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

Nissim Fraija
and Magda Gonzalez for the HAWC Collaboration

ICRC 2019 Madison (W), 2019 July 30
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

The maximum photon energy
Synchrotron radiation

\[ \sim 10 \text{ GeV} \left( \frac{\Gamma}{100} \right) (1 + z)^{-1} \]
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)  Ackermann et al 2019
GRB 160509A (z=1.17, 52 GeV at 77 s)

• 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 m²** 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
5160 m a.s.l.

Tliltepetl
Sierra Negra
4582 m a.s.l.
> 10 GeV gamma-ray observatories

Wide Field of View
Continuous Operation

TeV Sensitivity

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 $\sim 100 \text{ m}^2$ at 100 GeV

Fermi with $\sim 1 \text{ m}^2$ has detected $\sim 100 \text{ GeV}$ gamma-rays from GRBs

GRB 090510 (multiwavelength observations)

$E_{\text{iso}} = 10^{53} \text{ erg} \quad z = 0.9 \quad T_{90} = 0.3 \text{ s}$

Fraija et al. 2016

HAWC simulated lightcurve for Fermi
GRB 130427A

- 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)

Evidence for inverse Compton emission?
**GRB 170206A**

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

**Upper limits can constrain parameters of afterglow physics**

- **Alfaro and HAWC Collab. 2017**
  - 64 (short and long) GRBs

- **Abeysekara and HAWC Collab. (in process)**
  - 29 short GRBs

- **Dichiara, Fraija et al 2018**
  - $n < 1.1$ cm$^{-3}$ \[\Gamma > 600\]
GRB 170817A

associated with NS-NS merger

$E_{\text{iso}} = 5 \times 10^{46}\text{ erg}$ $z=0.009$

$d_z \sim 40\text{ Mpc}$ $T_{90} = 2\text{s}$

Abbott et al 2017

HAWC upper limits

Fraija et al 2019

Inverse Compton scattering from X-ray flux

Poster 58 (Indirect)
Recent IACT detections of GRB afterglow by MAGIC and HESS

**GRB 190114C**
- $E_{\text{iso}} = 3 \times 10^{53}$ erg
- $z = 0.42$
- $T_{90} = 25$ s

**GRB 180720B**
- $E_{\text{iso}} = 4 \times 10^{53}$ erg
- $z = 0.654$
- $T_{90} = 150$ s

<table>
<thead>
<tr>
<th>Bursts</th>
<th>Energy Range</th>
<th>Observation</th>
<th>HAWC Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRB 180720B</td>
<td>(2 - 60) TeV</td>
<td>18 - 22 hours</td>
<td>1.81</td>
</tr>
<tr>
<td>GRB 190114C</td>
<td>(7 - 170) TeV</td>
<td>5 - 7 hours</td>
<td>4.46</td>
</tr>
</tbody>
</table>
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.