First Detection of Very High Energy Emission from a Gamma-Ray Burst

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on behalf of the MAGIC Collaboration
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Gamma-Ray Bursts

- HE photons detected by Fermi/LAT challenge synchrotron origin
- **Synchrotron Self-Compton** (SSC) mechanism had been naturally expected to produce Very High Energy (VHE) photons (> GeV)
- Higher statistics & higher energy photons are necessary → IACTs
MAGIC Telescopes

- Two 17 m IACTs in stereoscopic mode since 2009 (mono 2003)
- La Palma, Canaries, Spain. 2200 m a.s.l.
- Energy range: ~30 GeV - > 50 TeV
- Light carbon fibre structure → Fast repointing to a GRB (slewing speed: ~7 deg/s)
- Observations under moonlight → Increased duty cycle
- Multi-threaded program handles communication between GCN and the telescope control
- Full automatic repointing starts once an alert is validated
History of GRB Follow-up

- Before 2019, no clear detection since 2005 (~8 GRBs/yr)
- $3\sigma$ hint of gamma-ray emission from GRB 160821B
  - Short GRB associated to a kilonova
  - One of the closest GRBs for MAGIC: $z = 0.16$
  - Fastest obs.: $T_0 + 24 \text{ s} - T_0 + 4 \text{ h}$
  - Bright moon, adverse weather
- Results were published in ApJ

First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C

ATel #12390; Razmik Mirzoyan on behalf of the MAGIC Collaboration on 15 Jan 2019; 01:03 UT
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, Gamma-Ray Burst
Referred to by ATel #: 12395, 12475


- MAGIC real-time analysis shows a significance > 20 sigma in the first 20 min of observations → First unequivocal detection of VHE gamma-rays from a GRB

- One of the closest GRBs for MAGIC: z = 0.4245

- Triggered the most extensive MWL campaign for a GRB (Radio - VHE gamma)
  - No neutrino detected by IceCube
Light curves & Timeline


- Started from Zd of 55.8°
- Good weather, but under moderate moonlight
- Night sky background noise (NSB) is 6 × NSB in dark
- Follow our standard procedure for data taken under moonlight
- Dedicated Monte Carlo γ simulation was produced
  - Matching the trigger settings
  - Zenith-Azimuth distribution
  - NSB level

Automatic alert system worked perfectly

- Magic observed (>300 GeV)
- Crab Nebula flux

Fast repointing (28 s)  DAQ stabilization + safe margin (5 s)
Brightest TeV Source

- Event rate of GRB190114C: $\sim 0.1 \text{kCrab} @ 0.3 \text{ TeV}$
- Brightest TeV source ever detected

**Power law index:**

- **T0 +62s - T0 +2454s**
  
  -2.22 ±0.23/-0.25

- **Extragalactic background light absorption**

- **No break or cutoff**
Extensive MWL Campaign

First GRB TeV light curve
-1.51 ± 0.04

Similarity in X/GeV/TeV afterglow LCs

Beyond Synchrotron


**Figure:**
- **X-axis:** $T-T_0$ (s)
- **Y-axis:** Energy (GeV)
- **Z-axis:** Number of events

- **Legend:**
  - **Stellar wind medium**
  - **Homogeneous external medium**

**Caption:** MAGIC detected photon energies are much above the synchrotron burn off limit.
New component

Peak of Synchrotron component

Comparably amount of power to that of synchrotron radiation

Same spectral index within stat. error

Synchrotron + SSC Model

- First modeling of TeV emission from a GRB
- Discovery of SSC afterglow radiation
- Obtained parameters indicate that this GRB is a relatively common kind of bursts → SSC might be a common component of GRB afterglows. However, SSC has difficulty accounting for the putative TeV flux of GRB 160821B. Need more GRBs
More GRBs coming!

GRB 201015A

- Relatively low luminosity long GRB @ z=0.42
- Strong hint of detection of VHE emission

GRB 201216C

- Long GRB @ z=1.1
- Clear detection of VHE emission
- Most distant source for IACTs

GRB 201015A:

- Relatively low luminosity long GRB @ z=0.42
- Strong hint of detection of VHE emission

On October 15, 2020, the MAGIC telescopes observed GRB 201015A following the Swift-BAT trigger (D’Elia et al., GCN 28632). MAGIC started observations under good conditions about 40 seconds after the initial Swift trigger, revealing a hint of signal with significance >3 sigma in the very high energy band. Refined off-line analyses of the data are ongoing.

Further MAGIC observations on GRB 201015A are planned in the coming night. We strongly encourage follow-up observations by other instruments at all wavelengths.

The MAGIC point of contact for this burst is O. Blanch (blanch@ifae.es). Burst Advocate for this burst is M. Gaug (Markus.Gaug@uab.cat)

GRB 201216C: MAGIC detection in very high energy gamma rays

ATel #14275; Oscar Blanch (IFAE-BIST) on behalf of the MAGIC Collaboration on 17 Dec 2020; 17:23 UT

Credential Certification: Oscar Blanch (blanch@ifae.es)

Subjects: Gamma Ray, >GeV, TeV, VHE, Gamma-Ray Burst

Referred to by ATel #: 14277

On December 16, 2020, the MAGIC telescopes observed GRB 201216C following the trigger by Swift-BAT and Fermi-GBM (Beardmore et al., GCN 29061, Fermi/GBM team GCN 29063). MAGIC started observations under good conditions about 57 seconds after the GRB onset. The preliminary off-line analyses show an excess above 3 sigma, compatible with the GRB position reported by the Swift and Fermi teams. Refined off-line analyses of the data are ongoing.
• Breakthrough detection of a GRB afterglow emission by the MAGIC telescopes, which triggered the most extensive MWL campaign for a GRB

• MAGIC could start the observations of GRB 190114C in a minute after the Swift/BAT trigger

• MAGIC found a significant energy release in VHE regime, which can be naturally explained by a synchrotron + SSC model

• GRB 190114C is a bright GRB, but seems not atypical. SSC component might be common in GRB afterglows

• More GRBs coming. Stay tuned!
Thank you very much!

YouTube "The MAGIC telescopes detect the first GRB at TeV energies"