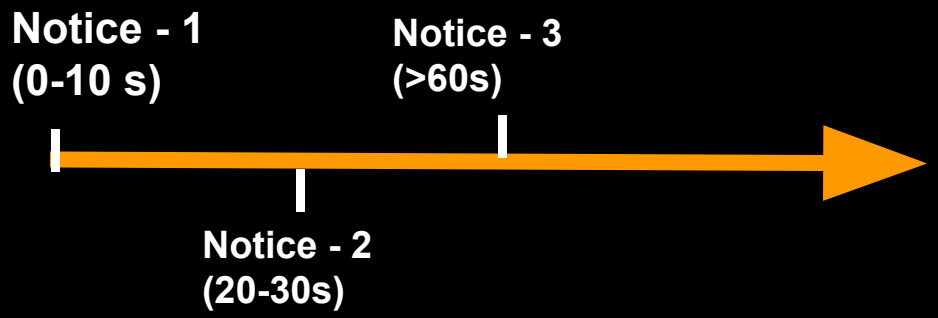
Pre-cursor

- Long GRBs

LIV - EBL

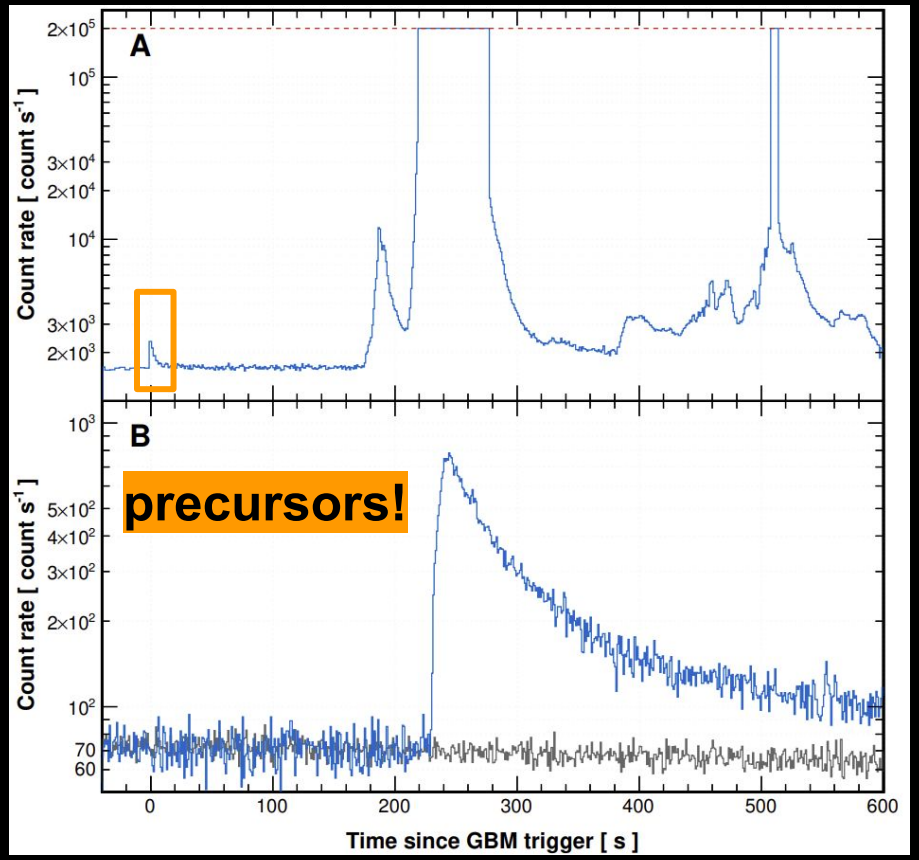
Observation proposal to MAGIC

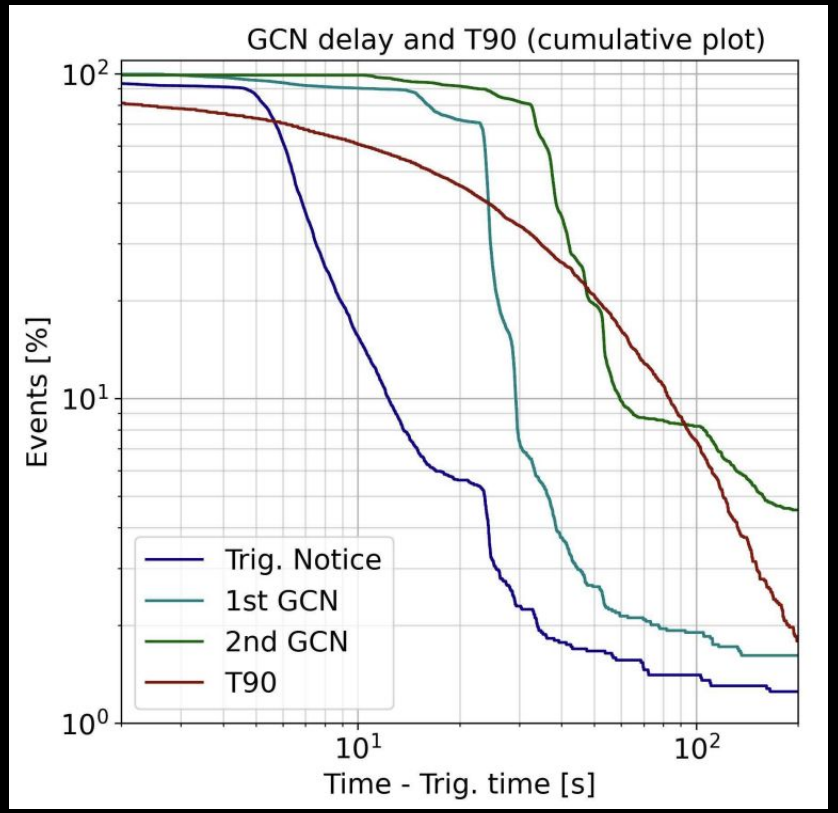




1. Detection of a GRB: initial notice: Its a GRB
2. Where is it: Gives a location
3. Better location
4. MAGIC slews and makes several observations

Observation proposal to MAGIC





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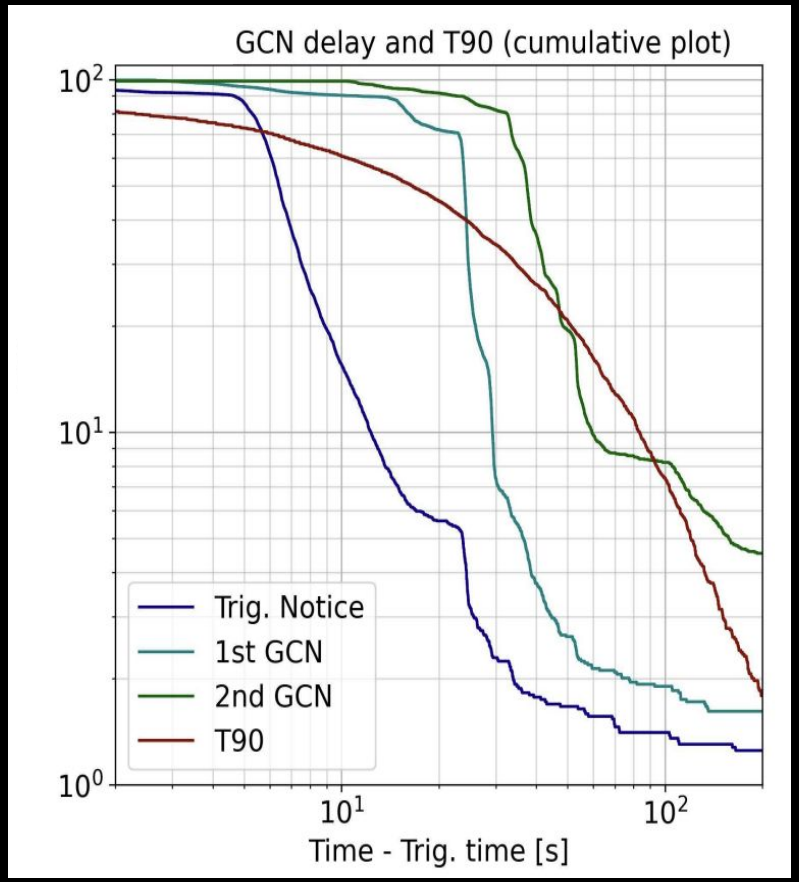
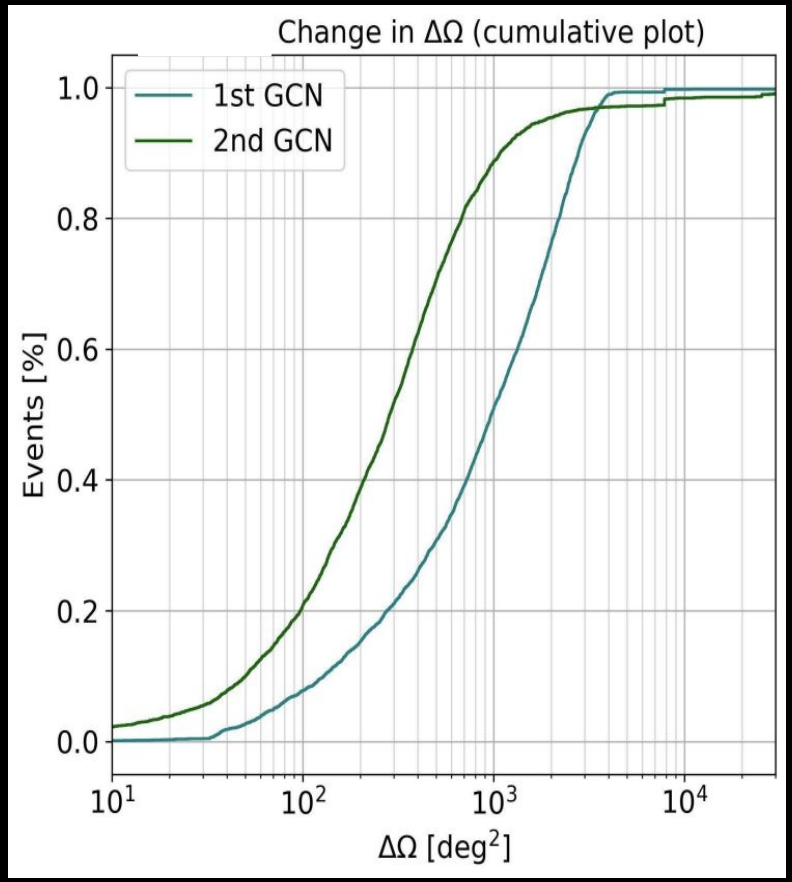
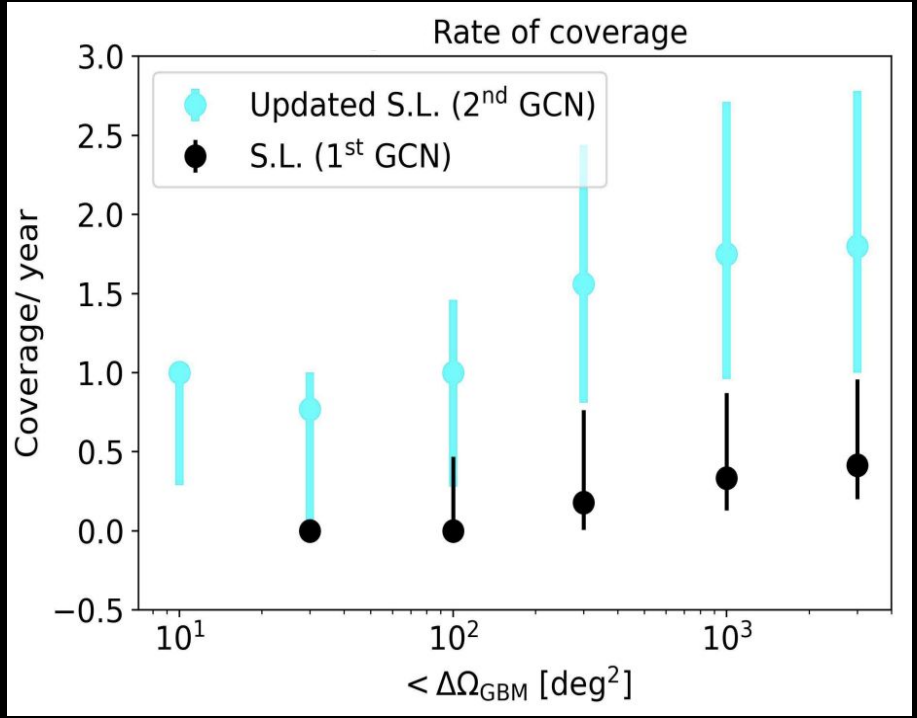
Observation proposal to MAGIC





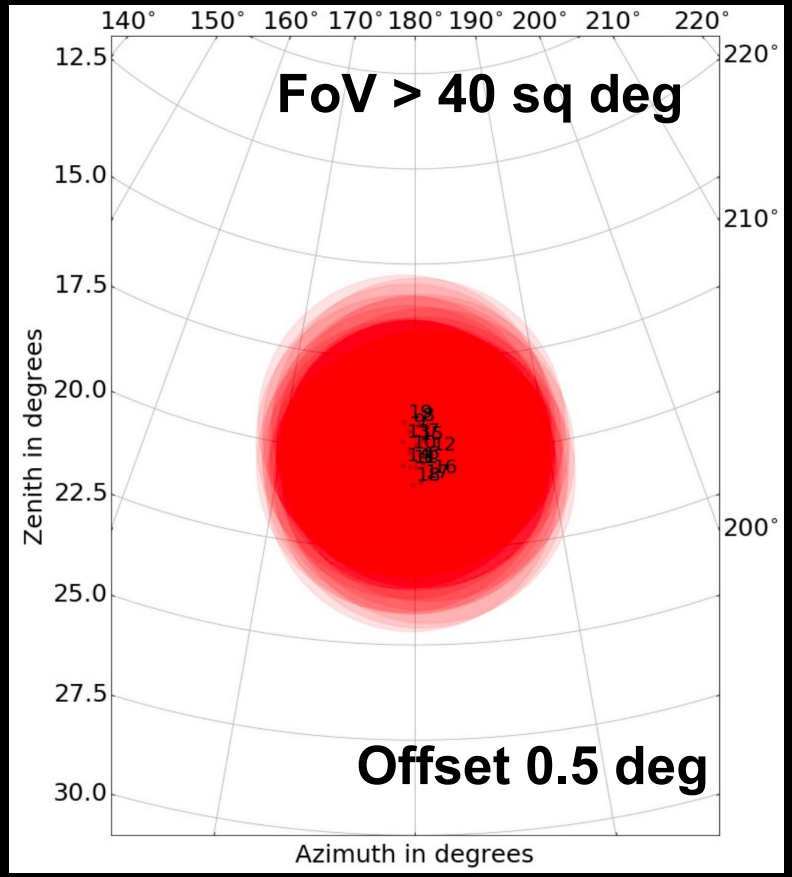
Observation proposal to MAGIC

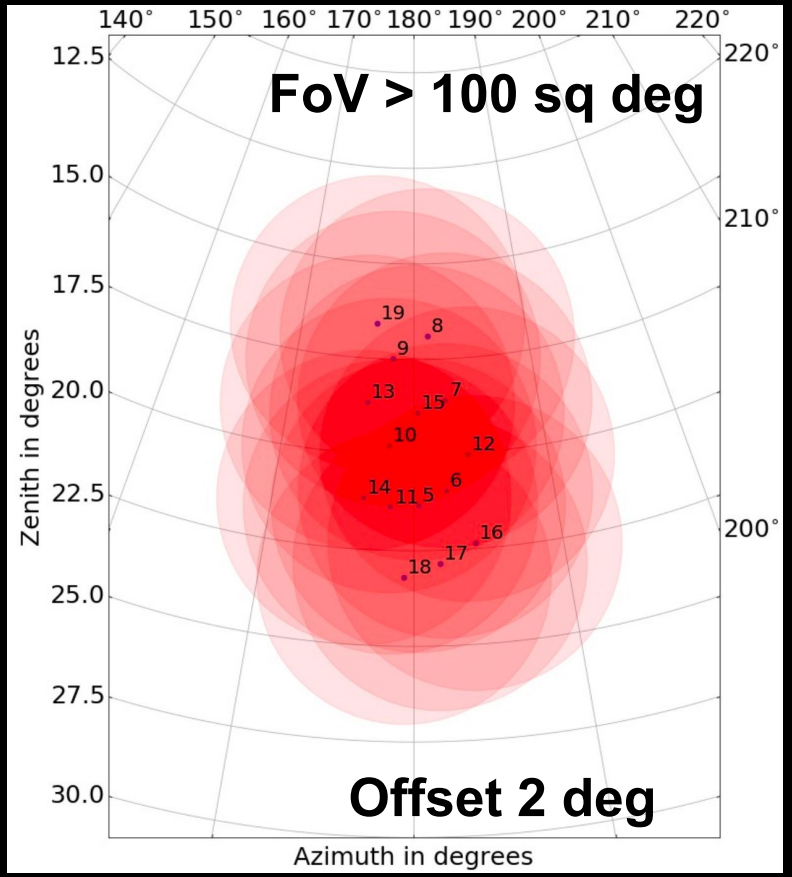


More slides:

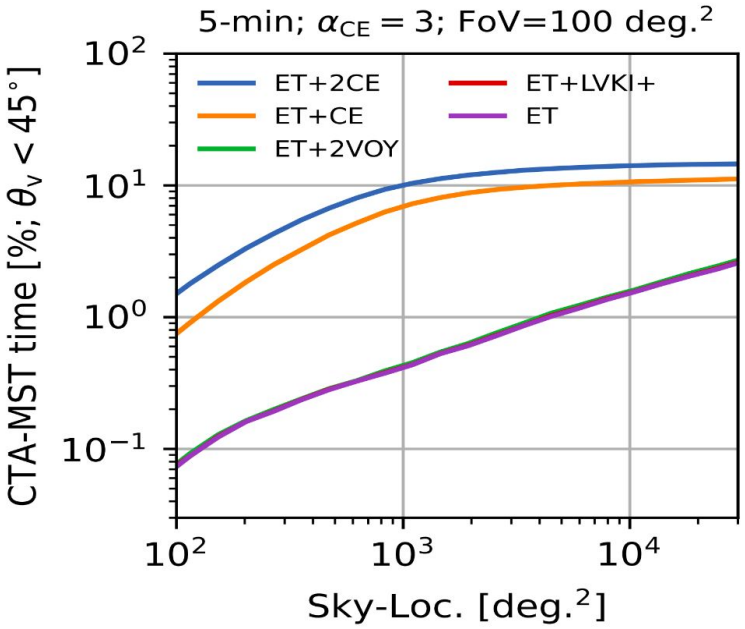
Divergent pointing:

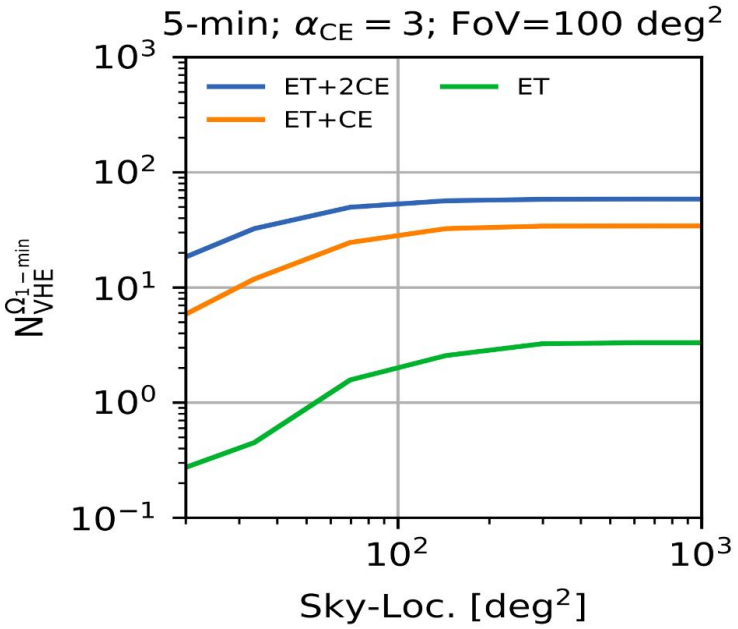
Donini et al 2019





Observation strategy: Divergent Pointing





t_{alert}= 30s; t_{slew}= **90s**; t_{rep}= 10s; t_{exp}= 20 s

$$\mathrm{CTAtime}(\%) = \frac{\mathrm{N}(<\Omega) \times \mathrm{t_{obs}} \times \mathrm{CTA_{vis}}}{\mathrm{CTA_{TOT}}}$$

$$\mathrm{N_{VHE}} = \sum_{i=1}^{\mathrm{N}_{\theta<10^\circ}(<\Omega)} \frac{\mathrm{FoV}}{\Omega_i} \times \mathrm{D.C.} \times \mathrm{CTA_{vis}}$$