The MAGIC Transients and Multimessenger program

Francesco Longo

on behalf of the MAGIC Transients WG
The Multimessenger sky

Stamerra et al. 2019
Observing the Sky with IACTs
The MAGIC telescopes
The MAGIC telescopes

- Mono up to 2009, then stereo system
- Energy range: \( \sim 50 \text{ GeV}-50 \text{ TeV} \)
  (with Sum-Trigger, \( E_{\text{thr}} \sim 30 \text{ GeV} \))
- Field of view: 3.5°
- Sensitivity: \( \lesssim 0.7\% \) Crab flux above 220 GeV in 50 h
  \( (\sim 2 \times 10^{-10} \text{ cm}^{-2} \text{ s}^{-1}) \)
- Good sensitivity for short timescales
- Energy resolution:
  15% (@1 TeV) \( \div \) 24% (@100 GeV)
- Angular resolution:
  0.06° (@1 TeV) \( \div \) 0.1° (@100 GeV)
- Light-weight telescopes: \( \sim 70 \text{ t} \)
- Fast repositioning: 7°/s (4°/s in std mode)
The Autonomous Alert System

- Originally designed for GRBs
- Adapted to neutrino and GW alerts
- New protocol VOEvent is being implemented
- Enables multi-messenger observations

Credit: A. Carosi

Berti et al. 2019
Sensitivity to Transients

The graph shows the differential energy flux (erg s\(^{-1}\) cm\(^{-2}\)) as a function of needed observing time (s). The lines represent different energy thresholds:

- Fermi-LAT
- MAGIC (2013)
- 75 GeV
- 100 GeV
- 250 GeV
The MAGIC Transients program

Gamma-Ray Bursts
- Automatic (prompt) follow-up
- Late-time observations
- Detection of GRB 190114C

Neutrinos
- Follow-up of alerts from IceCube
- Real-time and archival events
- EHE-170922/TXS 0506+056 detection

Gravitational Waves Counterparts
- Signed MoU with LIGO/Virgo in 2014
- Follow-up of several alerts
- New strategy implementation

Fast Radio Bursts
- FRB 121102 observed in VHE/optical
- Coordination with radio observatories

Berti et al. 2019
### The MAGIC Transients Program

**Gamma-Ray Bursts**
- Detection of 201216C
- Hints of 201015A

**Neutrinos**
- New channels analysis
  - e.g. Gold/Bronze alerts

**Gravitational Waves Counterparts**
- Implementation of scan procedure

**Fast Radio Bursts**
- New Optical Pixel in M1
GRBs with MAGIC

- Since 2013, new follow-up procedure + late-time observations
- 105 GRBs observed so far
- Filters for GCN alerts
- 8-10 GRBs/year
- 40 GRBs with known redshift

Berti et al. 2019
GRBs with MAGIC
GRBs with MAGIC

- Perform follow-up as soon as possible for prompt/early afterglow observation
- Late time observations for delayed emission (for Fermi-LAT triggers)

Updated from Berti et al. 2019
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

The MAGIC telescopes performed a rapid follow-up observation of GRB 190114C (Gropp et al., GCN 23688; Tyurina et al., GCN 23690, de Ugarte Postigo et al., GCN 23692, Lipunov et al. GCN 23693, Selsing et al. GCN 23695). This observation was triggered by the Swift-BAT alert; we started observing at about 50s after Swift T0: 20:57:03.19. The MAGIC real-time analysis shows a significance >20 sigma in the first 20 min of observations (starting at T0+50s) for energies >300 GeV. The relatively high detection threshold is due to the large zenith angle of observations (>60 degrees) and the presence of partial Moon. Given the brightness of the event, MAGIC will continue the observation of GRB 190114C until it is observable tonight and also in the next days. We strongly encourage follow-up observations by other instruments. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) and K. Noda (nodak@icrr.u-tokyo.ac.jp). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.
MAGIC detection

MAGIC observed (>300 GeV)

GRB 190114C

Acciari et al. 2019a
MAGIC detection

GRB 190114C

Acciari et al. 2019a
MAGIC detection

GRB 190114C

Acciari et al. 2019b
MAGIC detection

GRB 190114C  

Acciari et al. 2019b
ABSTRACT

The coincident detection of GW170817 in gravitational waves and electromagnetic radiation spanning the radio to MeV gamma-ray bands provided the first direct evidence that short gamma-ray bursts (GRBs) can originate from binary neutron star (BNS) mergers. On the other hand, the properties of short GRBs in high-energy gamma rays are still poorly constrained, with only ~20 events detected in the GeV band, and none in the TeV band. GRB 160821B is one of the nearest short GRBs known at $z = 0.162$. Recent analyses of the multiwavelength observational data of its afterglow emission revealed an optical-infrared kilonova component, characteristic of heavy-element nucleosynthesis in a BNS merger. Aiming to better clarify the nature of short GRBs, this burst was automatically followed up with the MAGIC telescopes, starting from 24 seconds after the burst trigger. Evidence of a gamma-ray signal is found above $~0.5$ TeV at a significance of $~3\sigma$ during observations that lasted until 4 hours after the burst. Assuming that the observed excess events correspond to gamma-ray emission from GRB 160821B, in conjunction with data at other wavelengths, we investigate its origin in the framework of GRB afterglow models. The simplest interpretation with one-zone models of synchrotron-self-Compton emission from the external forward shock has difficulty accounting for the putative TeV flux. Alternative scenarios are discussed where the TeV emission can be relatively enhanced. The role of future GeV-TeV observations of short GRBs in advancing our understanding of BNS mergers and related topics is briefly addressed.

Keywords: Radiation mechanisms: non-thermal - Gamma rays: general - Gamma-ray burst: individual: GRB 160821B

acciari et al. 2021
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)

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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 under good conditions about 57 seconds after the GRB onset. The preliminary offline analyses show an excess above 5 sigma, compatible with the GRB position reported by the Swift and Fermi teams. Refined off-line analyses of the data are ongoing.

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 F. Longo (francesco.longo@ts.infn.it).

MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

GW counterparts searches


- $t_0$: 2015-12-26 03:38:53.648 UT (internal GCN Circular)
- $t_{\text{notice}}$: 2015-12-27 17:40:00 UT
- 90% (50%) credible region: 1337 deg$^2$ (430 deg$^2$)
- False Alarm Rate: 1/100 year

- Observation by MAGIC started on 2015-12-28 21:00:00 UT
- Four targets pointed
- Selection by hand according to visibility, probability, EM partners observations and catalogs
- No signal found

Berti et al. 2019
GW searches

Example of a skymap (left) and the visibility computation from the MAGIC site (right).

Ribò et al. 2019
Neutrino counterparts searches

IC+Fermi+MAGIC++, Science 361, 146 (2018)

- After IceCube alert (IC-170922, 290 TeV), H.E.S.S., VERITAS and MAGIC followed-up the alert: no detection
- Fermi-LAT detected GeV emission from the blazar TXS 0506+056, positionally consistent with IC alert
- MAGIC collected 13h from 28th of September to 4th of October: detection above 90 GeV
- First time observation of VHE $\gamma$-rays in coincidence with high energy neutrinos

Berti et al. 2019
Neutrino counterparts searches

SED (Spectral energy distribution) of TXS 0506+56

Science 361, eaat1378 (2018)
Stamerra et al. 2019
Neutrino counterparts searches

Ansoldi et al. 2018 ApJL 863 10

Stamerra et al. 2019
FRBs with MAGIC

- Associated sources in optical and radio
- Located at $z = 0.193$ in a dwarf galaxy
- Search of counterparts at other wavelengths
- From September 2016, MAGIC observations together with Arecibo (8.9 h simultaneous, out of 22 h)

- Constraints on VHE (burst and persistent) and optical burst emission
- Test of the magnetar scenario with improved limits observing more bursts
- Most stringent constraints on the putative optical burst emission of FRB 121102 to date

Credit: Canadian Observations/ACT/MPI/NRC

![Image of FRB 121102 with host galaxy](image)

![Graph showing emission versus energy](graph)

MNRS 481, 2479–2486 (2018)

Berti et al. 2019
Conclusions

- The MAGIC Transients program is a successful one!
- Rapid movement of the telescope and Fast analysis proved to be crucial
- Analysis of “not-standard” conditions
- Thanks to all the “Transients” advocates