

# MAGIC telescopes: the Gathering (Highlights from the MAGIC telescopes)





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Image Credit: Urs Leutenegger (@urs.leutenegger)

26.10.2021 -- TeVPa 2021 --

# The Very-High-Energy gamma-ray sky

MAGIC





### MAGIC telescopes: Characteristics



- MAGIC I from 2004, MAGIC II from 2009
- Located in the Canary island of La Palma, 2200m a.s.l
- Mirror dish diameter: 17 m
- Active reflective mirror surface: 236<sup>2</sup> m
- Upgrade of MAGIC I camera and readout system in 2012
- 1039 PMTs cameras (FoV 3.5°)
- Energy range: 30 GeV to 100 TeV
- Fast repositioning (180° in less than 30s)
- Energy threshold can be lowered to 15 GeV
- Sensitivity above 220 GeV is ~0.66% of the Crab nebula flux (for 50 hs)
- In total 300 MAGICians from 12 countries



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### MAGIC telescopes: Sensitivity





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-Astroparticle Physics, Volume 72, p. 76-94





## **Physics working groups**

- Astroparticle and Fundamental Physics
- Transients objects
- Galactic objects
- Extragalactic objects



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EVOCATION

# Evocation: Gamma-Ray Bursts studies

First GRB detected by MAGIC: Long GRB 190114C

- after more than 100 observations of GRB alerts, finally the first GRB was detected!
- years of preparation, coordination with other facilities, software development, technical maintenance to allow fast repositioning...
  - a long wait that was finally worth it



MAGIC

**Major Atmospheric** 

Gamma Imaging Cerenkov Telescopes

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Image Credit: NASA's Goddard Space Flight Center

#### \*Nature 575, 459 (2019) and Nature 575, 455 (2019)



## Evocation: Gamma-Ray Bursts studies

First GRB detected by MAGIC: Long GRB 190114C

 $T_0$  = 20:57:03 UT : Swift-BAT and Fermi-GBM triggered on GRB190114C  $T_0$  + 22s: MAGIC received the alert  $T_0$  + 50s: MAGIC started tracking  $T_0$  + 57s: MAGIC started data acquisition (35s after the alert)  $T_0$  + 62s: MAGIC data acquisition stabilised



\*Nature 575, 459 (2019) and Nature 575, 455 (2019)



# Evocation:

### Gamma-Ray Bursts studies

### First GRB detected by MAGIC: Long GRB 190114C

- MAGIC spectra in 5 different time intervals
- For the first two time intervals, observations in the gigaelectronvolt and X-ray bands are also available
- During the first time interval Swift-XRT, Swift-BAT and Fermi-GBM data show that the afterglow synchrotron component peaks in the X-ray band
- Up to 1 GeV, the SED is a decreasing function of energy
- At higher energies, the MAGIC flux above 0.2 TeV implies a spectral hardening
- The newly discovered teraelectronvolt radiation is not a simple extension of the known afterglow synchrotron emission, but a separate spectral component.

#### \*Nature 575, 459 (2019) and Nature 575, 455 (2019)





### Evocation: Gamma Ray Bursts studies

- The prompt phase lasts for ~25s
- MAGIC start observing in the early afterglow phase
- VHE gamma-rays have been detected up to 1TeV.
- First evidence of an extra component beyond synchrotron emission in the afterglow of a GRB
- The new emission component in the afterglow has a power comparable to that of the synchrotron component.
  - $\rightarrow$  flat energy flux, d $\phi$ /dE ~ E <sup>-2</sup> (after EBL de-absorption),
  - $\rightarrow$  incompatible with synchrotron (burnoff limit E >100 GeV),
  - $\rightarrow$  compatible with synchrotron self Compton (SSC).



modelling of the multi-band data in the synchrotron and SSC afterglow scenario

#### MAGIC detected another GRB, 201216C at z=1.1?!

\*Nature 575, 459 (2019)

\*See Yusuke Suda's talk tomorrow at 9:00 CEST (Session 1, EGAL sources)

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# Illusion: LIV studies with GRB 190114C \*

Probing Quantum Gravity with MAGIC Light curve



• Competitive Lower limits for the QG energy scale derived in this work using an unbinned analysis

### Phys. Rev. Lett. 125, 021301 (2020)

\*See Tomislav Terzić talk, tomorrow at 11:55 CEST (Session 1 Gamma rays)

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Plot by J. Strišković, Terzić et al., Universe, vol. 7, issue 9, p. 345 (2021)



#### **Enchantment:** Geminga pulsar detection hints at a power-law tail emission beyond 15 GeV $10^{-9}$





Energy range: between 15 GeV and 75 GeV thanks to the Sum-Trigger II system and the dedicated analysis (IEEE Transactions on Nuclear Science, Volume 68, Issue 7, pp. 1473-1486)

- First time a middle-aged pulsar has been detected up to these energies
- P2 is detected in the MAGIC energy range, with a significance of 6.3  $\sigma$  with 80 hours of data
- The power-law tail emission detected by MAGIC is interpreted as the transition from curvature radiation to Inverse Compton scattering of particles accelerated in the northern outer gap.

MAGIC **Major Atmospheric Gamma** Imaging **Cerenkov Telescopes** 

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# Summoning: Multimessenger astrophysics: the first neutrino blazar, TXS 0506+056

- First time observation of VHE y-rays in coincidence with a high energy neutrino
- Impressive multi-collaboration effort
- Firm detection of the blazar TXS 0506+056 by MAGIC
- Complex observational strategies for following neutrino alerts rewarded
- Still waiting for the next neutrino blazar or other neutrino sources to be detected



### Science 361, eaat1378 (2018)



• Jet-sheath scenario with E p,max = 10<sup>16</sup> eV

- hadronic emission components
- The neutrino and MWL data can be interpreted with a one-zone model and external photons from structured jets
- The inferred proton luminosity is in the range  $\approx$   $10^{45}$   $4x10^{46}\,erg/\!s\,$  and
- maximum CR energies in the comoving frame of  $10^{14}$  to  $10^{18}$  eV



#### Astrophysical Journal Letters, 863 (2018) L10

\*See Ilaria Viale's talk tomorrow at 10:00 CEST for the multiyear study of TXS 0506+056 (Session 2, EGAL sources)



# **Abjuration:** Measurement of the Cosmic ray spectrum

-Charged cosmic rays can be successfully used to study the spectra of protons and helium and iron nuclei in a wide range of energies

- Supervised Feed-Forward Neural Networks
- Energy range of the p spectrum 1-100 TeV
- Element composition of cosmic nuclei using background data
- Paper in preparation



Preliminary proton spectrum obtained by MAGIC background data

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**Major Atmospheric** Gamma Imaging **Cerenkov Telescopes** 



# **Divination:** High redshift sources \*

- Farthest sources detected in VHE gamma rays are both FSRQs at a redshift of 0.9
- PKS 1441+25 z=0.939
- QSO B0218+357 (gravitational lens) z=0.944
- Important for EBL studies
- At the limit of the Gamma-ray horizon
- Remarkably the GRB 201216C is located at z=1.1!



AGN unification scheme by J.E. Thorne

\*See Francesco de Palma's talk tomorrow for the gravitational lensed blazar QSO B0218+357 (11:40 CEST Session 1 Gamma rays)

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# Divination: Transitional blazars

Blazars looking like BL Lac but presenting FSRQs characteristic. Challenging to be modelled. Very interesting!

#### S40954+56



#### A&A 617, A30 (2018)



Paper in preparation



### Transmutation: Extreme sources \*

-First definition by Costamante 2001 (A&A, 371, 51)

-EHBLs (extremely High Energy peaked BL Lacs)

- Synchrotron peak shifted towards high energies
- IC peak in the VHE gamma-ray range
- Expected to be very faint according to the blazar sequence
- Recently some of them, detected in the VHE gamma-ray range, have shown an intermittent nature making the hunt more intriguing
- A first systematic study of such very interesting objects has beer published recently by MAGIC (ApJ SS, 247, 16, (2020))
- Both leptonic and hadronic models are able to describe the observations at the cost of extreme parameters.

\*See Serena Loporchio's talk tomorrow at 10:20 CEST (Session 2, EGAL sources) and Axel Arbet-Engel's talk at 11:20 CEST (Session 2, EGAL sources)



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SED of 1ES2344+514, an "intermittent" EHBL (MNRAS 496, 3912 (2020))



## **Necromancy:** Dark Matter \*

Dark MAGIC is practised within many different projects:



- Dark Matter lines in the Galactic Center\*
- Dwarf spheroidal satellite galaxies observations
- Multi-dSphs combined analysis\*\*
- Galaxy clusters
- Axion like particles hunting

\*Talk today by Moritz Huetten 9:00 CEST Dark Matter session \*\*Talk today by Daniel Salazar 10:40 CEST Dark Matter session





- Detection of 2 GRBs and other 2 at the edge of detection: one of the goal of MAGIC from the beginning is now a reality!
- Quantum gravity has been probed with the GRB 190114C MAGIC lightcurve!
- The strategies of real-time follow-up of neutrino events have been successfully! Now we wait for the next neutrino blazar...
- The development of Sum-Trigger II allowed MAGIC to reach a lower threshold of only 15 GeV... Geminga pulsar has been detected and studied in a range of 15GeV-75 GeV and farthest AGNs are waiting to be detected!
- 18 years of observations...the magic is still here!



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### **Thanks for your attention!**





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Image Credit: Chiara Righi (@chirighi)

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