Detection of VHE γ rays by MAGIC from a direction consistent with IceCube-170922A

Elisa Bernardini, Konstancja Satalecka, **Luca Foffano**,
Michele Peresano, Elisa Prandini, Abelardo Moralejo
Wrijupan Bhattacharyya, Fabrizio Tavecchio, Susumu Inoue
for the MAGIC collaboration
https://magic.mpp.mpg.de

JPS, Tokyo
March 23rd, 2018

Luca Foffano
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Overview

- Very high energy astrophysics with MAGIC telescopes
- EHE-170922A follow-up observations: the MAGIC history
- MAGIC detection of TXS 0506+056
- Discussion and conclusions

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Very high energy astrophysics with

MAGIC telescopes

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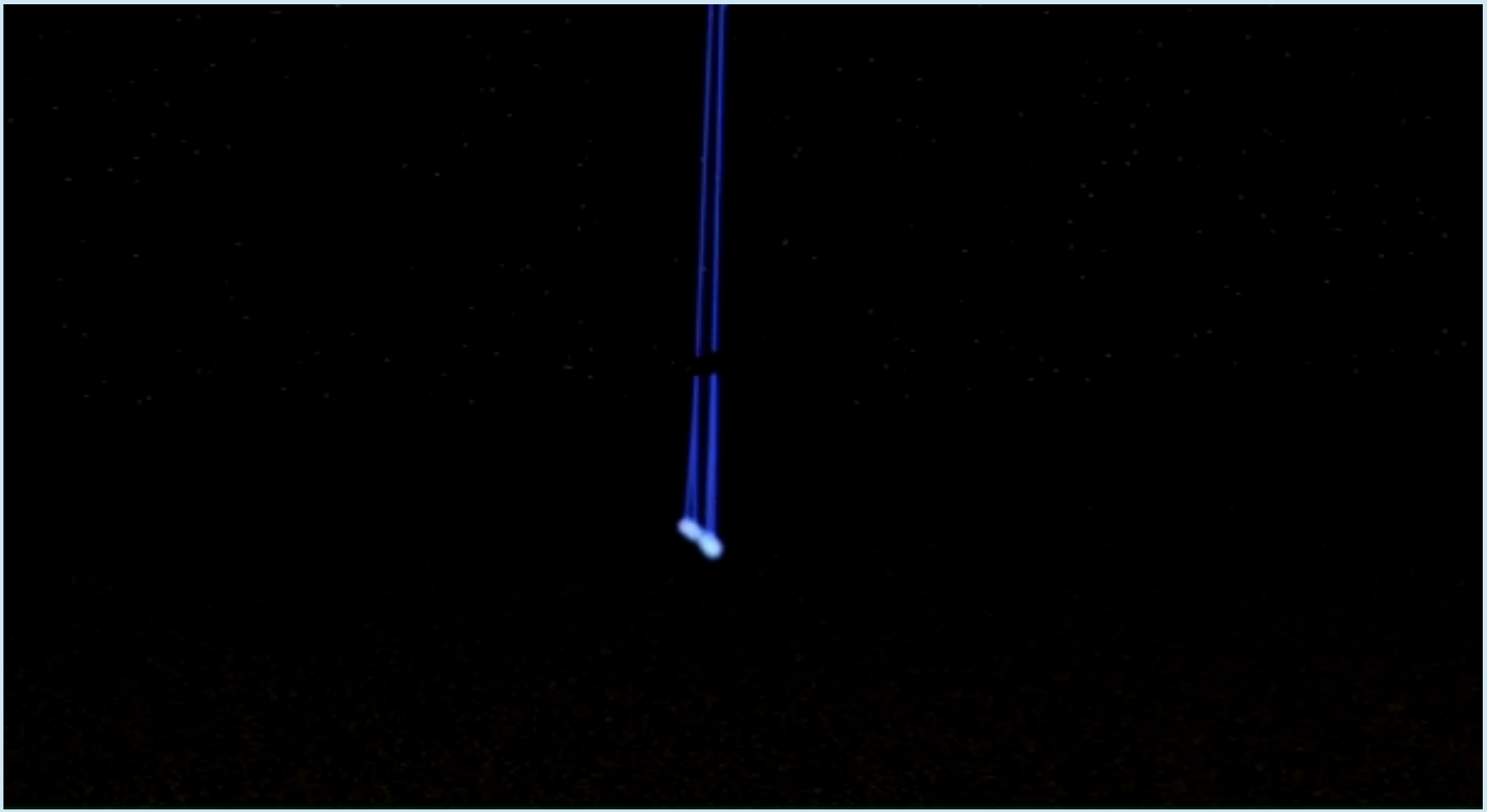
Cherenkov telescopes



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MAGIC Collaboration

Major IACTs in the world

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IACT

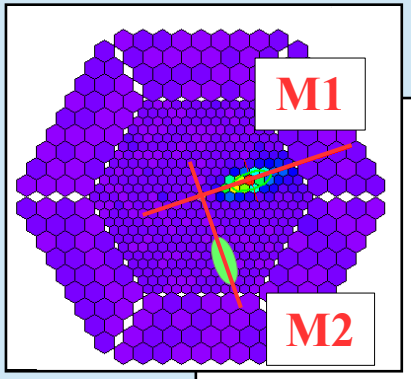
The idea

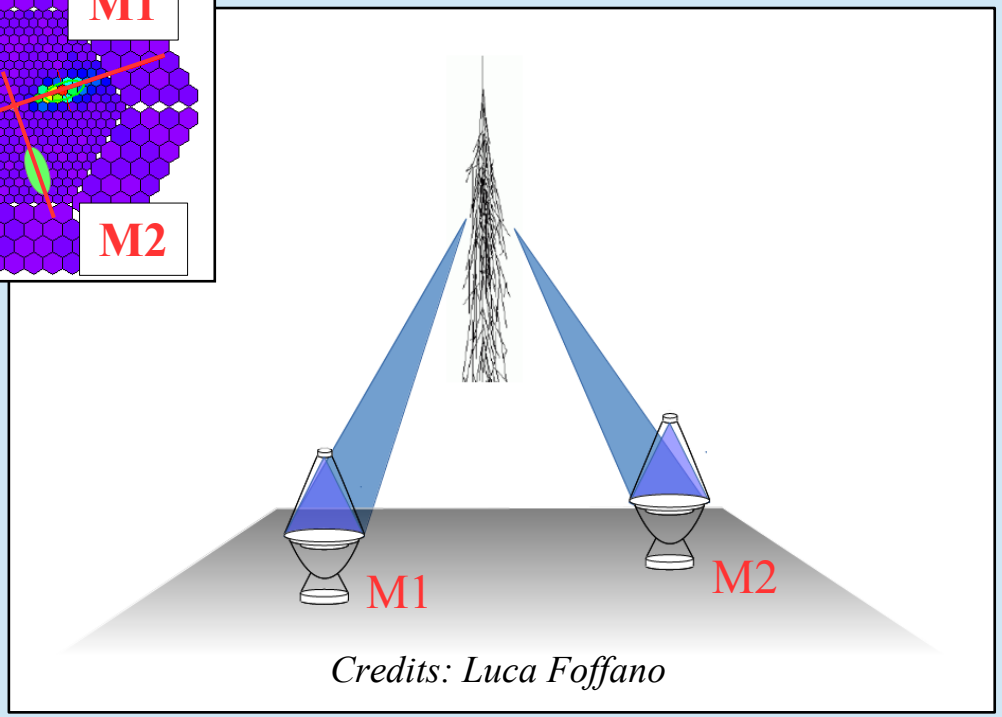
Imaging

Atmospheric

Cherenkov

Telescopes





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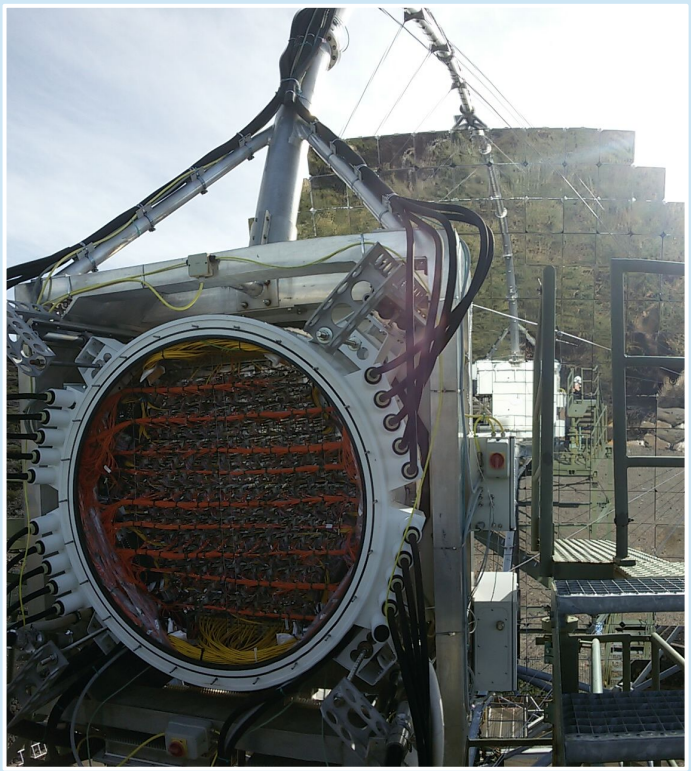
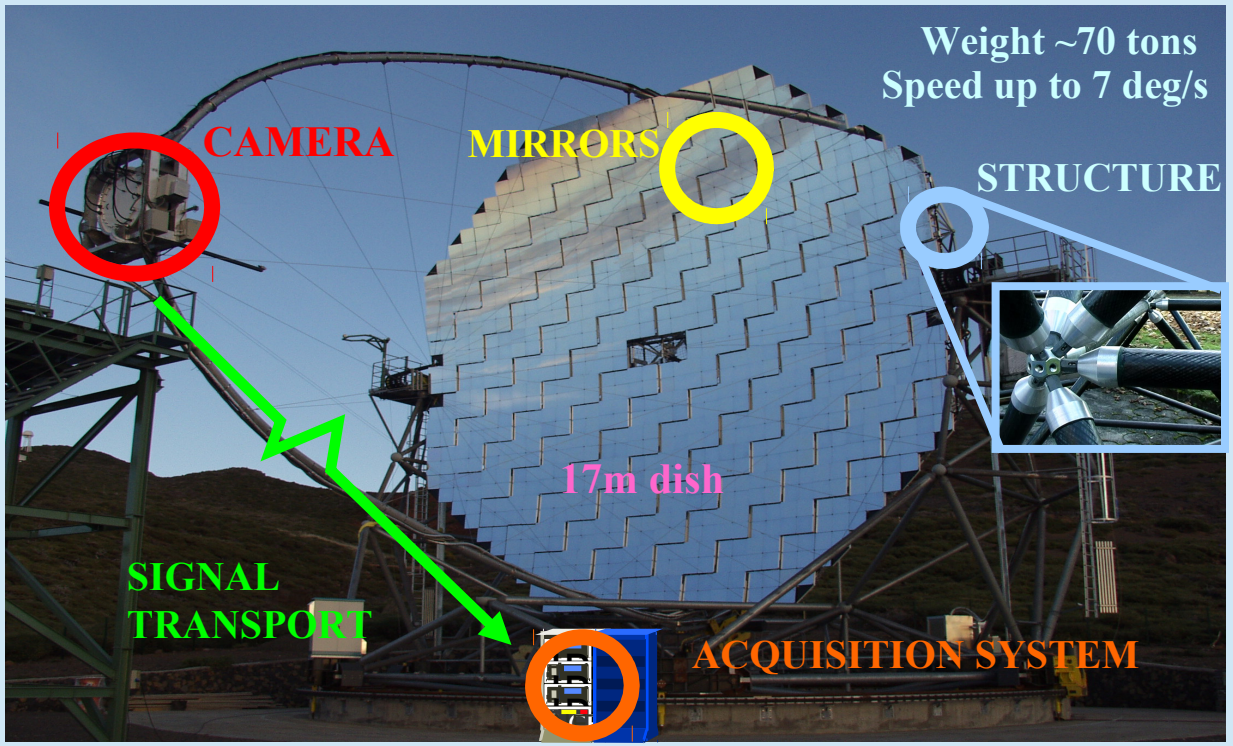
MAGIC telescopes





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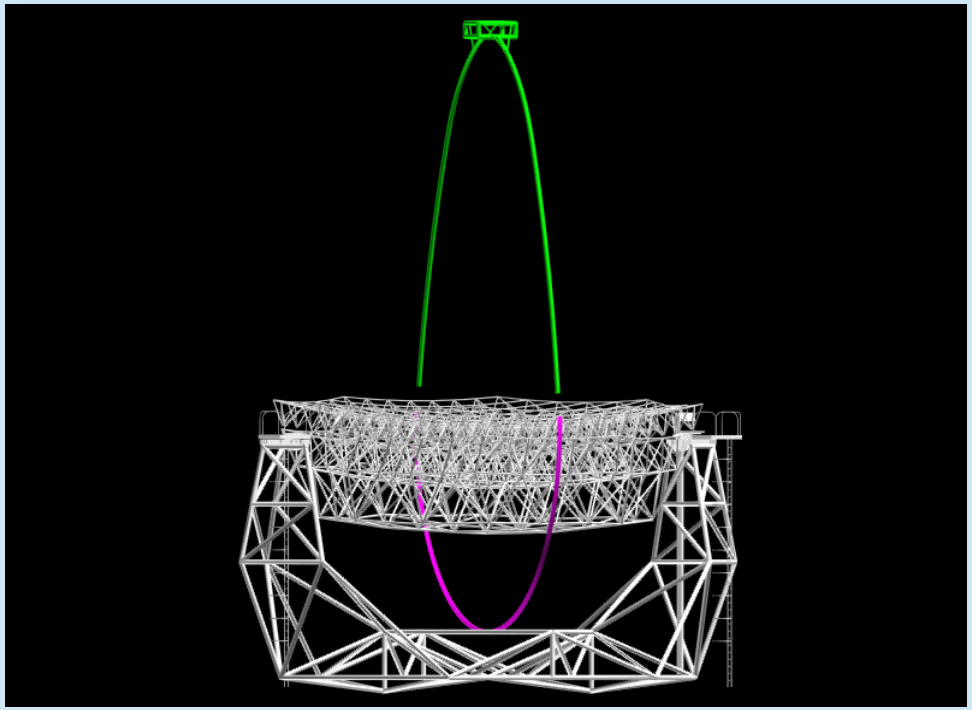
MAGIC telescopes

moving fast!



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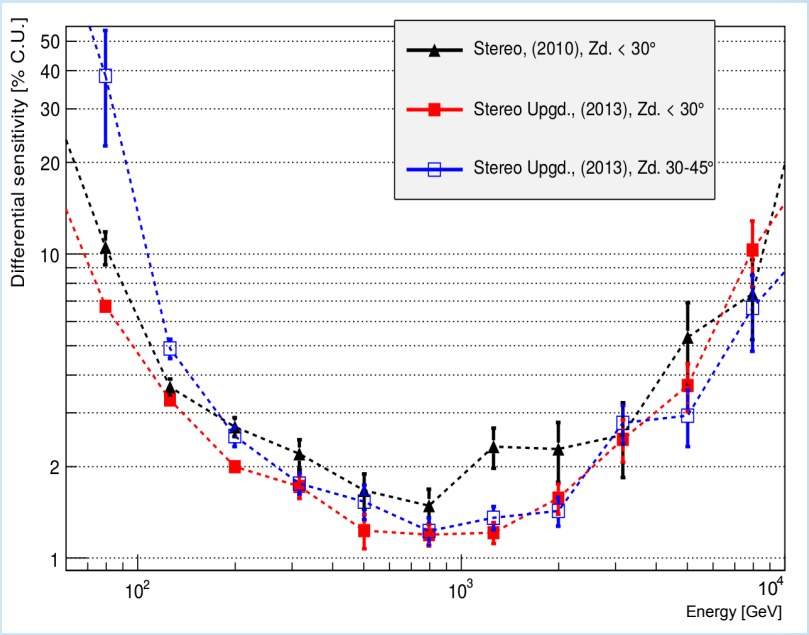
MAGIC telescopes



- Energy range from ~50 GeV to ~50 TeV
- Energy resolution ~20%
- Field of view of about 3.5°
- Angular Resolution ~0.1°
- Integral sensitivity (5 σ in 50 hours) ~ 0.6% CU > 250 GeV of Crab Nebula VHE flux

→ *"The major upgrade of the MAGIC telescopes, Part II: A performance study using observations of the Crab Nebula" Astroparticle Physics – arxiv 1409.5594*

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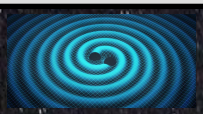
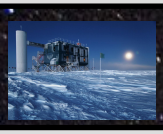
GRBs

FRB follow-up obs

Transient sources



GW follow-up obs



Blazars

Supernova remnants

Neutrino follow-up obs

Pulsar

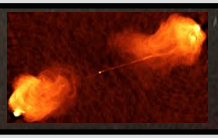
X-ray binaries

Unidentified objects

.?

Starburst galaxies

Galaxy clusters



Dwarf galaxies

Radio galaxies

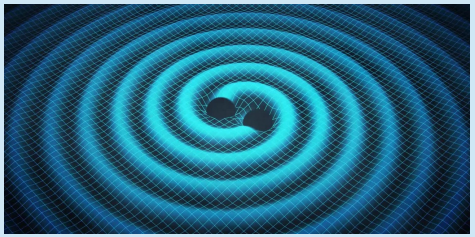
MAGIC observational program

MAGIC Transient follow-up

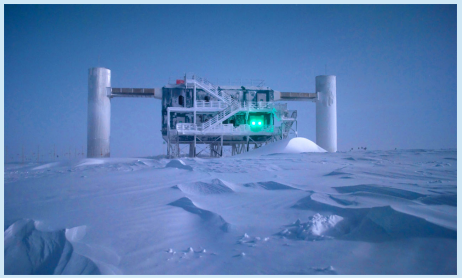
- **Gamma Ray Bursts (GRB)**
- Each year 50h reserved
- ~ 100 GRBs observed so far
- Prompt follow-up and late-time observations
- Hint of signal in short GRB 160821B at z=0.16 (paper in preparation)

- **Neutrinos**

- **Gravitational Waves (GW)**
- Joined the LIGO/Virgo call for identification and follow-up in 2014
- Several alerts observed
- Prompt follow-up and dedicated analysis in preparation



- **Fast Radio Burst (FRB)**
- MWL observations since 2016 of repeating FRB121102



Each year about 15% of total observation time
Automatic alert system

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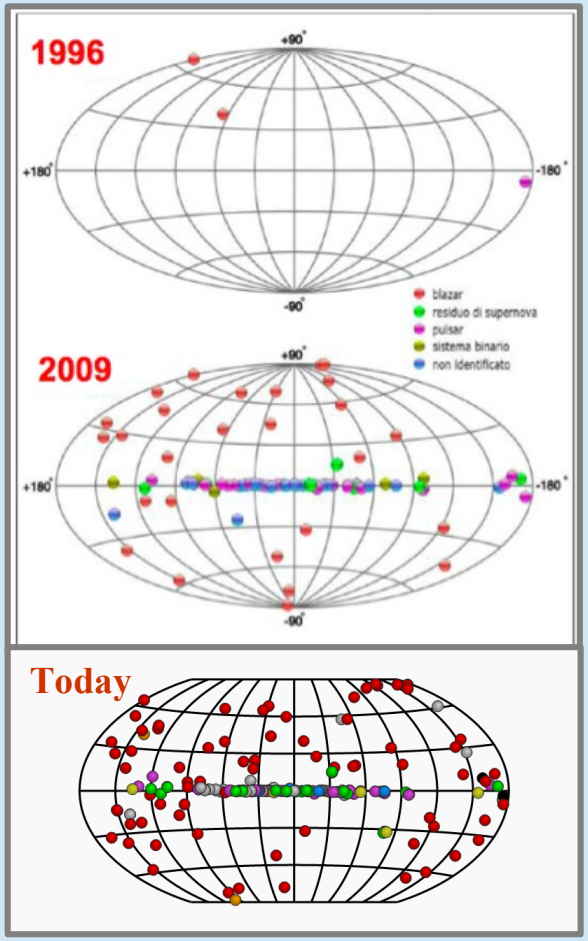
MAGIC telescopes
and the VHE sky



Credits: http://tevcat.uchicago.edu/

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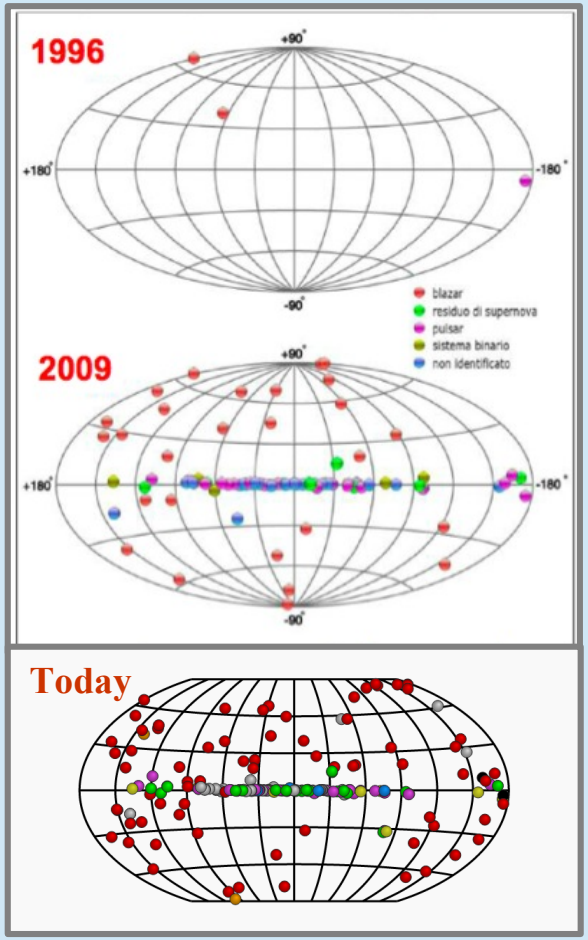
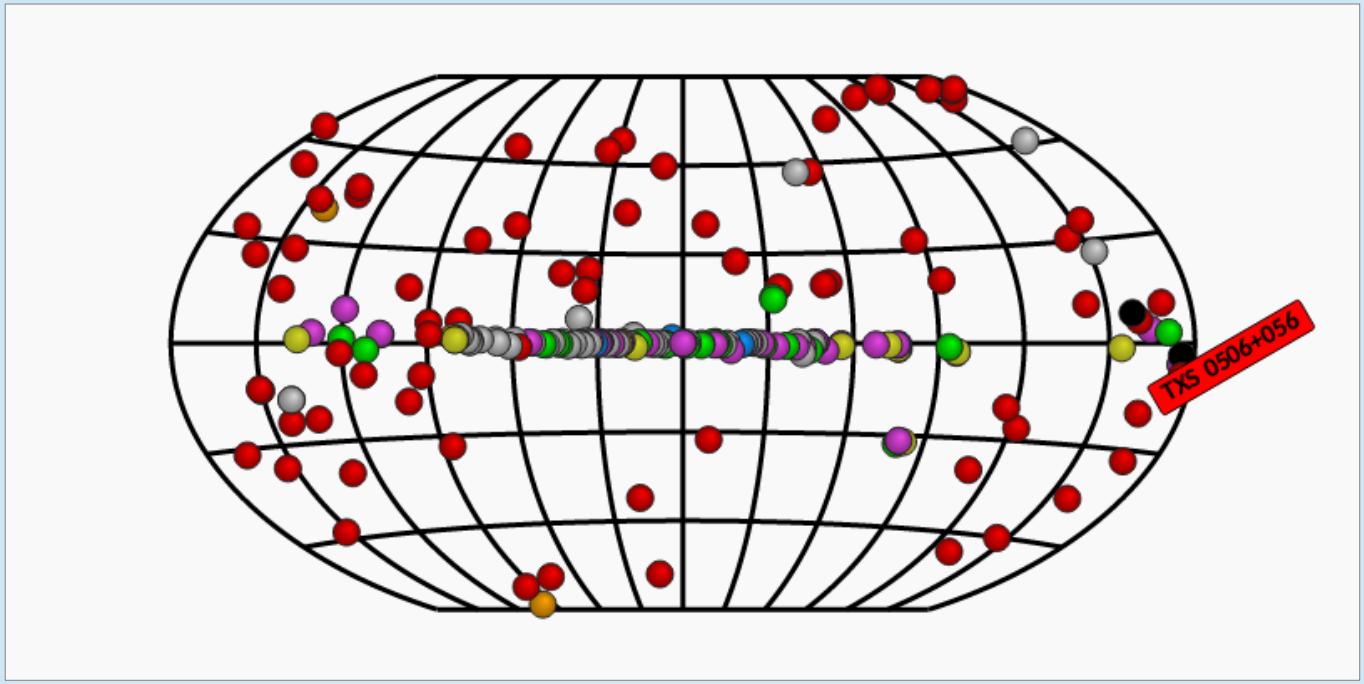


Credits: http://tevcat.uchicago.edu/



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EHE-170922A follow-up observations: the MAGIC history

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University of Padova, Italy

September 22nd

43 s after event

Original neutrino alert

```
////////////////////////////////////////

TITLE:              GCN/AMON NOTICE
NOTICE_DATE:        Fri 22 Sep 17 20:55:13 UT
NOTICE_TYPE:        AMON ICECUBE EHE
[...]
SRC_RA:              77.2853d {+05h 09m 08s}
SRC_DEC:             +5.7517d {+05d 45' 06"}
[...]
SRC_ERROR:          14.99 [arcmin radius,
                    stat+sys, 50% containment]
[...]
DISCOVERY_TIME:     75270 SOD {20:54:30.43} UT
N_EVENTS:           1 [number of neutrinos]
[...]
ENERGY :            1.1998e+02 [TeV]
SIGNALNESS:         5.6507e-01 [dn]
CHARGE:             5784.9552 [pe]
[...]
```


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MAGIC Collaboration

September 22nd

43 s after event

Original neutrino alert

```
////////////////////////////////////////////

TITLE:              GCN/AMON NOTICE
NOTICE_DATE:        Fri 22 Sep 17 20:55:13 UT
NOTICE_TYPE:        AMON ICECUBE EHE
[...]
SRC_RA:              77.285[d [=05h 09m 08s]
SRC_DEC:             +5.751
[...]
SRC_ERROR:          14.99 [
                    stat+sy
[...]
DISCOVERY_TIME:     75270 S
N_EVENTS:           1 [numb
[...]
ENERGY :            1.1998e
SIGNALNESS:         5.6507e
CHARGE:             5784.95
[...]
```

September 22nd

Trying to trigger observations… BAD WEATHER

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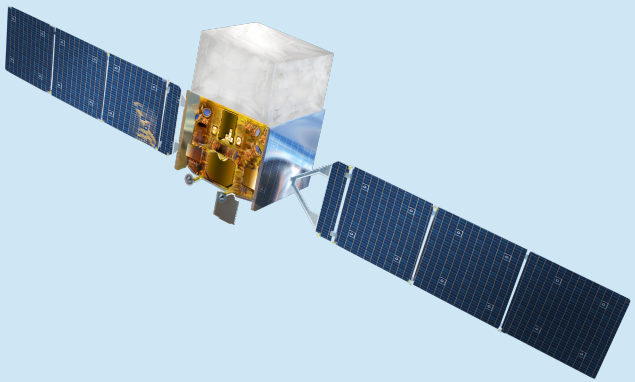
September 27th

Fermi-LAT flare alert

- Fermi-LAT Collaboration followed-up the IceCube-170922 error circle
- They found that TXS 0506+056 was showing brightening in GeV band
- Hard spectrum in HE band → ask for triggering VHE observations



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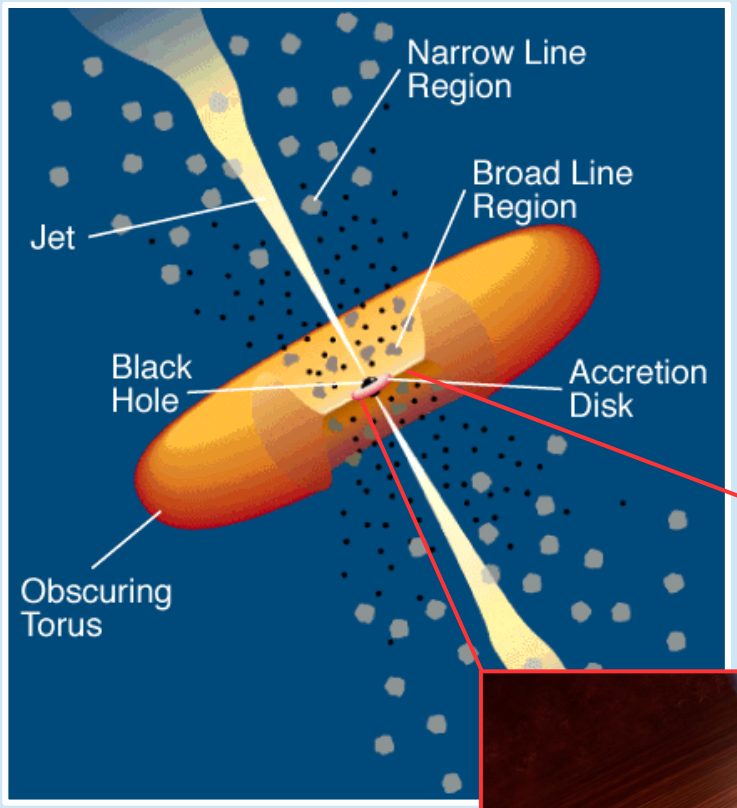
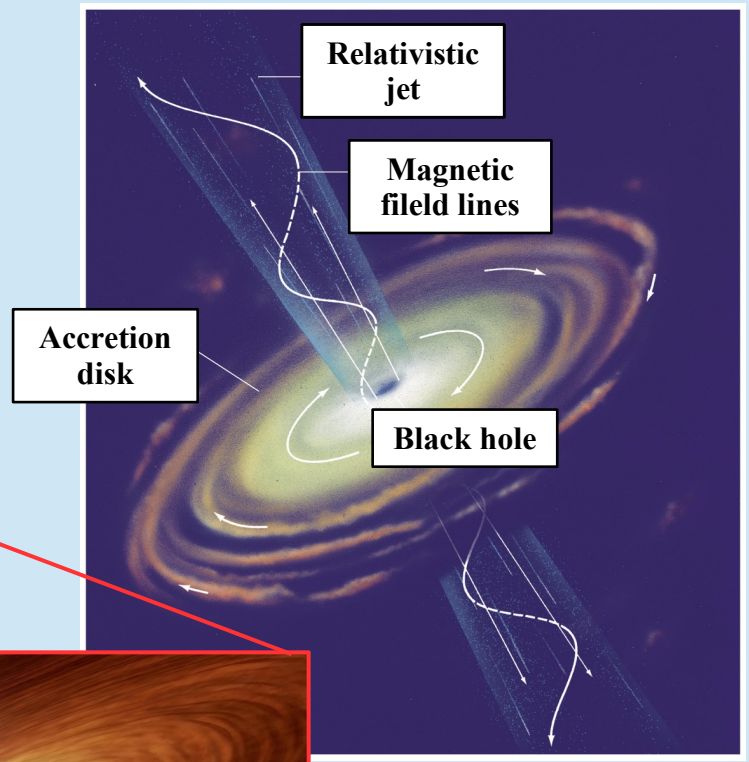
TXS 0506+056





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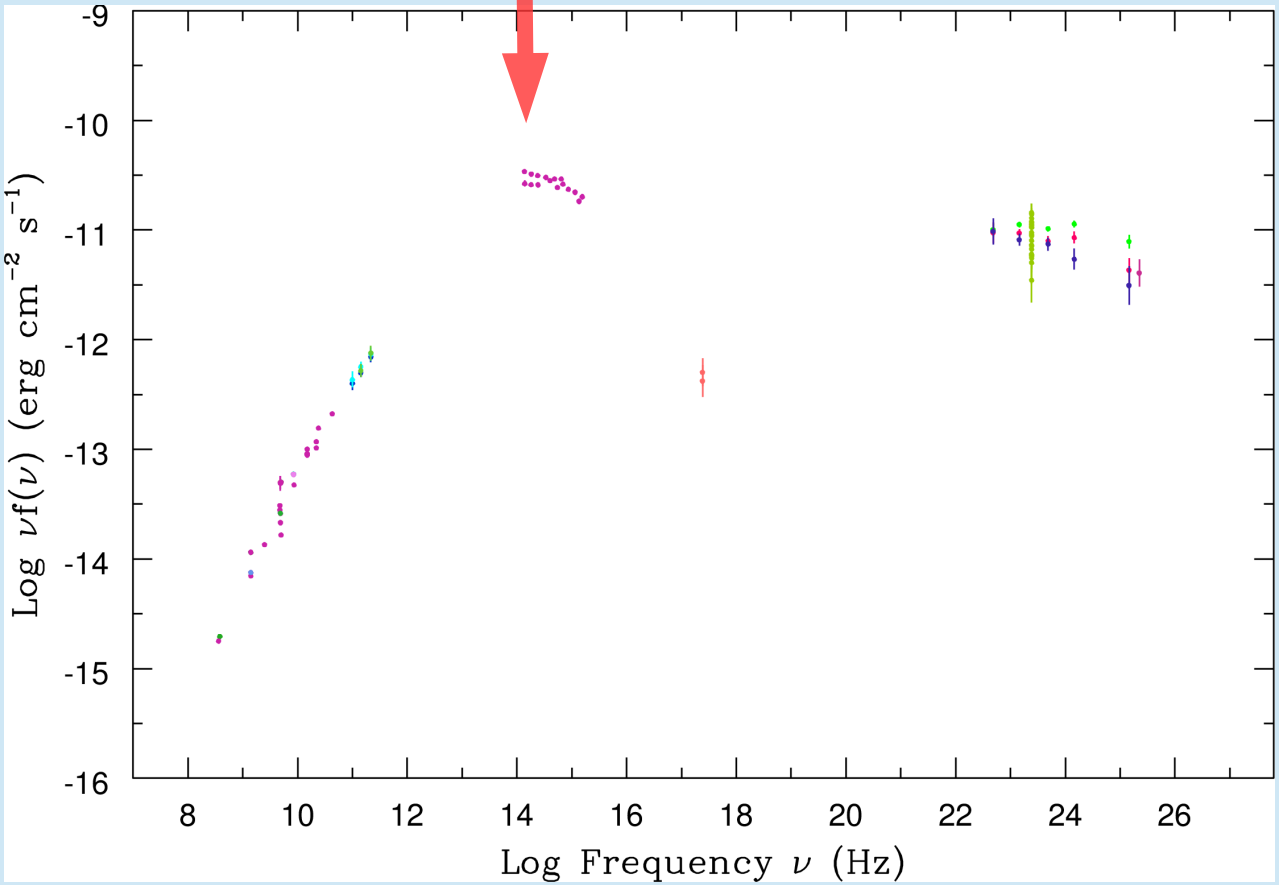
TXS 0506+056



Archival data (SSDC website)

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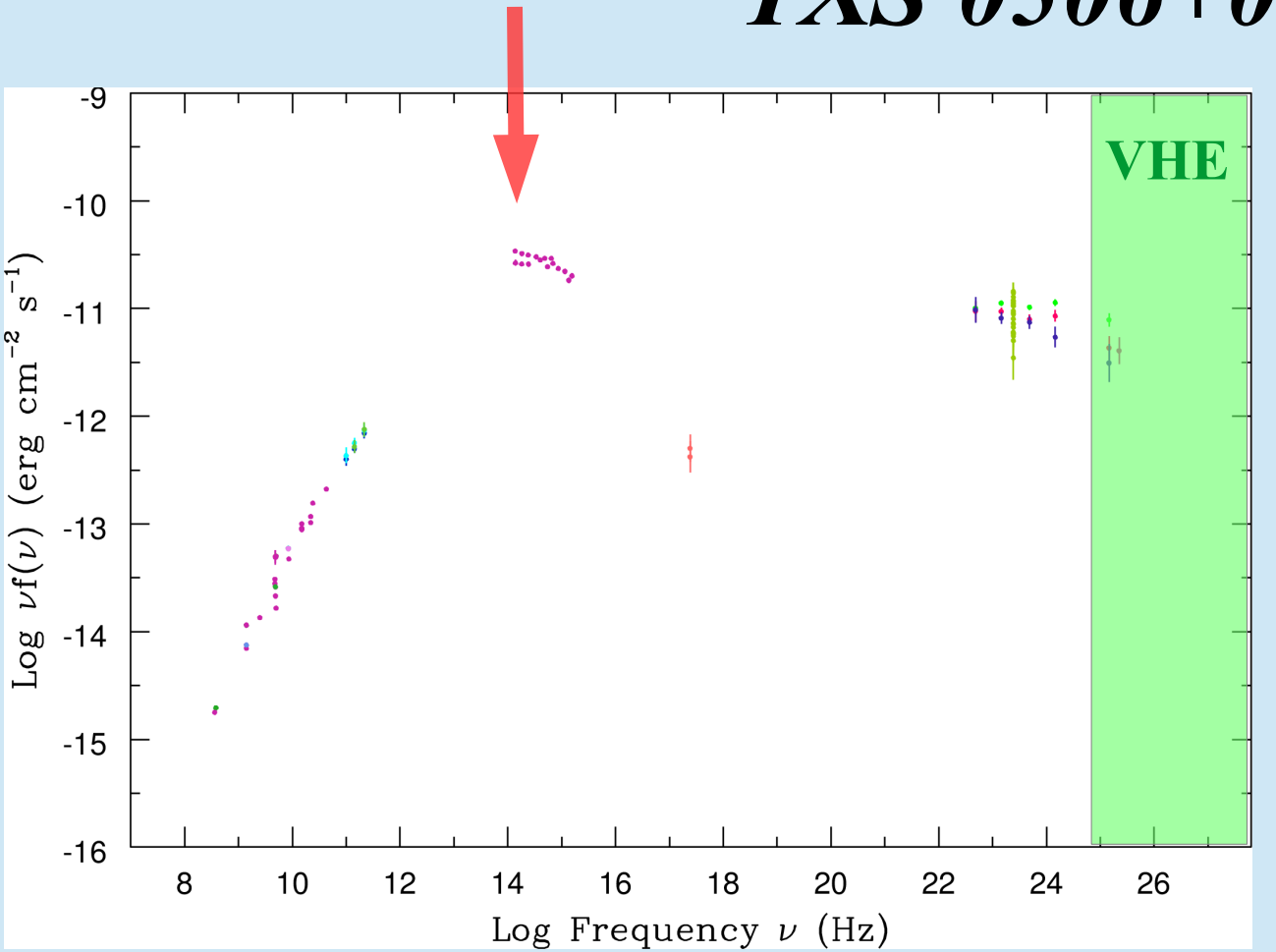
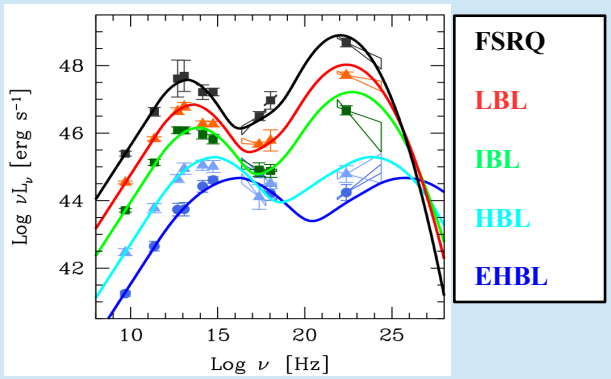
TXS 0506+056



Archival data (SSDC website)



Ref.: Fossati et al 1998

TXS 0506+056 shows a synchrotron peak around 10^{14} Hz
→ classified as **LBL/IBL**

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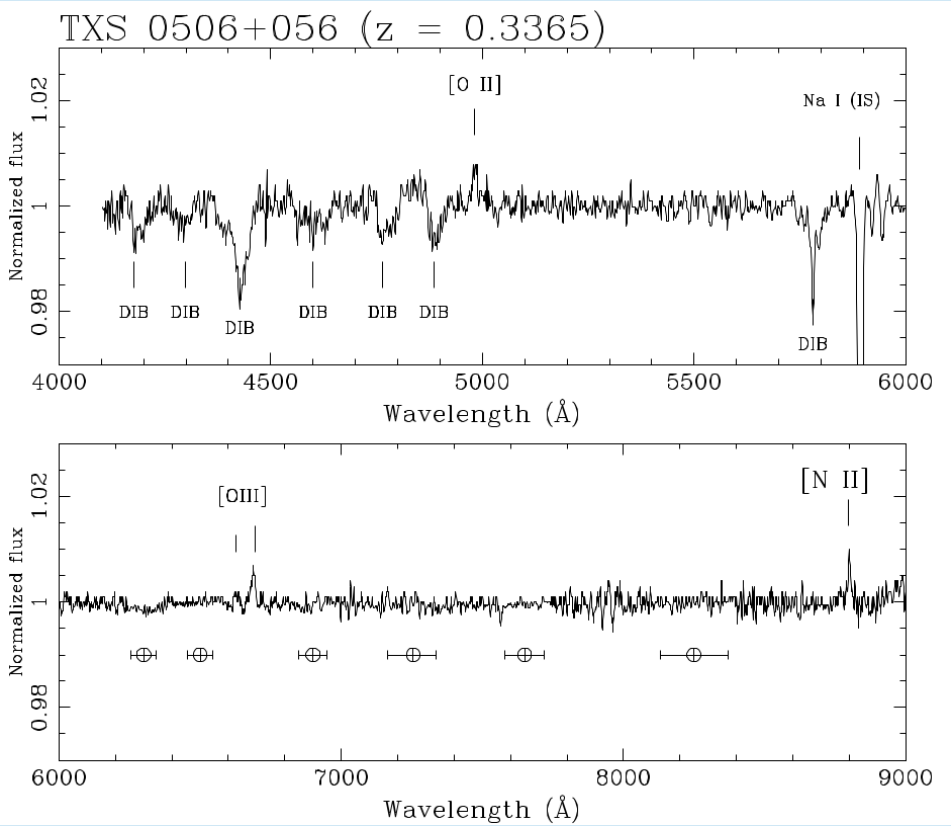
TXS 0506+056
redshift estimation



A special observational campaign with GTC optical telescopes in La Palma island, led to report:

"We obtained an unprecedented high S/N spectrum of the BL Lac object TXS 0506+056, that it is the likely counterpart of the IceCube neutrino event.
On the basis of three faint emission lines, we found the redshift is "

z = 0.3365 ± 0.0010

Simona Paiano et al. 2018
Accepted for publication in ApJ

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MAGIC Collaboration

EHE follow-up observations from telescopes all over the world

Fermi-LAT detection of increased gamma-ray activity of TXS 0506+056, located inside the IceCube-170922A error region.

ATel #10791; *Yasuyuki T. Tanaka (Hiroshima University), Sara Buson (NASA/GSFC), Daniel Kocevski (NASA/MSFC) on behalf of the Fermi-LAT collaboration*
on 28 Sep 2017; 10:10 UT

H.E.S.S. follow-up of IceCube-170922A

ATel #10787; *Mathieu de Naurois for the H. E.S. S. collaboration*
on 27 Sep 2017; 14:33 UT

HAWC gamma ray data prior to IceCube-170922A

ATel #10802; *Israel Martinez, Ignacio Taboada, Michelle Hui and Robert Lauer for the HAWC collaboration*
on 30 Sep 2017; 02:10 UT

VERITAS follow-up observations of IceCube neutrino event 170922A

ATel #10833; *Reshmi Mukherjee*
on 9 Oct 2017; 22:32 UT

AGILE confirmation of gamma-ray activity from the IceCube-170922A error region

ATel #10801; *F. Lucarelli (SSDC/ASI and INAF/OAR), G. Piano (INAF/IAPS), C. Pittori, F. Verrecchia (SSDC/ASI and INAF/OAR), M. Tavani (INAF/IAPS, and Univ. Roma Tor Vergata), A. Bulgarelli (INAF/IASF-Bo), P. Munar-Adrover, G. Minervini, A. Ursi (INAF/IAPS), S. Vercellone (INAF/OA-Brera), I. Donnarumma (ASI), V. Fioretti, A. Zoli (INAF/IASF-Bo), E. Striani (CIFS and INAF/IAPS), M. Cardillo (INAF/OA-Arcetri and INAF/IAPS), F. Gianotti, M. Trifoglio (INAF/IASF-Bo), A. Giuliani, S. Mereghetti, P. Caraveo, F. Perotti (INAF/IASF-Mi), A. Chen (Wits University), A. Argan, E. Costa, E. Del Monte, Y. Evangelista, M. Feroci, F. Lazzarotto, I. Lapshov, L. Pacciani, P. Soffitta, S. Sabatini, V. Vittorini (INAF/IAPS), G. Pucella, M. Rapisarda (ENEA-Frascati), G. Di Cocco, F. Fuschino, M. Galli, C. Labanti, M. Marisaldi (INAF/IASF-Bo), A. Pellizzoni, M. Pilia, A. Trois (INAF/OA-Cagliari), G. Barbiellini, E. Vallazza (INFN Trieste), F. Longo (Univ. Trieste and INFN Trieste), A. Morselli, P. Picozza (INFN and Univ. Roma Tor Vergata), M. Prest (Univ. dell'Insubria), P. Lipari, D. Zanello (INFN and Univ. Roma Sapienza), P. W. Cattaneo, A. Rappoldi (INFN Pavia), S. Colafrancesco (INAF/OAR and Wits University), N. Parmiggiani (University of Modena and Reggio Emilia), A. Ferrari (Univ. Torino and CIFS), F. Paoletti (East Windsor RSD Hightstown and INAF/IAPS), A. Antonelli (SSDC/ASI), P. Giommi, L. Salotti, G. Valentini, and F. D'Amico (ASI)*
on 29 Sep 2017; 15:41 UT

Joint Swift XRT and NuSTAR Observations of TXS 0506+056

ATel #10845; *D. B. Fox (PSU), J. J. DeLaunay (PSU), A. Keivani (PSU), P. A. Evans (U. Leicester), C. F. Turley (PSU), J. A. Kennea (PSU), D. F. Cowen (PSU), J. P. Osborne (U. Leicester), M. Santander (UA) & F. E. Marshall (GSFC)*
on 12 Oct 2017; 16:54 UT

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MAGIC detection of TXS 0506+056

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MAGIC detection

First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A

ATel #10817; ***Razmik Mirzoyan for the MAGIC Collaboration***
on ***4 Oct 2017; 17:17 UT***
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Optical, Gamma Ray, >GeV, TeV, VHE, UHE, Neutrinos, AGN, Blazar

Referred to by ATel #: 10830, 10833, 10838, 10840, 10844, 10845, 10942

Tweet Recommend 448

After the IceCube neutrino event EHE 170922A detected on 22/09/2017 (GCN circular #21916), Fermi-LAT measured enhanced gamma-ray emission from the blazar TXS 0506+056 (05 09 25.96370, +05 41 35.3279 (J2000), [Lani et al., Astron. J., 139, 1695-1712 (2010)]), located 6 arcmin from the EHE 170922A estimated direction (ATel #10791). MAGIC observed this source under good weather conditions and a 5 sigma detection above 100 GeV was achieved after 12 h of observations from September 28th till October 3rd. This is the first time that VHE gamma rays are measured from a direction consistent with a detected neutrino event. Several follow up observations from other observatories have been reported in ATels: #10773, #10787, #10791, #10792, #10794, #10799, #10801, GCN: #21941, #21930, #21924, #21923, #21917, #21916. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) E. Bernardini (elisa.bernardini@desy.de), K.Satalecka (konstancja.satalecka@desy.de). 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.

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University of Padova, Italy

Discussion and conclusions

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Discussion

Several questions arising after TXS 0506+056 detection

- **TXS 0506+056** is the likely **counterpart** of the IceCube **EHE-170922A** neutrino event
  → a new multi-messenger correlation?

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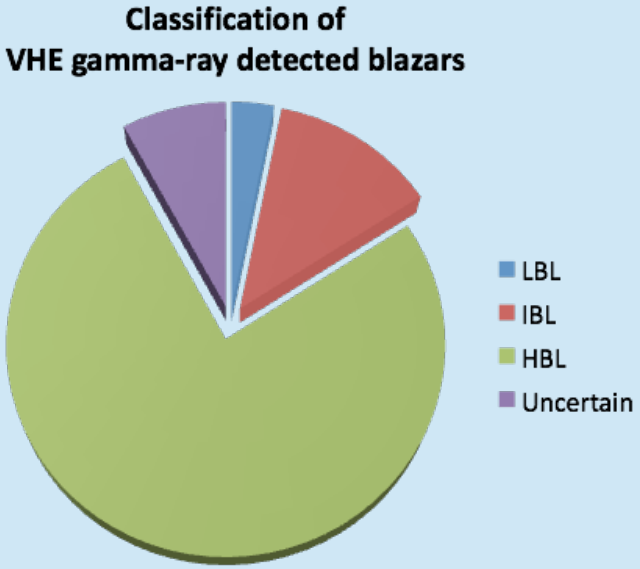
University of Padova, Italy

Discussion

Several questions arising after TXS 0506+056 detection

- **TXS 0506+056** is the likely **counterpart** of the IceCube **EHE-170922A** neutrino event
  → a new multi-messenger correlation?
- Detected at VHE by MAGIC (one of the **few VHE-detected IBLs**)
  → important info for modelers



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Discussion

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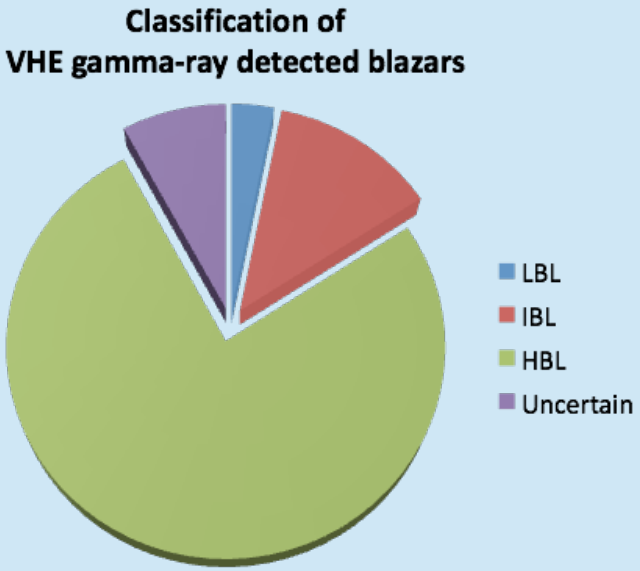
  → a new multi-messenger correlation?
- Detected at VHE by MAGIC (one of the **few VHE-detected IBLs**)
  → important info for modelers
- Can neutrinos be produced efficiently by BL Lac objects?
- - MWL SED appears predominantly leptonic: potential **hadronic** contributions?
- - Evidence of proton acceleration: can it be a source of **UHECRs**?
  → Constraints from MWL SED including VHE



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Conclusions

- Very **exciting** results!!!
- Source **variable** in VHE γ-rays
- **First detection** of VHE emission in coincidence with neutrino alert!
- Stay tuned for the upcoming publications:

  - further observations (light curve, spectrum, MWL information)
  - theoretical interpretation (multi-messenger modeling, implications for blazar physics and UHECRs, etc)

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Conclusions

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Thank you!

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