SEARCH FOR VERY-HIGH-ENERGY PHOTONS FROM GAMMA-RAY BURSTS WITH HAWC

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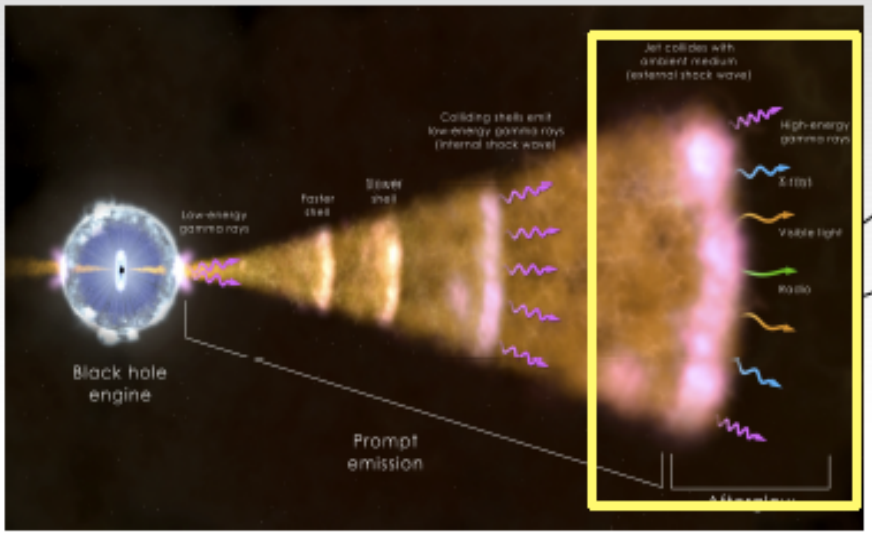
MOTIVATION

- Recent IACT detections of GRB afterglow by MAGIC and HESS

- The LAT-detected bursts exhibit two crucial similarities:

i) The first high-energy photon (>100 MeV) was delayed with the onset of the prompt phase
ii) The high-energy emission was temporarily extended, with a duration much longer than the prompt emission



ISM $n = const$

Wind $n \propto r^{-2}$

Short GRBs (only ISM)
Long GRBs (ISM and/or Wind)

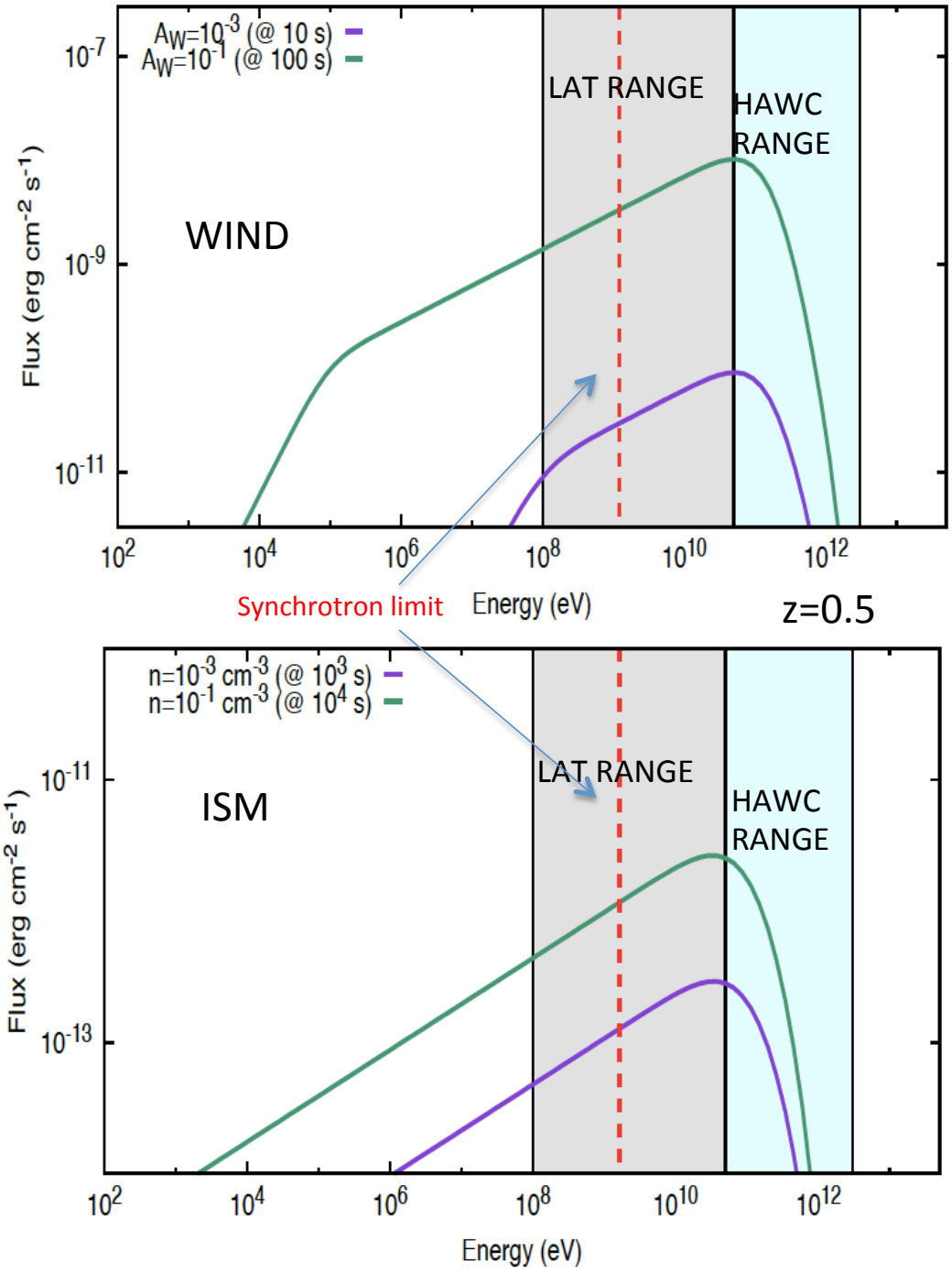
The maximum photon energy
Synchrotron radiation

$$\sim 10\ \mathrm{GeV}\ \left(\frac{\Gamma}{100}\right)(1+z)^{-1}$$

Duran Barniol 2019

SSC forward-shock emission

- Synchrotron photons are Compton scattered by the same jet electrons. **It is unavoidable**
- The maximum flux lies in the HAWC energy range with typical parameters of GRB afterglows.
- Detection of GRBs at hundreds of GeVs:
  - dense circumburst medium
  - low-redshift
  - high equivalent kinetic energy
  - Not in KN regime



Possible Candidates

- 29 GRBs with photons > 10 GeV
  (LAT second catalog)

For example:

GRB 130427A (z=0.3, 95 GeV at 244 s)
GRB 160509A (z=1.17, 52 GeV at 77 s)

Ackermann et al 2019

- Recent IACT detections of GRB afterglow by MAGIC and HESS

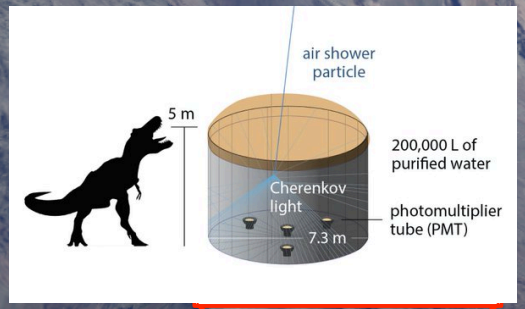
GRB 190114C (z=0.42, >300 GeV, up to 20 minutes) Mirzoyan et al 2019
GRB 180720B (z=0.654, 420 GeV, ~ a few hours) CTA symposium 2019

- **We are still waiting for a powerful GRB in HAWC field of view**

High Altitude Water Cherenkov (HAWC) Extensive Air Shower Detector

- **22,000 m^2** air shower array
- **300 Water Cherenkov detectors** (WCD)
- **200,000 liters** of purified water **per WCD**
- **4 sensors (photo-multiplier tubes) per WCD**
- **Completed March 2015**

Citlaltepetl
Pico de Orizaba
5160m a.s.l.



Large
Millimeter
Telescope

HAWC
4100 m a.s.l.

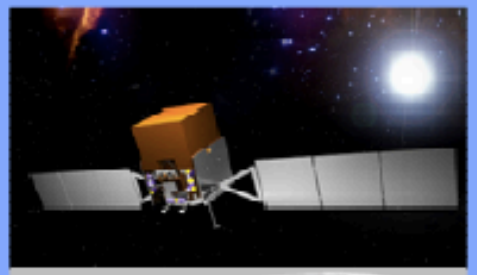
Tliltepetl
Sierra Negra
4582m a.s.l.

> 10 GeV gamma-ray observatories

Wide Field of View

Continuous Operation

TeV Sensitivity



Artist impression of Fermi.
Credit: Fermi collaboration

Fermi

AGILE

EGRET

HAWC

Milagro

ARGO

Tibet AS-γ

H.E.S.S.

VERITAS

MAGIC

Search for TeV Counterparts to Gamma Ray Bursts

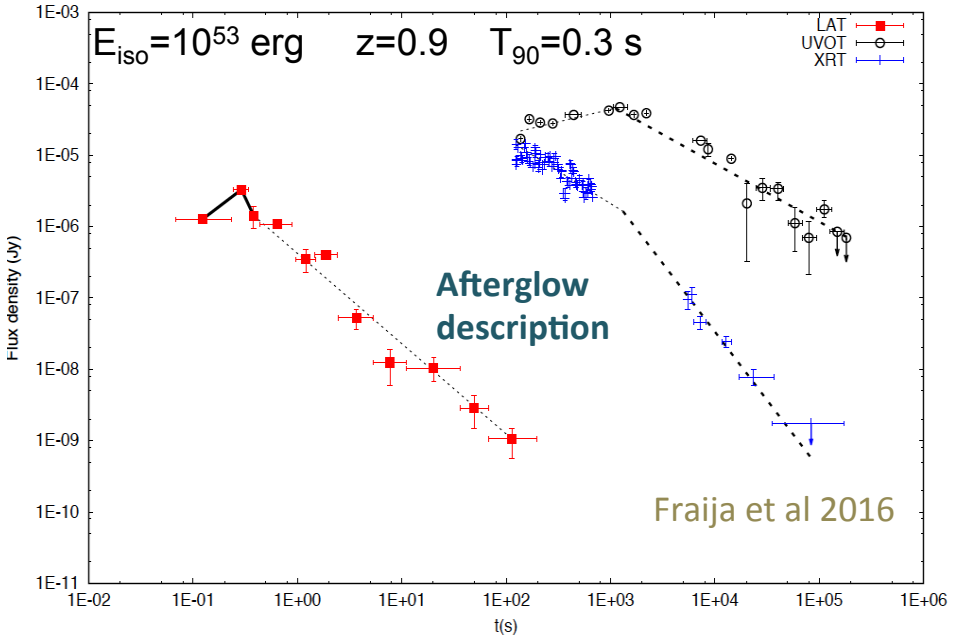
(still waiting for a big one)

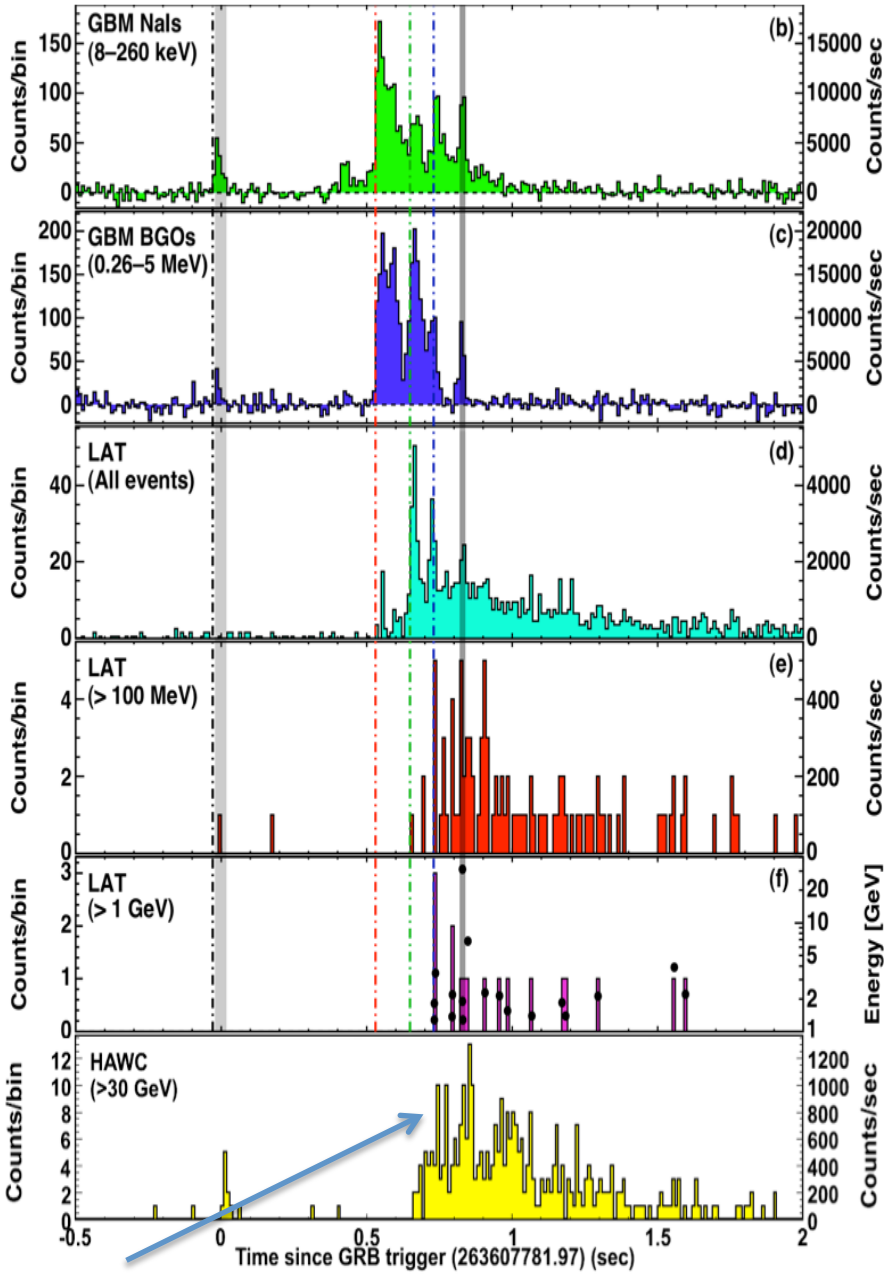
Fermi (GBM and LAT) has observed GRBs that HAWC could detect

HAWC effective area ~ 100 m^2 at 100 GeV

Fermi with ~ 1 m^2 has detected ~ 100 GeV gamma-rays from GRBs

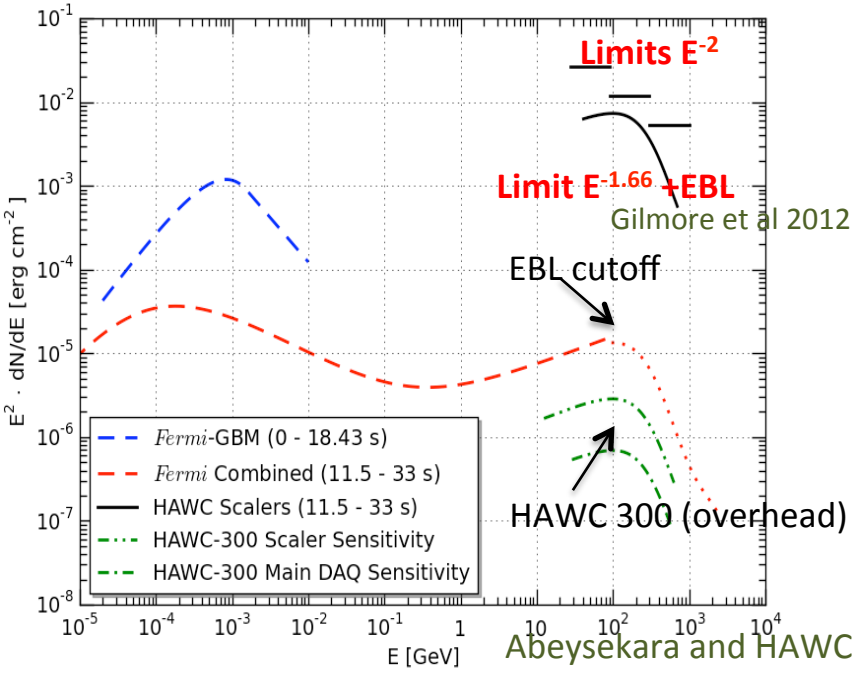
GRB 090510 (multiwavelength observations)





HAWC simulated lightcurve for Fermi

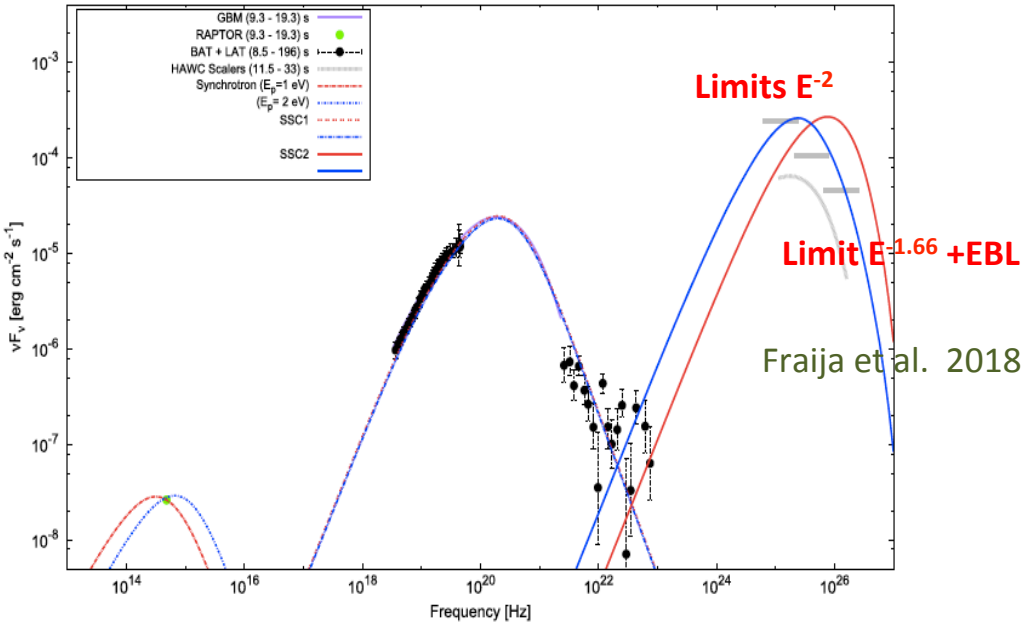
GRB 130427A



Gilmore et al 2012

Abeysekara and HAWC Collab. 2015

- Brightest burst ever detected by *Swift*
- Very close (z=0.34)
- Most powerful GRB detected z< 0.5
- Longest lasting high energy emission ever detected (~20 h)
- Most energetic photon ever detected (95.3 GeV)

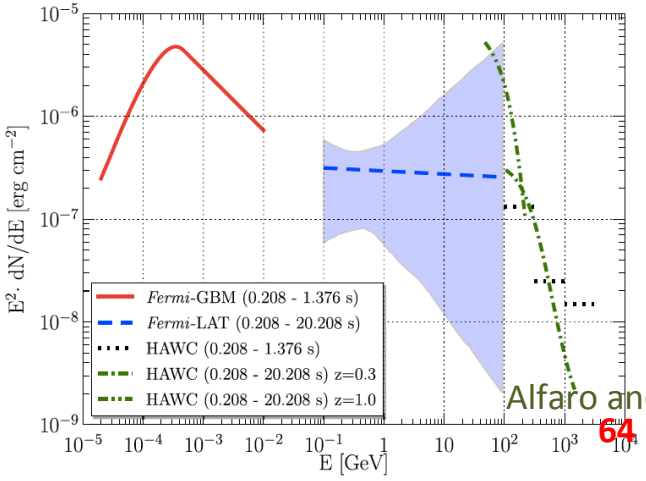


Fraija et al. 2018

Evidence for inverse Compton emission?

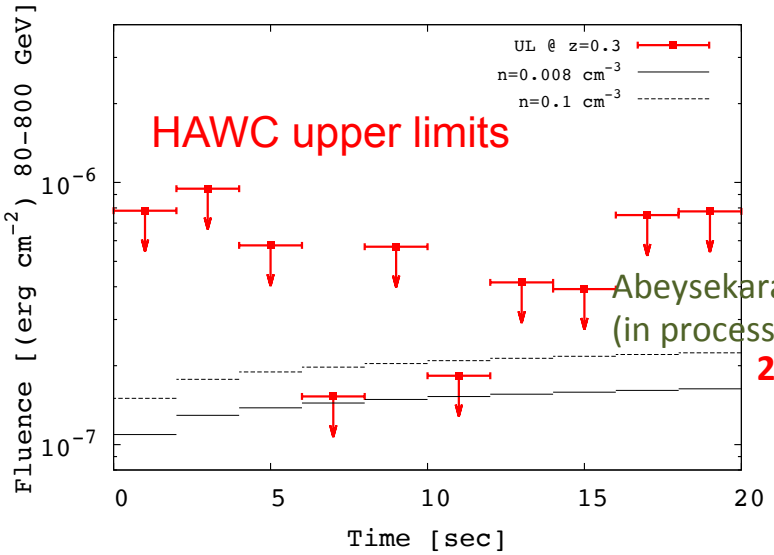
GRB 170206A

- The 3rd short brightest burst detected by GBM (T_{90}=1.2 s)



Alfaro and HAWC Collab. 2017

64 (short and long) GRBs

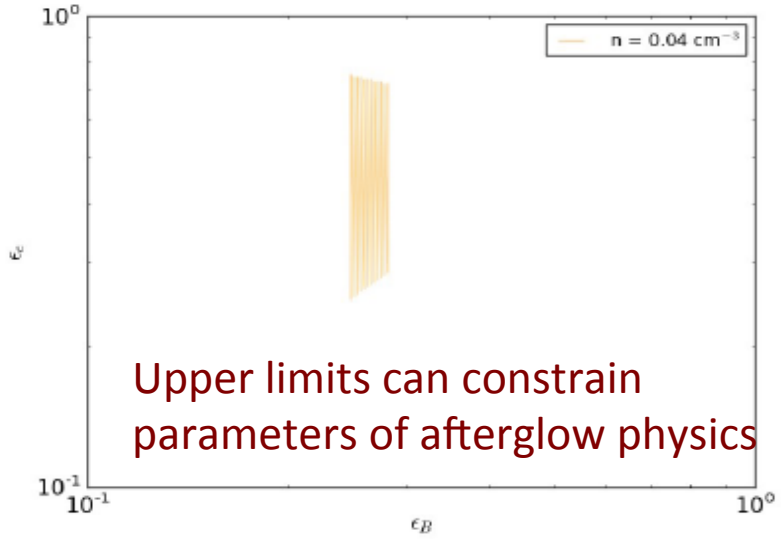


Abeysekara and HAWC Collab. (in process)

29 short GRBs

z = 0.3

n < 0.05 cm^{-3} ⇒ **Γ > 800**

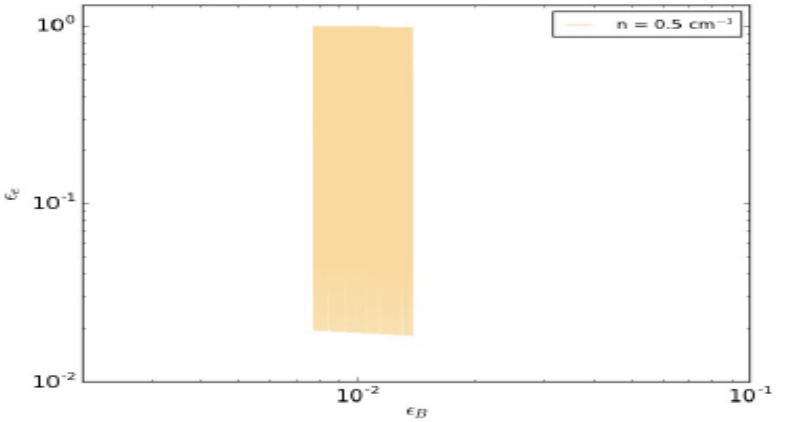


Upper limits can constrain parameters of afterglow physics

Dichiara, Fraija et al 2018

z = 1.0

n < 1.1 cm^{-3} ⇒ **Γ > 600**

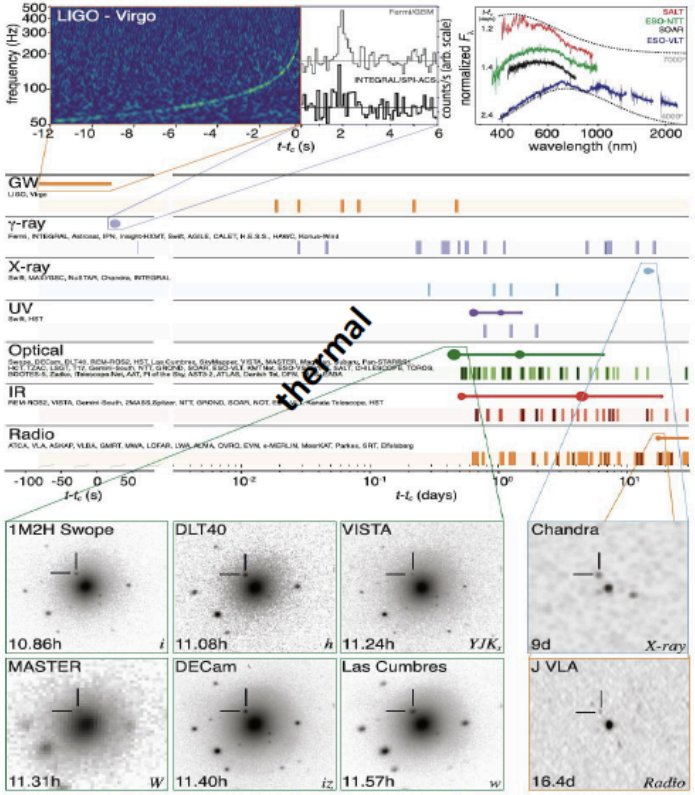


GRB 170817A

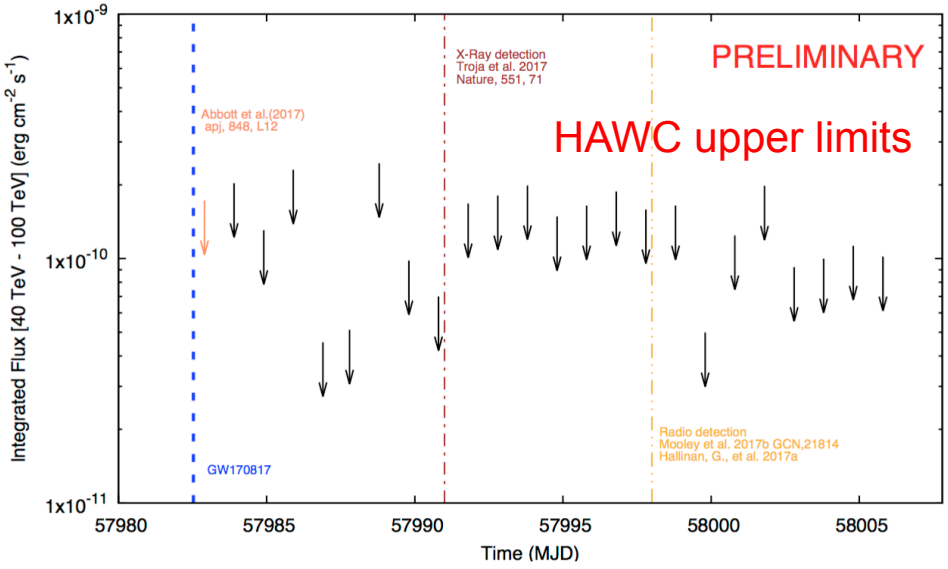
associated with NS-NS merger

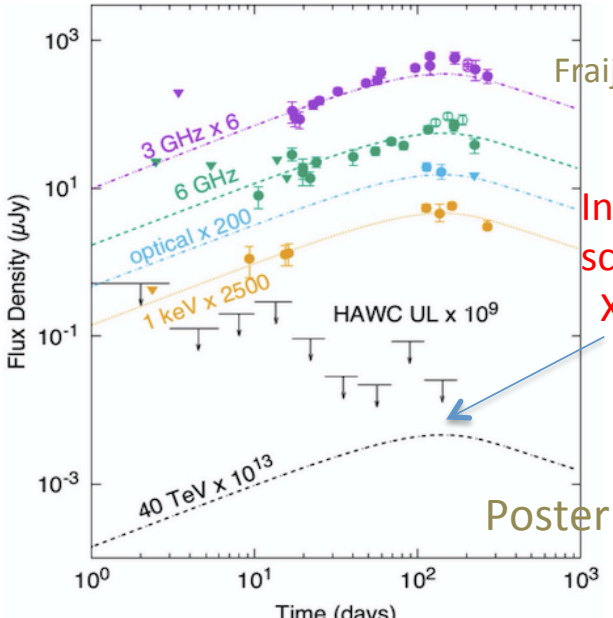
E_{iso}= 5 x 10^{46} erg z=0.009
d_z~ 40 Mpc T_{90}= 2s

Timeline of the discovery



Abbott et al 2017



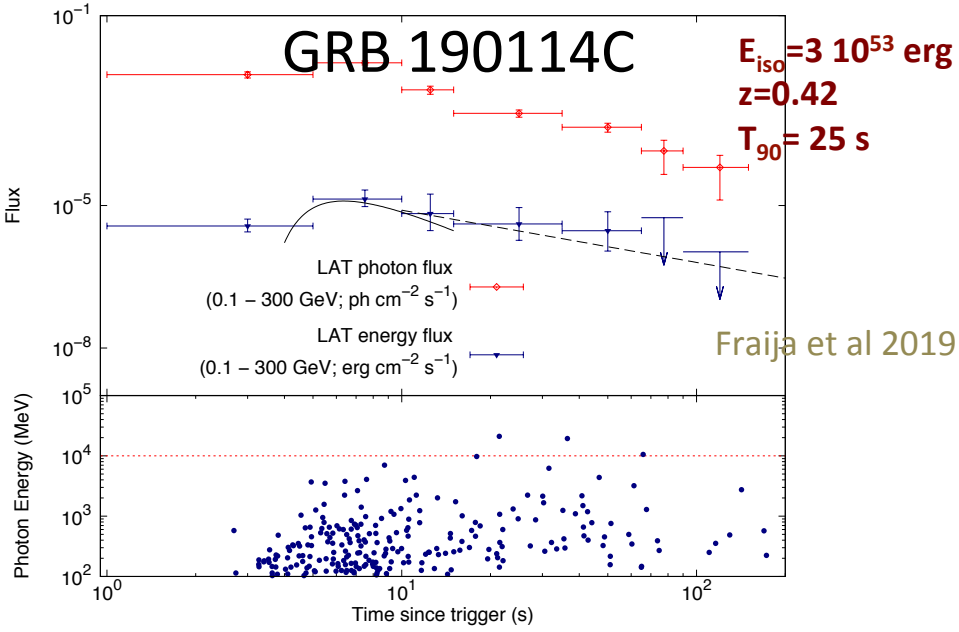


Fraija et al 2019

Inverse Comptor scattering from X-ray flux

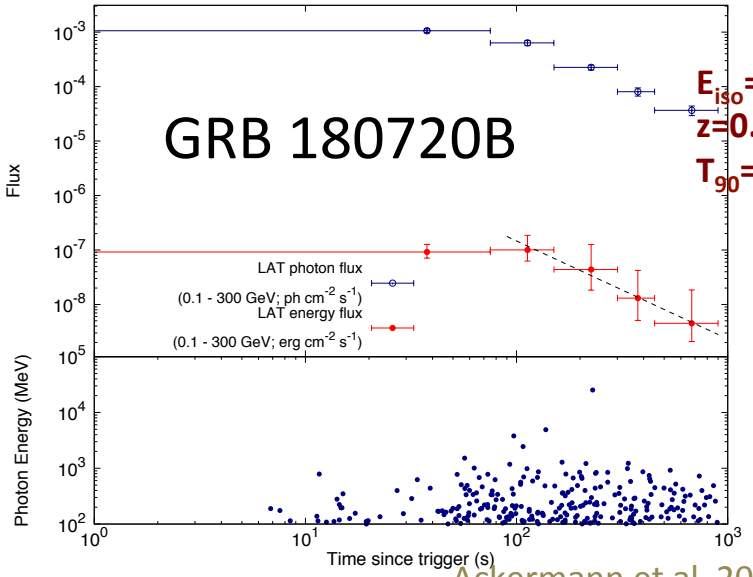
Poster 58 (Indirect)

Recent IACT detections of GRB afterglow by MAGIC and HESS



E_{iso}=3 10^{53} erg
z=0.42
T_{90}= 25 s

Fraija et al 2019



E_{iso}=4 10^{53} erg
z=0.654
T_{90}= 150 s

Ackermann et al 2019
Fraija et al 2019

Bursts	Energy Range	Observation	HAWC Upper Limit $[10^{-8}\,\mathrm{erg\,cm^{-2}\,s^{-1}}]$
GRB 180720B	(2 - 60) TeV	18 - 22 hours	1.81
GRB 190114C	(7 - 170) TeV	5 - 7 hours	4.46

Summary

- The VHE upper limits derived with HAWC together with the multi-wavelength observations reported by the orbiting instruments and ground telescopes can constrain the physics of GRBs

- We present the upper limits in the GeV - TeV energy range of the recent IACT detections of GRB afterglow by MAGIC and HESS.

- We present the VHE upper limits of the electromagnetic counterpart of GW170817.

- HAWC continues to monitor the whole sky in search of signals from potential burst candidates.