

Istituto Nazionale di Fisica Nucleare Sezione di Padova



Major Atmospheric Gamma Imaging

MAGIC

Cerenkov Telescope

The MAGIC experiment: results

and future prospects

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Outline

The MAGIC telescopes

Galactic science

- Pulsar physics
- Cas A
- Binaries

Extragalactic science

- Far away sources
- Multiwavelength campaigns
- Multimessenger studies

Fundamental physics

- DM Annihilation in dSph
- DM Decay in Perseus cluster
- Lorentz invariance & Tau neutrinos Future prospects



The MAGIC telescopes

The MAGIC Collaboration: 170 collaborators in 10 countries.
Stereo system of two Imaging Atmospheric Cherenkov telescopes (IACTs) (MAGIC-I 2004, MAGIC-II 2009).
17m diameter reflectors.
Light weight → fast movement to catch GRBs (20s/180°).
The telescopes were recently upgraded to homogenize the system.
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MAGIC Performance

Performances of upgraded system today:

Trigger threshold reduced to ~50 GeV (low zenith observations). Analysis threshold down to 70 GeV.

Energy resolution **15%-23%** below 10 TeV

Angular resolution **<0.07**° above 300 GeV

Sensitivity **0.6%** Crab Nebula flux in 50 hours

SCIENTIFIC HIGHLIGHTS

Disclaimer: Highlights from my personal taste!

GALACTIC SOURCES

SNRs

PWNe Binary systems Rubén López-Coto - 06/09/18

Pulsars

Crab Pulsar

J. Aleksić et al. (MAGIC Coll.), A&A. 540 (2012) 69

• Discovery of emission up to TeV energies (2016).

- MAGIC discovered pulsed gamma-ray emission above 25 GeV (Science, 2008, 322, 1221).
- VERITAS detected this emission above
 100 GeV (Science, 2011, 334, 69)
 MAGIC extended the spectrum up to 400
 GeV (A&A, 2012, 540, 69) and separately
 measured the spectrum of P1 and P2.

S. Ansoldi et al. (MAGIC Coll.), A&A, 585, A133 (2016) Rubén López-Coto - 06/09/18

Geminga pulsar

- 30 hours of observations using a new stereoscopic analogue trigger dubbed Sum Trigger-II
- Detection of P2 with a significance > 5σ
- Geminga is the third known pulsar in VHE gamma rays

Fermi-LAT phaseogram (E > 10 GeV)

(A couple of) VHE pulsar models

Cold ultrarelativistic wind

Aharonian, F. et al., Nature 482 (2012) 507

VHE gamma rays are produced inside the magnetosphere in an "outer gap"

It can explain the spectrum extending up to 400 GeV and also the bridge emission if the magnetic field also has a toroidal component.

It proposes that VHE gamma-rays are produced in the wind region.

Predicts bridge emission but broader peaks than observed.

Hirotani, K., ApJ, 733 (2011) L49 Hirotani, K., ApJ, 766 (2013) 98

- Longly thought to accelerate PeV protons.
- Spectrum shows a cut-off at a few TeV.
- The analysis made largely use of observations during moon-time conditions. M. Ahnen et al. (MAGIC Coll.), APh, 94, 29A (2017)

Binaries

- Cygnus X-1 has never shown any steady/flaring emission. M. Ahnen et al., MNRAS, 472, 3 (2017)
- V404 Cygni -> Inefficient acceleration in the jets.
 M. Ahnen et al., MNRAS, 472, 3 (2017)
 We do not see SS 433/W50 (although HAWC does see it, but at higher energies).
 M. Ahnen et al., A&A, 612, A14 (2018).

Dec (J2000)

EXTRAGALACTIC SOURCES

Low energy = Look further

- MAGIC is designed to have the lowest possible energy threshold
- This implies that it can observe further objects at an energy range less affected by the Extragalactic Background Light
- MAGIC holds the distance record for VHE gamma-ray detections!

Blazar	Redshift	Discover	Year
B0218+35	0.944	MAGIC	2014
PKS 1441+25	0.939	MAGIC	2015
TON 599	0.725	MAGIC	2017
PKS 1424+240	>0.6	VERITAS	2009
3C 279	0.536	MAGIC	2006
1ES 0033+113	0.467	MAGIC	2016
PKS 1222+216 (4C +21.35)	0.432	MAGIC	2010
PG 1553+113	>0.4	MAGIC/ HESS	2005
S4 0954+65*	0.368	MAGIC	2015
PKS 1510-089	0.361	HESS	2009

Gravitational lensed blazar

- QSO B0218+357 is a blazar that underwent a series of flares separated 11.5 days, interpreted as due to the gravitationally lensed effect
- Detection of a flare by MAGIC at the expected time of arrival of the Fermi gravitationally lensed component
- z=0.944 → breaking distance records: the most distance source ever detected at VHE

M. Ahnen et al., A&A, 595, A98 (2016)

Multi-wavelength

Balokovic, M. et al., ApJ, 819, 156 (2016).

 Yearly monitoring campaigns on sources as Mrk 421, Mrk 501

 MW studies of sources with extremely fast variability as IC 310

Multi-messenger

Gravitational Waves: MoU between MAGIC and LIGO/VIRGO and follow ups currently performed

• NS-NS merger missed because we were in the wrong hemisphere!

Neutrinos: Detection of TXS 0506+056, the blazar coincident with

IC-170922A

TXS 0656+056

- Chance coincidence: ~3σ (space + flux enhancement)
- Can neutrinos be produced efficiently by BL Lac objects?

MAGIC: First observation with ~32 h delay (Sep 24th 2017). (Sep 28th - Oct 4th) -> Detection above 90 GeV.

Multi-messenger spectrum

FUNDAMENTAL PHYSICS

DM Annihilation

UMA II

- Distance 30 kpc
- log10(J-factor) ~ 19.42

Segue 1

- The most dark matter dominated object known at that moment
- Distance 23 kpc
- 158 hours of observations

Aleksic et al. JCAP 1210 (2012) 032

DM Annihilation

Combined Fermi+MAGIC upper limits

DM limits between 10 GeV and 100 TeV

Combination lowers the limits in the range of ~hundreds of GeV

DM Decay in the Perseus Cluster

- Distance 77.7 Mpc
- log10(J-factor) ~ 19.1
- Limits derived using ~200 hours of observation

Other searches

Limits on the flux of tau neutrinos from 1 PeV to 3 EeV with the MAGIC telescopes MAGIC Collaboration (M.L. Ahnen (ETH, Zurich (main)) *et al.*). May 7, 2018. 14 pp. e-Print: <u>arXiv:1805.02750</u> [astro-ph.IM] | PDF

• See talk by M. Manganaro (yesterday!)

Constraining Lorentz invariance violation using the Crab Pulsar emission observed up to TeV energies by MAGIC

MAGIC Collaboration (M.L. Ahnen (ETH, Zurich (main)) et al.). Sep 1, 2017. 17 pp. Published in Astrophys.J.Suppl. 232 (2017) no.1, 9

- Low energy threshold provided by Sum Trigger-II
- Still some years of operation with a very low energy threshold

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15Ē

10

5

about 47 Ge\

100 MMcEvt.fEnergy

Open call for proposals

- A part of the MAGIC observation program will be devoted for external proposals.
- The next observing cycle spans from January 2019 to February 2020
- Go to https://magic.mpp.mpg.de/outsiders/ magicop/ for details.

Summary

- After 15 years, MAGIC keeps doing great science despite the substantial effort devoted to CTA!
 - Very active collaboration: New groups added every year.
- Doing the best Science as ever.
 - Deep observations on classical targets.
 - New sources still being discovered.
- MAGIC entered the Multi-messenger business as a big player.

Backup

Mrk 421

Shift to lower energies by more than one order of magnitude

DM in perseus

Decay limits compared to Fermi, VERITAS and previous MAGIC observations