FACULTY OF PHYSICS
AND APPLIED
INFORMATICS
University of Lodz

New results from MAGIC

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

https://magic.mpp.mpg.de

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for MAGIC Collaboration

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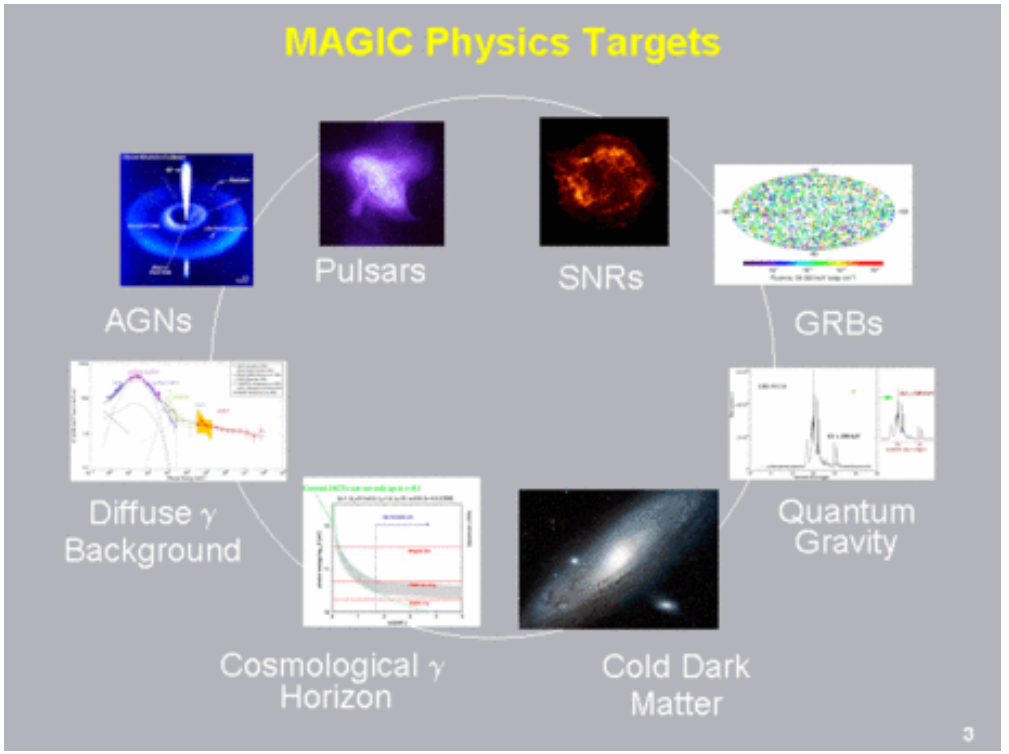
„Astrofizyka czastek w Polsce 2017”
Kraków 22.09.2017

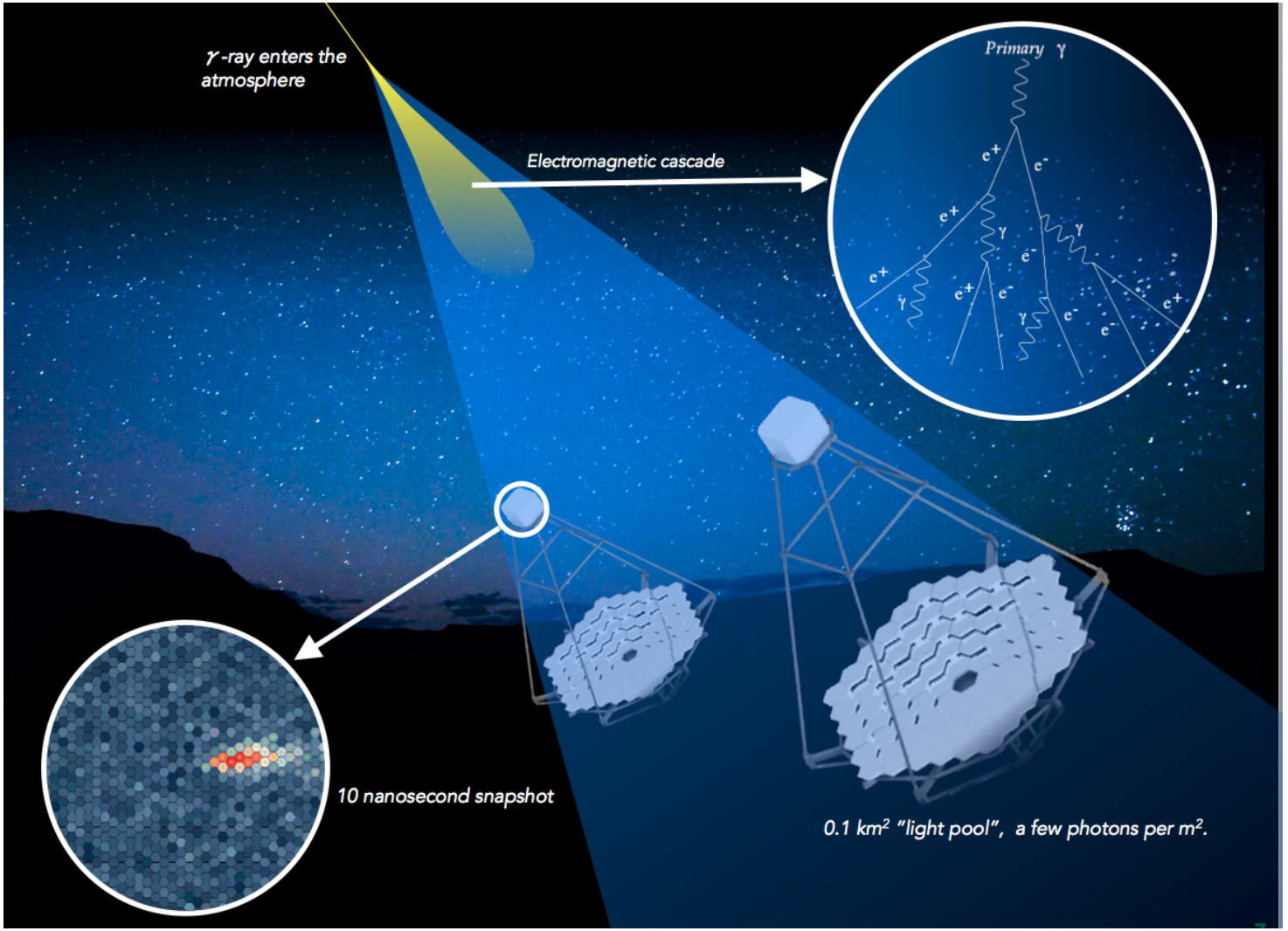
Outline

1) Imaging Air Cherenkov Technique
2) MAGIC Telescopes
3) Galactic sources
4) Extragalactic sources
5) Cosmology and fundamental physics
6) Summary



https://magic.mpp.mpg.de/newcomers/physics-goals/

Imaging Air Cherenkov Technique (IACT)



https://www.cta-observatory.org/about/how-cta-works/

MAGIC Telescopes

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

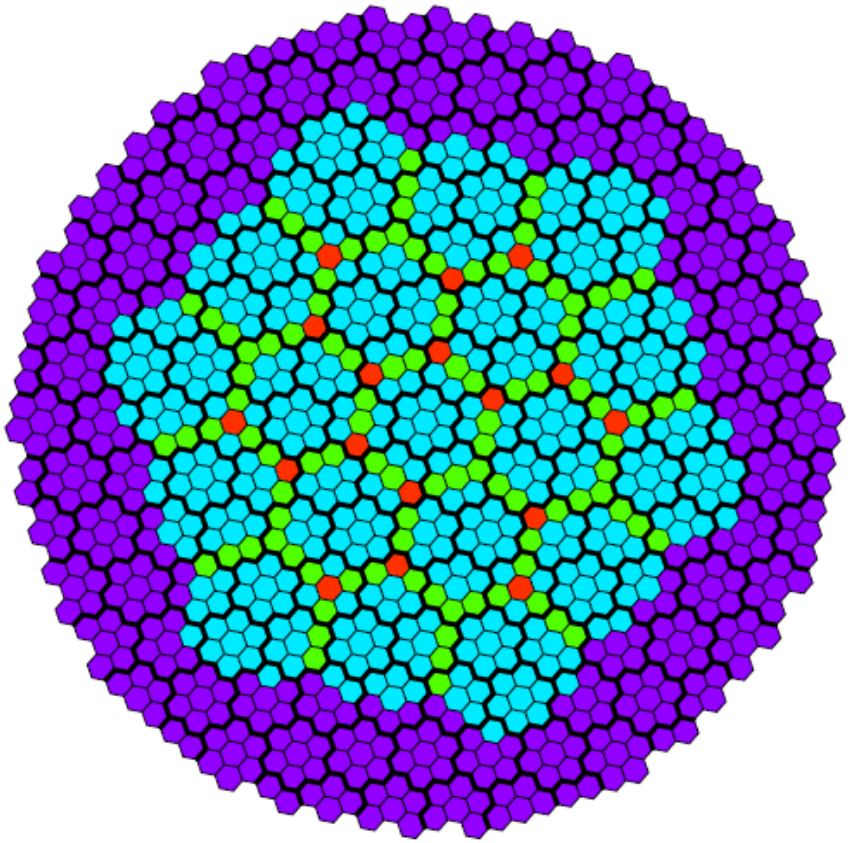
- Observatory is located in La Palma, Canary Island
- MAGIC-I in operation since 2004, MAGIC-II (stereo mode) since 2009

170 scientists from 10 countries across Europe & Asia & South America

MAGIC Telescopes

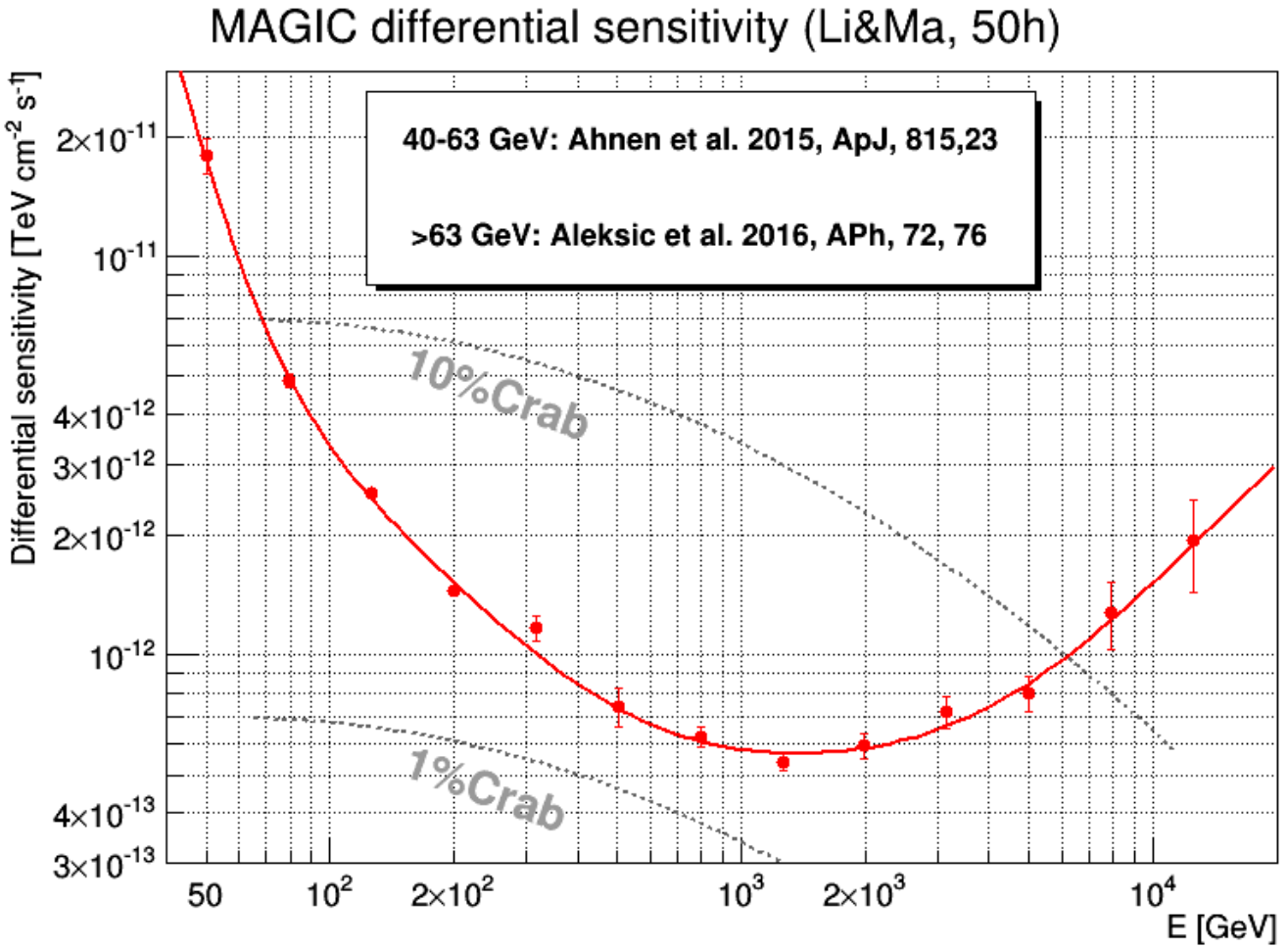
- Two parabolical telescopes (focal lenght 17m)
- Reflection area of 240 m^2 (each)
- Light-weight: ~ 70 t each
- Re-positioning speed: 7 deg/s ➡ prompt response to transients

MAGIC Telescopes



- Camera: total FoV 3.5° (1039 classical PMT's), trigger area of 4.3 deg^2
- Energy range: ~50 GeV – 50 TeV (for standard trigger conditions) ➡ low E threshold perfect for distant sources
- Energy resolution: 15% (@1TeV) – 23% (@100 GeV)
- Angular resolution: 0.06 deg @ 1TeV – 0.1 @100 GeV
- Special trigger so-called Sum Trigger ➡ energy from 30 GeV
- Fast Readout : 1.6 GSamples/s

Sensitivity curve



https://magic.mpp.mpg.de

Integrated sensitivity: ~ 0.66% Crab (5σ in 50h above 220 GeV)

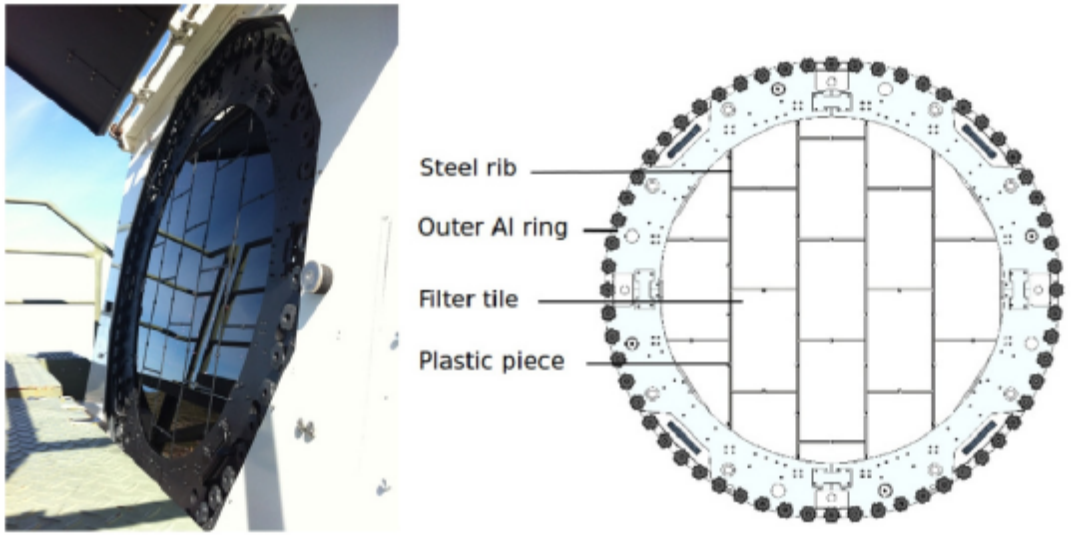
Performance under moonlight

More Night Sky Background (NSB) photons during a presence of the moonlight ➡

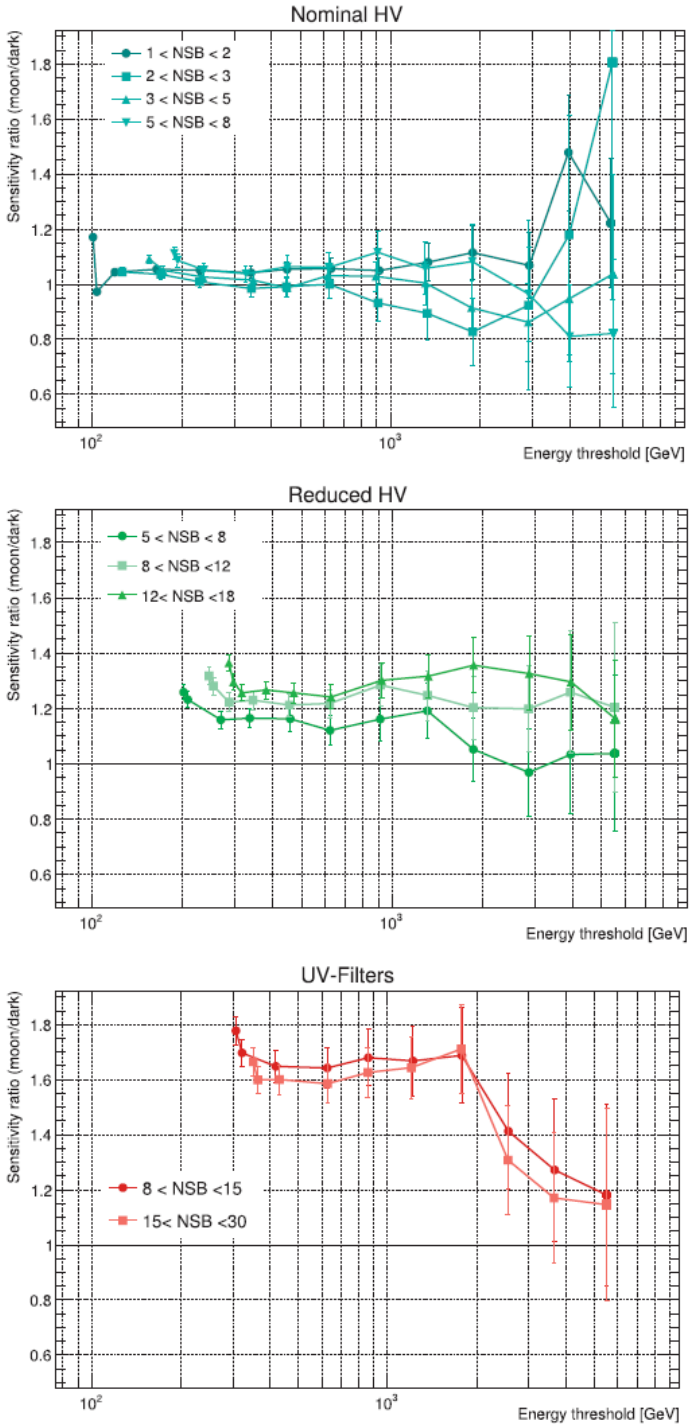
- more phe registered by all PMT ➡ higher cleaning level required
- possibility of damages of PMT for high Moon

Three scenarios of observations during moonlight

- With nominal setting for: NSB < ~8 NSB_{Dark}
- Reduced HV for: ~5 NSB_{Dark} < NSB < ~8 NSB_{Dark}
- Using UV-pass filter for: ~8 NSB_{Dark} < NSB < ~30 NSB_{Dark}



Ahnen et al., Astroparticle Physics 94, 29 (2017)



Special analysys (dedicated MC simulations for Reduced HV and UV-pass filter, higher cleaning level for all moon data)

For moonlight observation the energy threshold is increasing from 70 GeV (dark) to 300 GeV (NSB ~ 30xNSB_{Dark})

The angular resolution is not affected

Crab spectrum was reproduced

Sensitivity nearly not affected, except of the strongest moon conditionse

The duty cycle can be extended for the observation under moonligh condition (~40% more time to monitor sources, ToO project, etc.)

Ahnen et al., APh 94, 29 (2017)

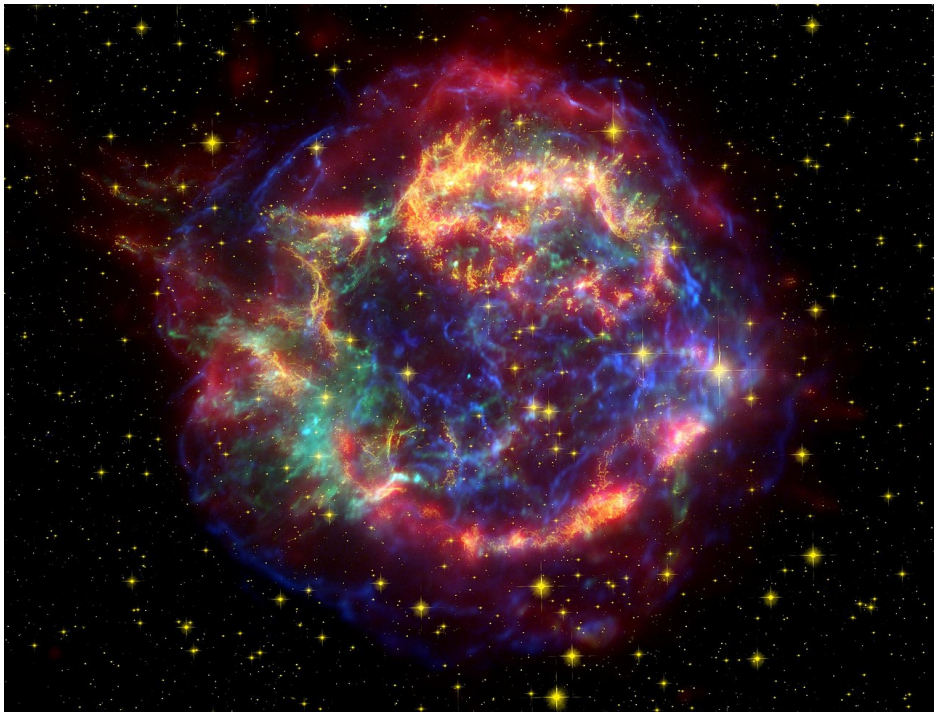
Galactic sources

In this talk:

- Supernova remnants (SNR)
- Pulsars
- Galactic Center
- Binary Systems

Cassiopeia A

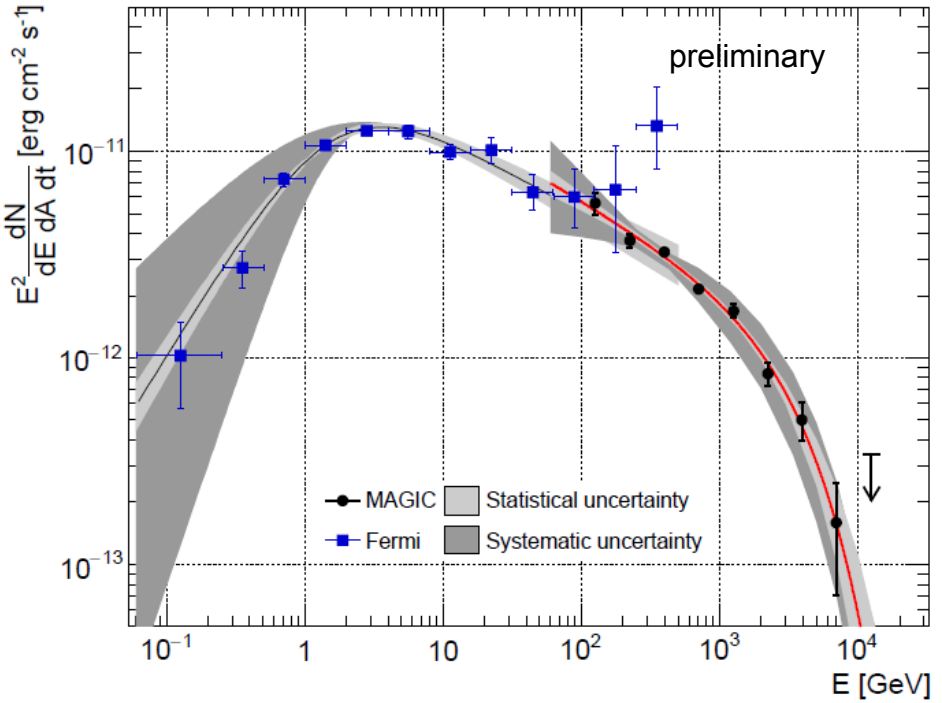
- Known TeV source (since 2001)
- Cas A is/was pevatron canditate. SNR's are supposed to be a Cosmic Ray sources up to the knee region.
- If so the simply power law spectrum was expected.
- MAGIC data (between 2014 and 2016) almost 160 h of the observations

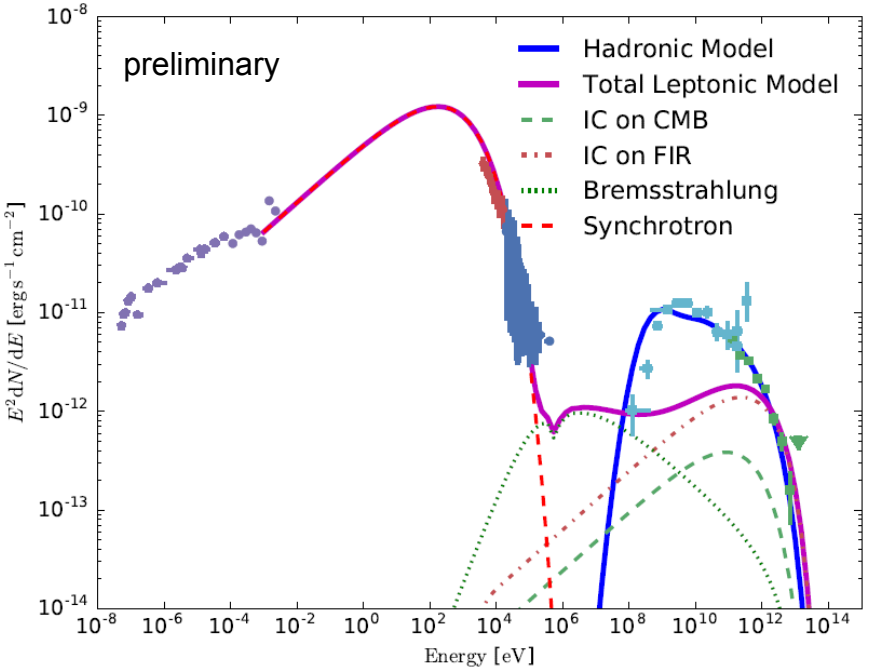


Ahnen et al., arXiv:1707.01583 submitted to MNRAS

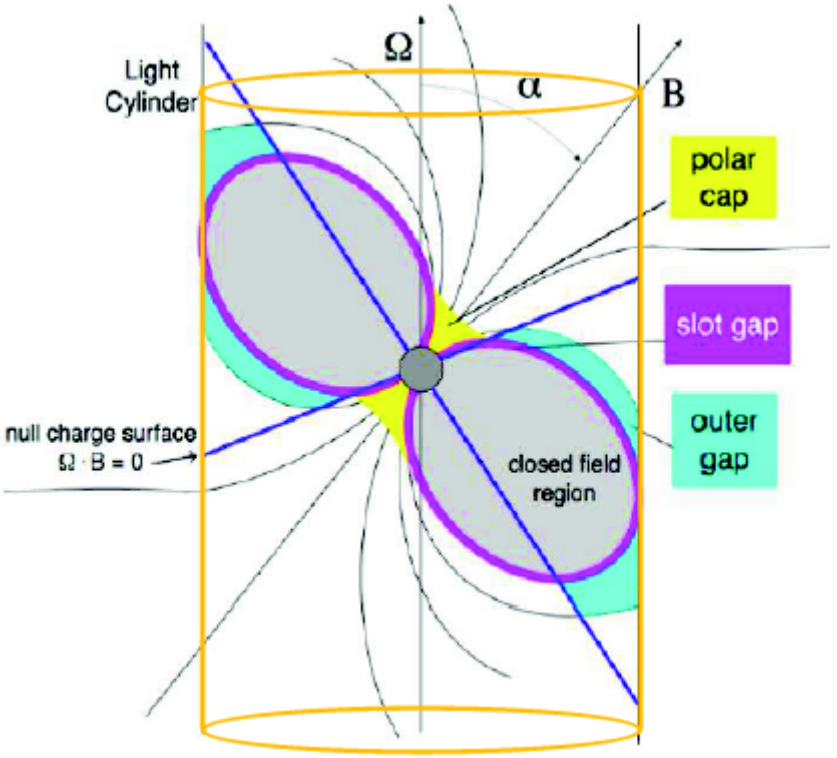
Cassiopeia A

- Results from Ahnen et al., arXiv:1707.01583 submitted to MNRAS
- Spectral Energy distribution (SED) up to 8 TeV – best fit of the MAGIC data: power law with exponetial cut-off (at 3.5 TeV)
- Cas A can not accelarate hadrons up to PeV energies – can not be a Pevatron
- Fitting a multiwavelenght SED led to the conclusion that in GeV – TeV region photons have to be produced in hadronic model





Ahnen et al., arXiv:1707.01583 submitted to MNRAS



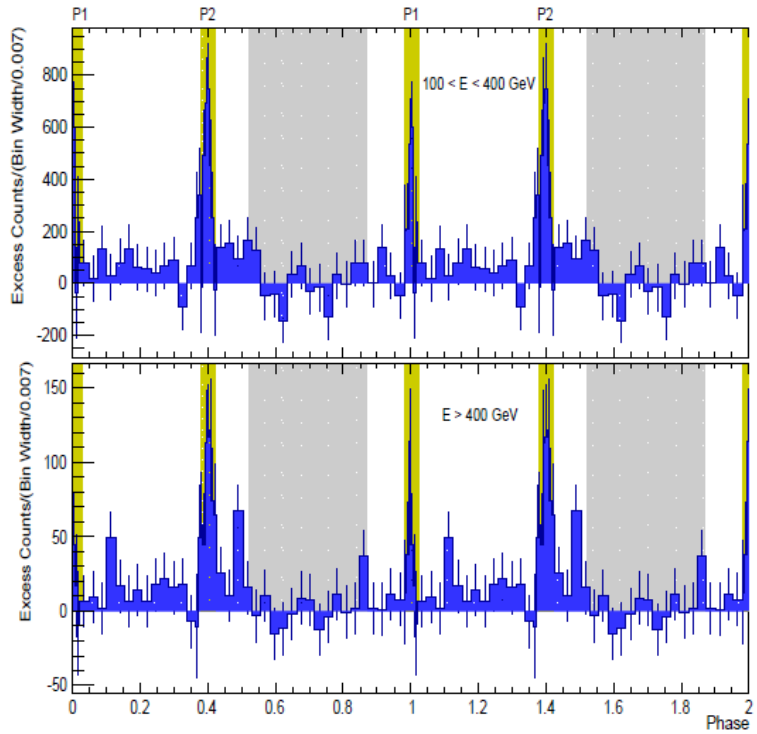
Lopez M. et al. ICRC20217

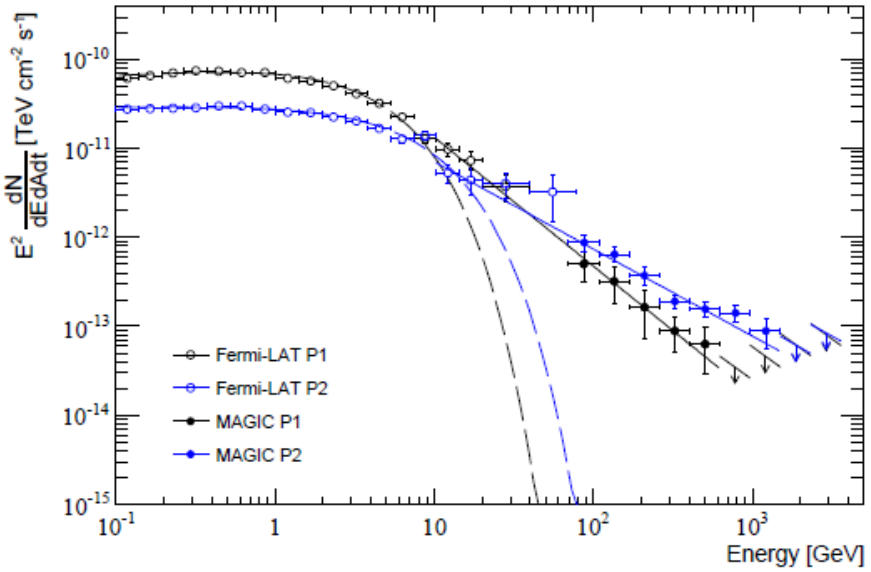
Pulsar Crab

Known pulsar in radio, optical, X-rays and γ-rays at low energies

MAGIC results in 2008 – pulsed emission above 25 GeV

The spectrum presented in 2012 extended up to 400 GeV





Ansoldi et al.,A&A 582, A133 (2016)

Pulsar Crab

Results from Ansoldi et al.,A&A 582, A133 (2016) -

8 years of data – 320 h (standard trigger)

Detection of both peaks

- P1 up to 0.6 TeV
- P2 up to 1.5 TeV
- Both peaks can be well fitted using power law function
- Synchrotron curvature ruled out
- Likely emisssion in TeV via IC in outer magnetosphere
- At the moment no model can fully explain pulsed emission in TeV energy range!

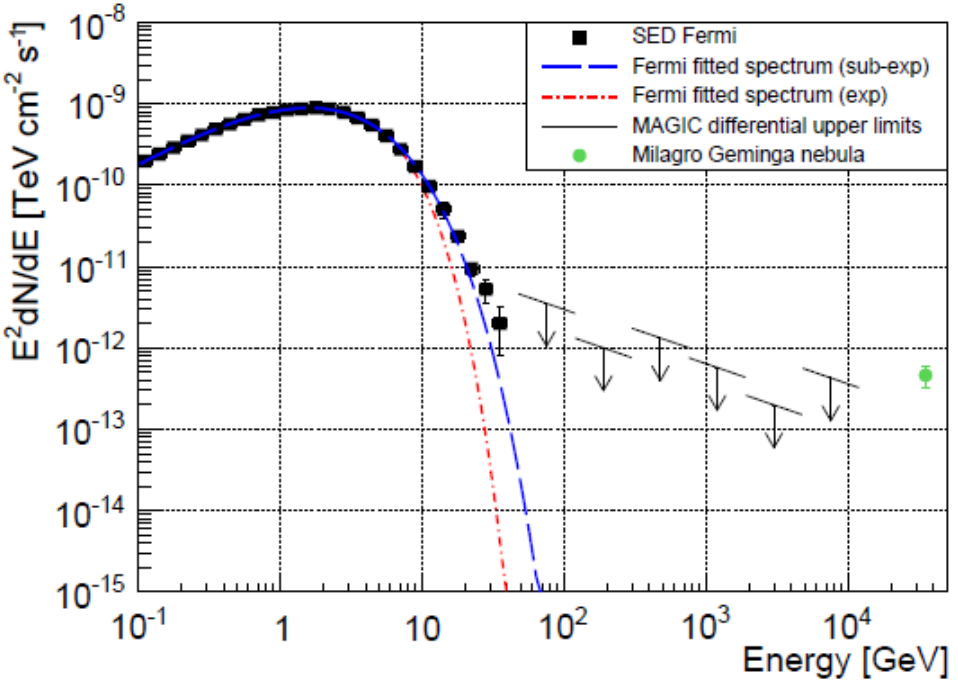
Pulsars

Geminga

Results from Ahnen et al., A&A 591, A138 (2016)

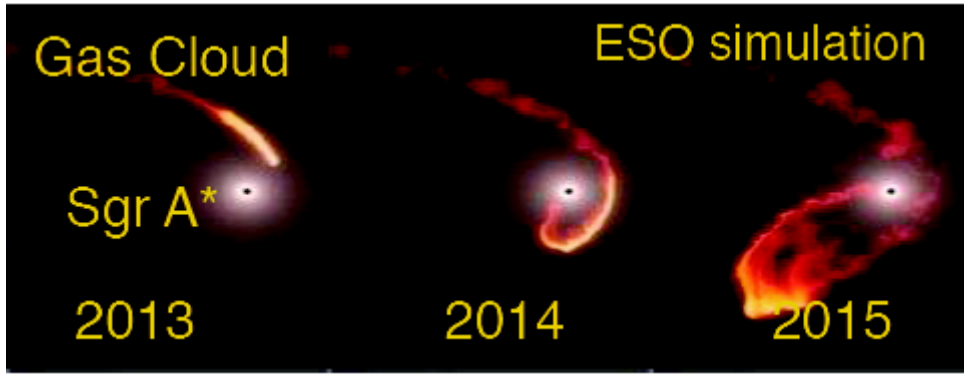
~75 h of data - no significant detection of pulsed emission

Upper limits for the emission from Nebula

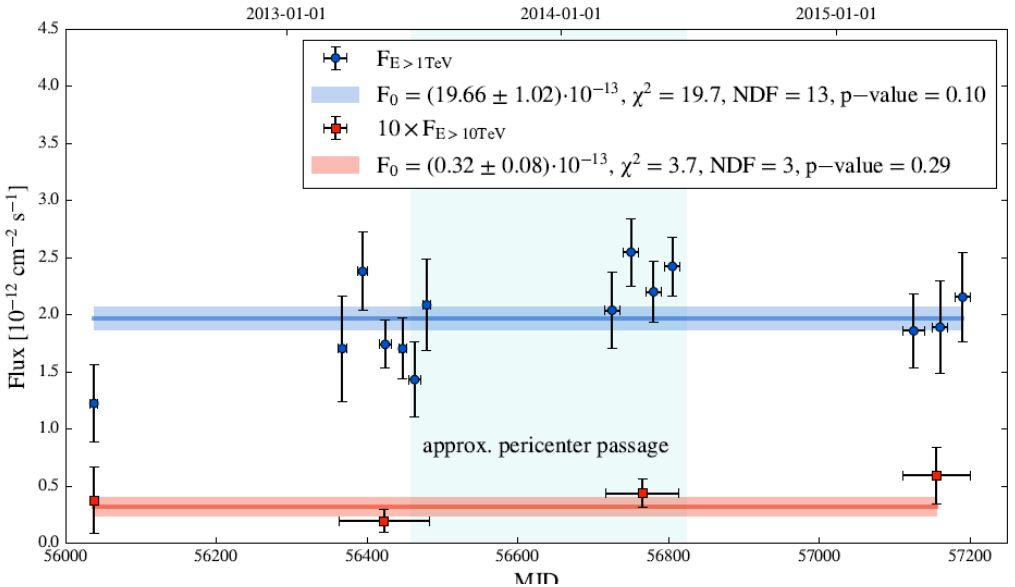


Ahnen et al., A&A 591, A138 (2016)

Galactic Center



Lopez M. Et al. ICRC20217



Ahnen et al., A&A 601, A33 (2017)

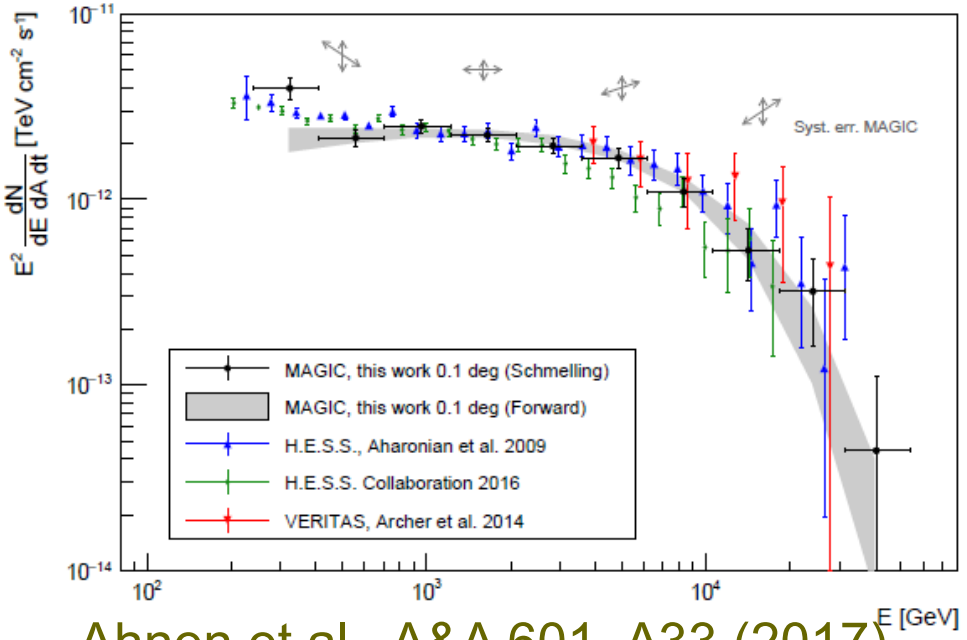
Results from Ahnen et al., A&A 601, A33 (2017)

Gas cloud orbiting a Sgr A* has been observed (from 2012)

~70 h of MAGIC data between 2012-2015

Flux in γ-rays during this time is stable

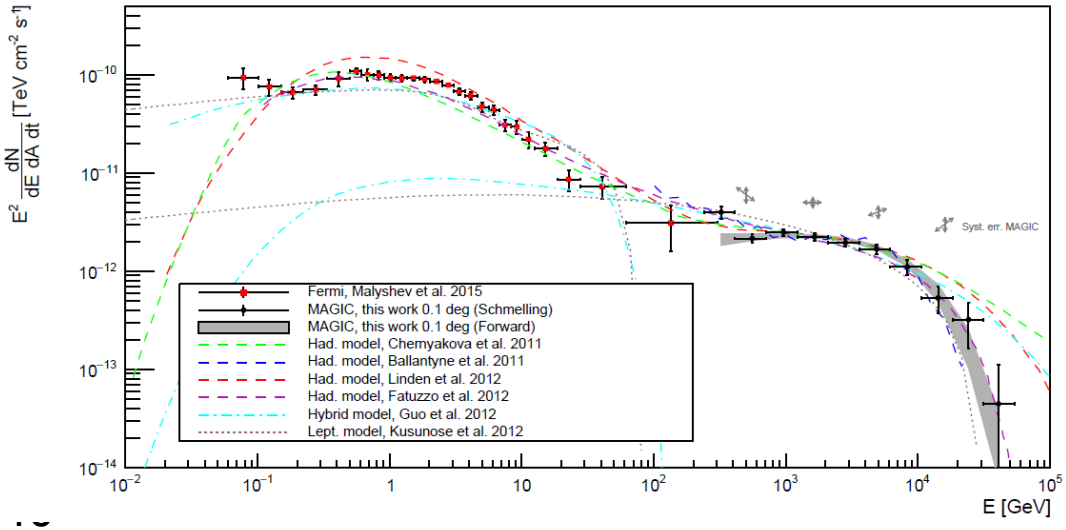
Galactic Center



Ahnen et al., A&A 601, A33 (2017)

Spectrum matches to other VHE data

Spectrum in the energy range from 0.3 up to 50 TeV - the power law with exponetial cutoff (at 8TeV)

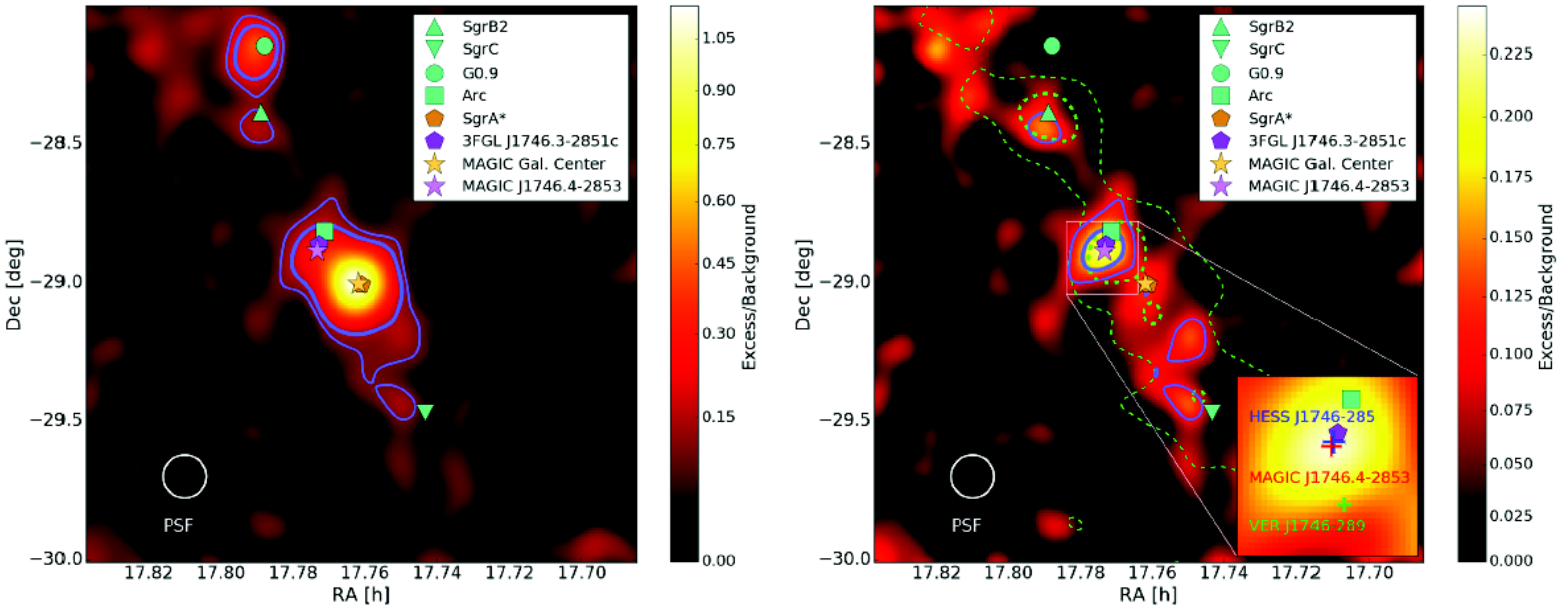


Ahnen et al., A&A 601, A33 (2017)

Spectrum matches to Fermi data

Both leptonic and hadronic scenario still possible

Galactic Center - morphology



Ahnen et al., A&A 601, A33 (2017)

Both Sgr A* and G0.9+0.1 has been detected (see skymap on the left)

Removing signal from both two sources using Bling Map method led to the detection of a source in the radio-Arc region ***MAGIC1746.4-2853***

Binary Systems – LS I+61°303

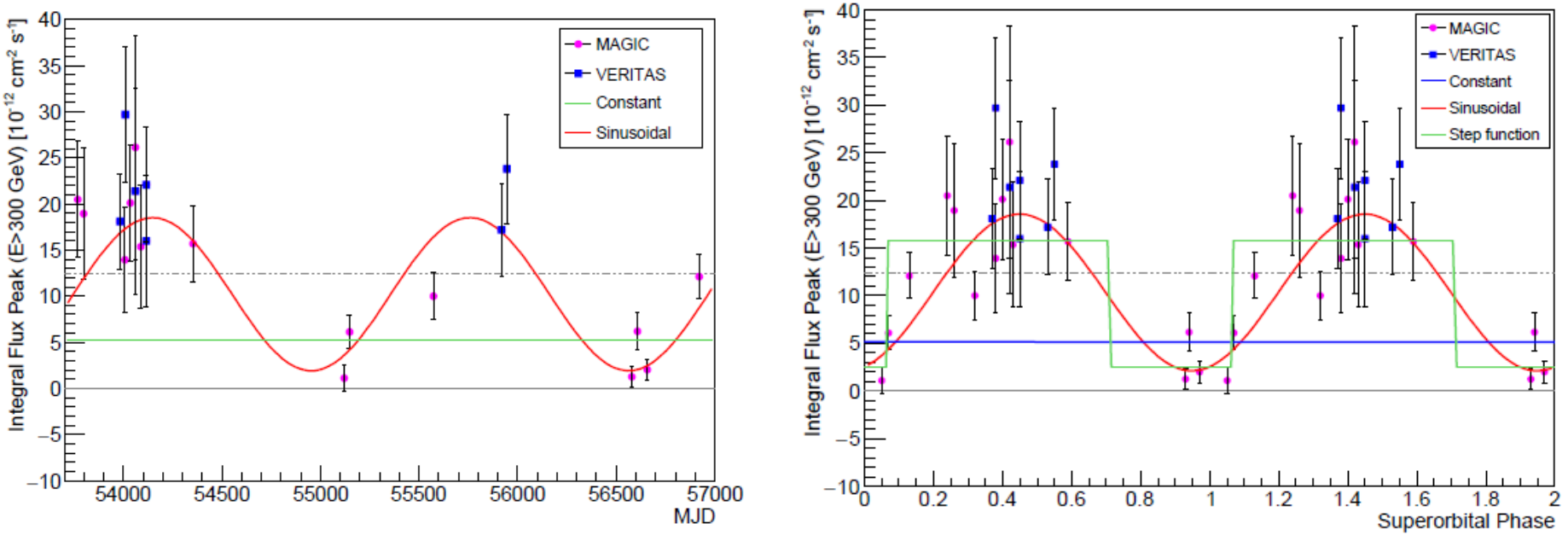
Results from Ahnen et al., A&A 591, A76 (2016)

Binary system: Be star+unknown compact object – orbital period 26.5 day

Orbital variability in VHE is the same (max flux at phase between 0.5 and 0.75) as in others wavelenghts

MAGIC, Veritas and optical telescopes (Liverpol) campain (2010- 2014) + archive MAGIC data

Binary Systems – LS I+61°303



Ahnen et al., A&A 591, A76 (2016)

Superorbital variability in TeV has been found with period of 4.5 year that is consistent with optical, radio and HE

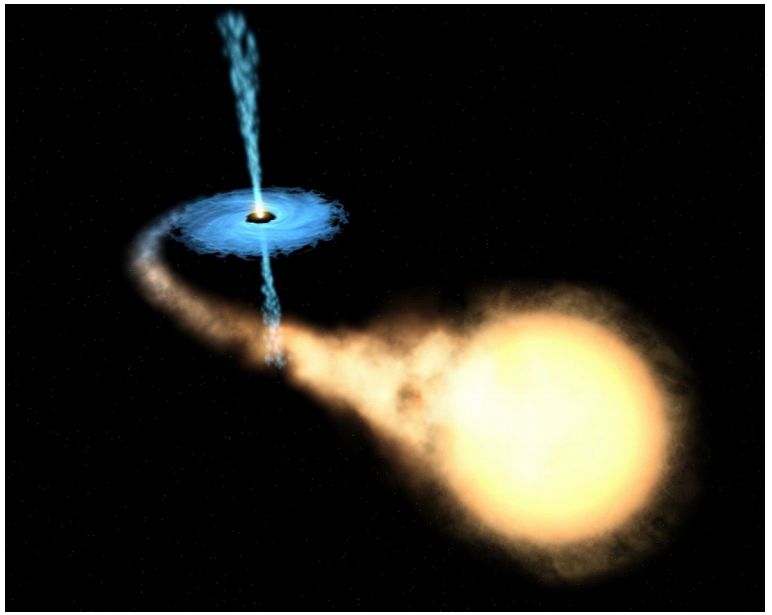
Binary - microquasars

Cygnus X1

Results from arXiv:1708.03689 (accepted inMNRAS)

~100 h of data

No detection above 200 GeV



Cygnus X-3

Results from Fernandez-Barral et al. (ICRC 2017)

~70h of data

No detection at TeV

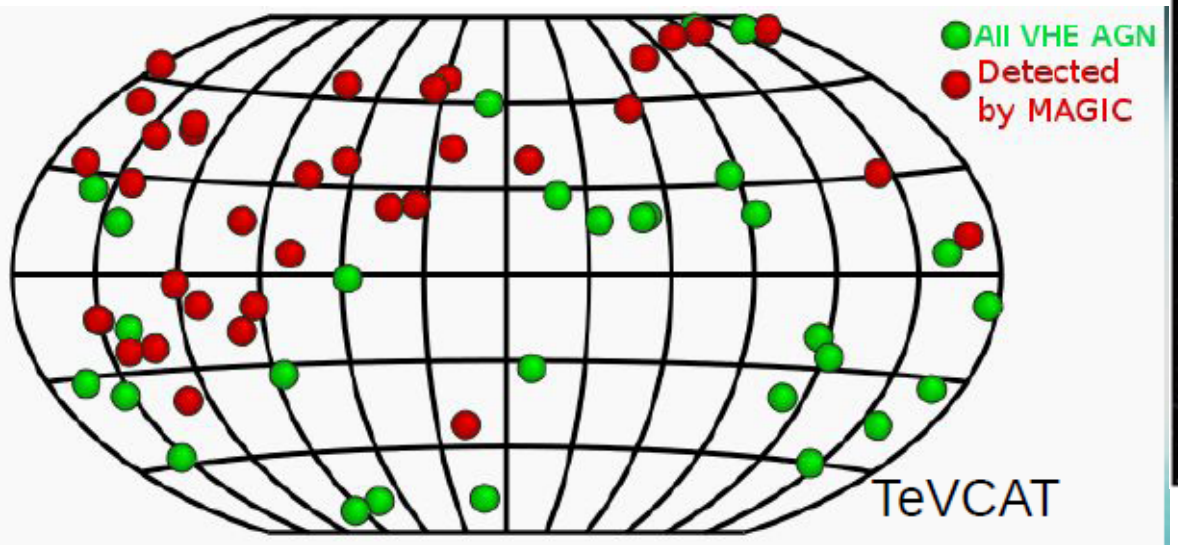
V404 Cygni

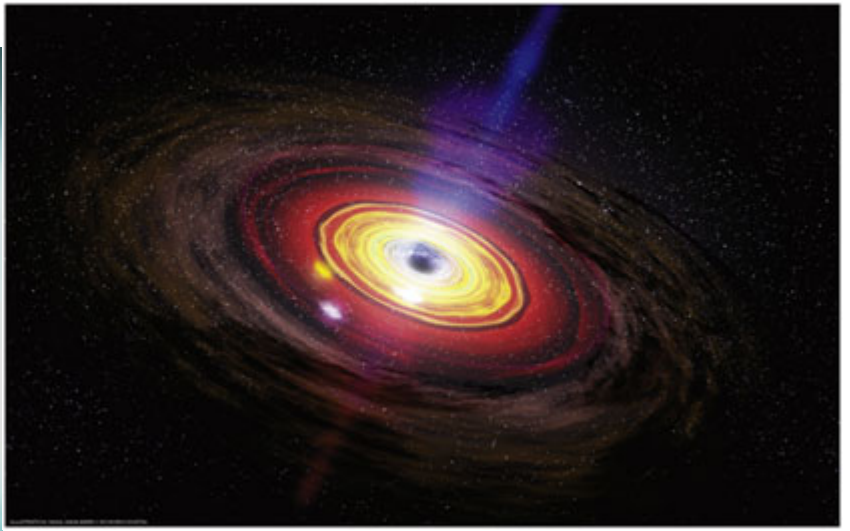
Results from Ahnen et al, MNRAS 471, 1688 (2017)

~10h during 2015 ouburst

No detection at TeV

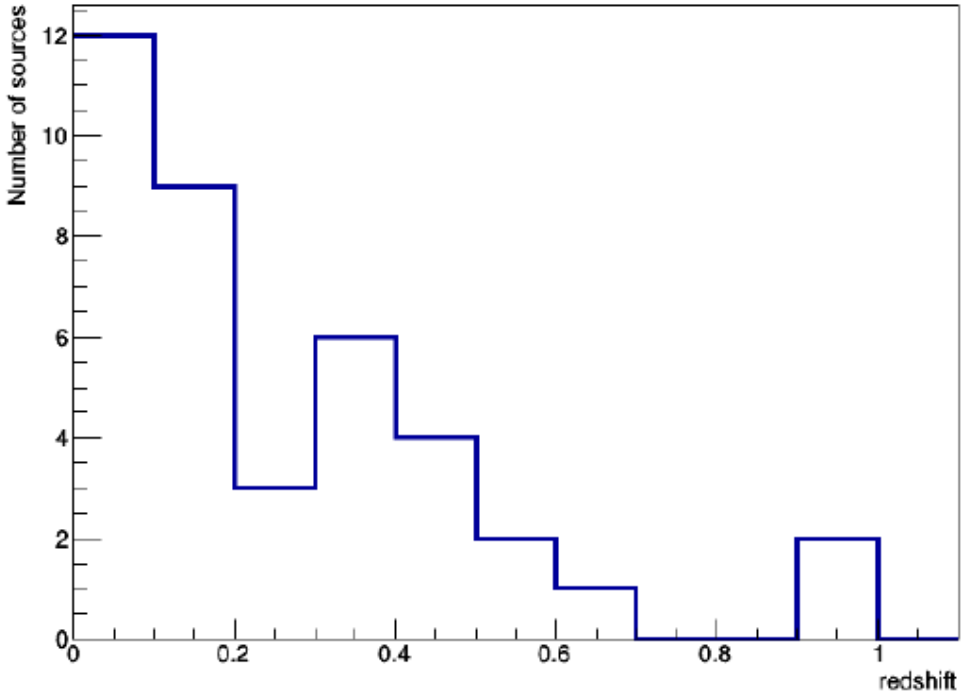
MAGIC extragalactic sky





Artist view of an Active Galactic Nuclei
Credits: courtesy of NASA, Dana Berry/Skyworks Digital

Observed γ-ray emission from 39/70 currently known VHE γ-ray AGN
Discovered emission from the two most distant (z~1) VHE γ-ray sources



(from J. Sitarek ICRC 2017)

Extragalatic sources

In this talk:

- Flat Spectrum Radio Quasar: FSRQ: PKS1510-089
- Gravitationally lensed blazar QSO B0218+357
- BL Lac: H1722+119

Extragalatic sources

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- Flat Spectrum Radio Quasar: FSRQ: PKS1510-089
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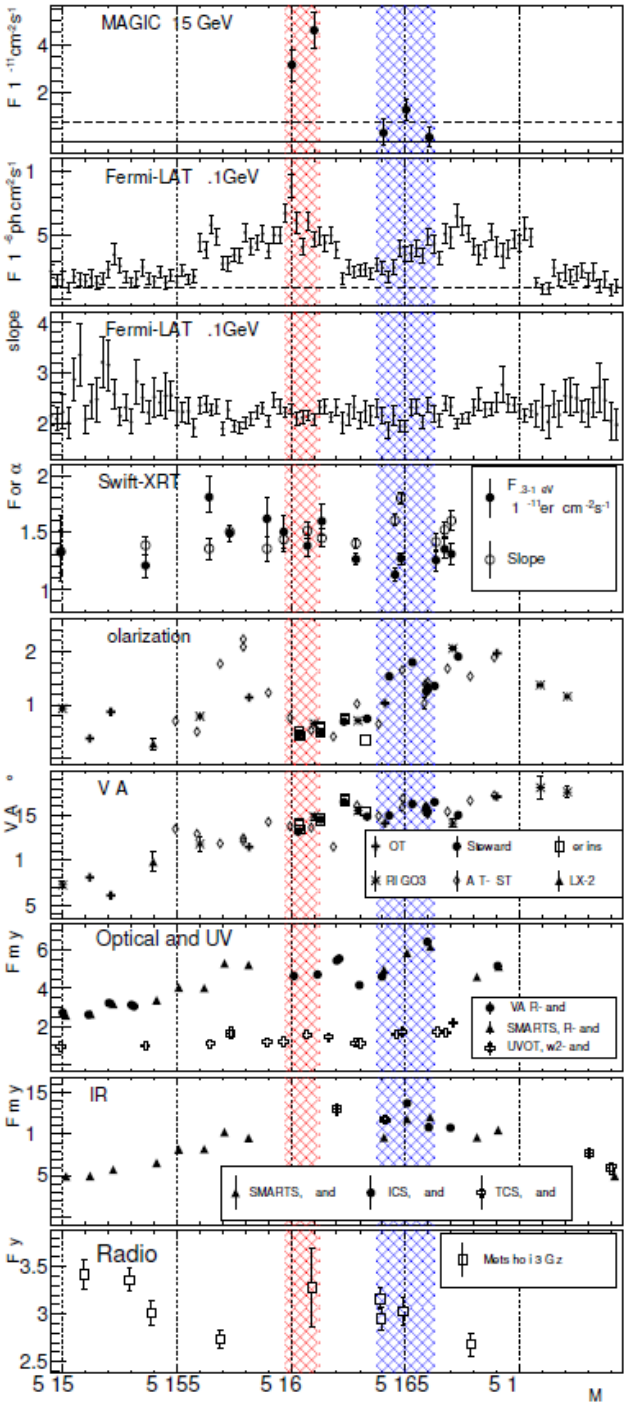
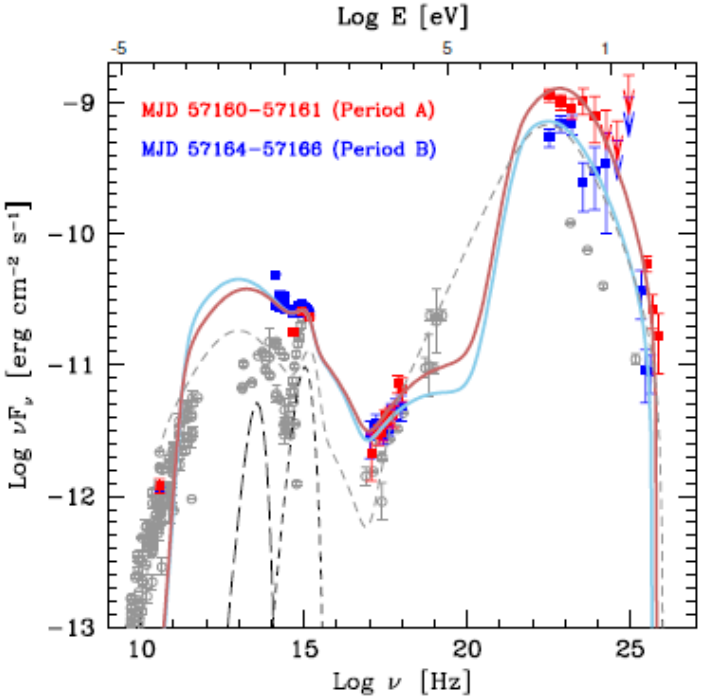
PKS 1510-089





Results from Ahnen et al., A&A 603, A29 (2017)

FSRQ (z=0.36) detected in VHE

Data from 2015 flare (5.4 h in 5 days)

Spectrum modeled by external Compton scenario

New flare in 2016 – under analysys in collaboration with H.E.S.S.

Ahnen et al., A&A 603, A29 (2017)

QSO B0218+357

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

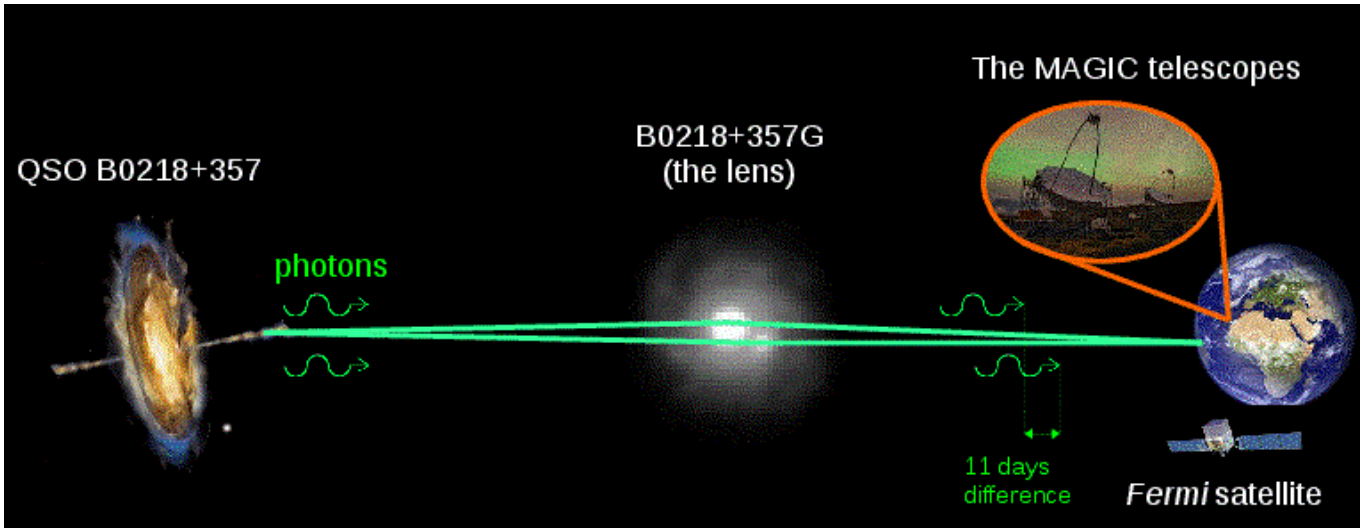
Gravitationally lensed blazar (z=0.944) – the only one detected in TeV

B02017 is the farest object detected in TeV

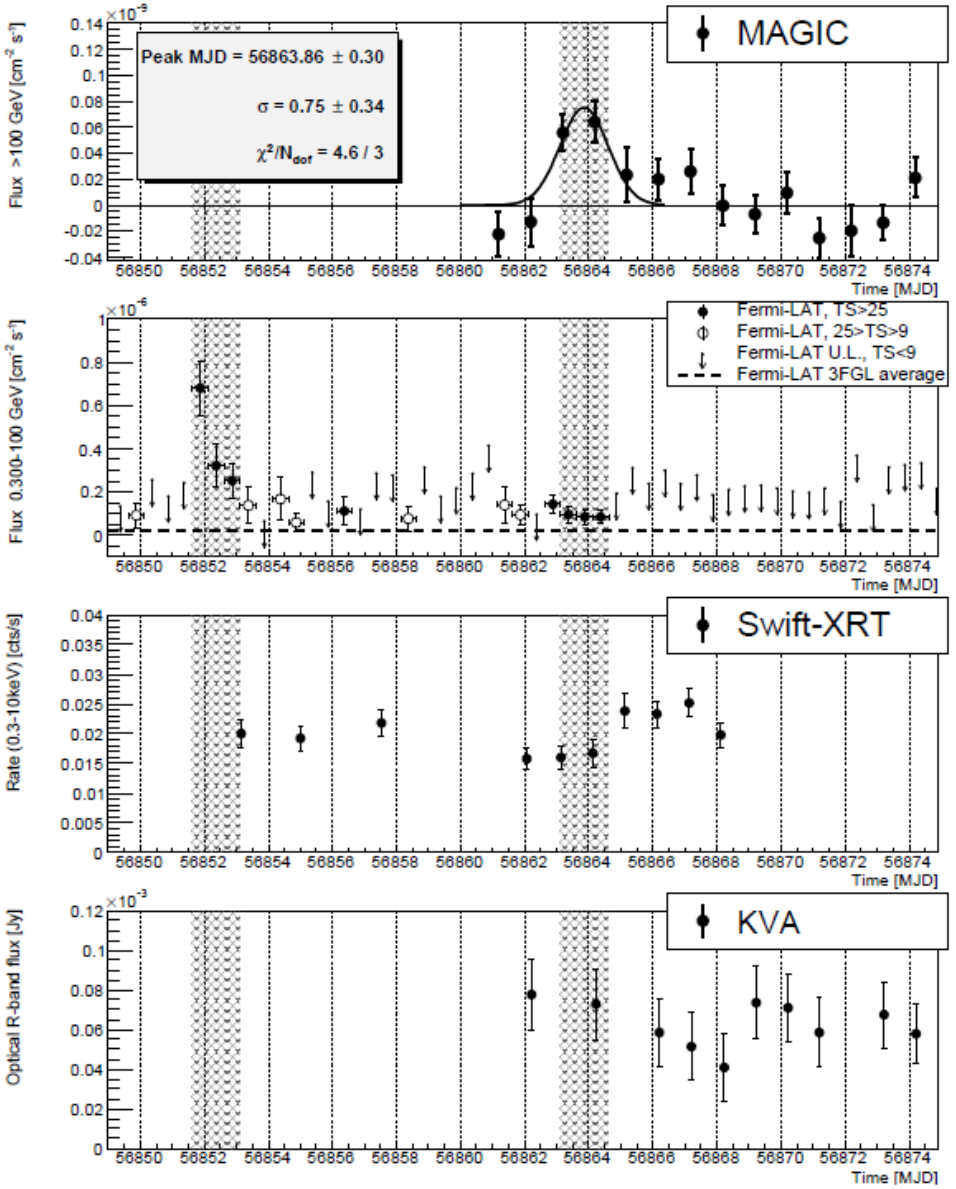
Flare observed by *Fermi*-LAT in June 2014

The second component of this flare expected after 10-11 days was observed and detected by MAGIC (2.11h)

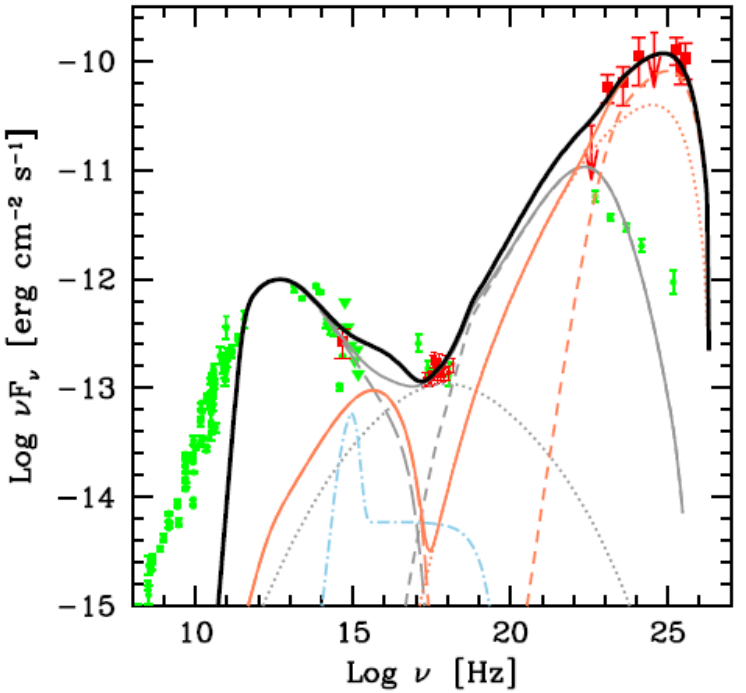
Flux (>100GeV) ~ 30% of Crab during a flare



QSO B0218+357



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



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

Two zone external Compton model used for modeling

Fermi and MAGIC data consistent with current EBL models

H1722+119

Results from Ahnen et al., MNRAS 459, 3271 (2016)

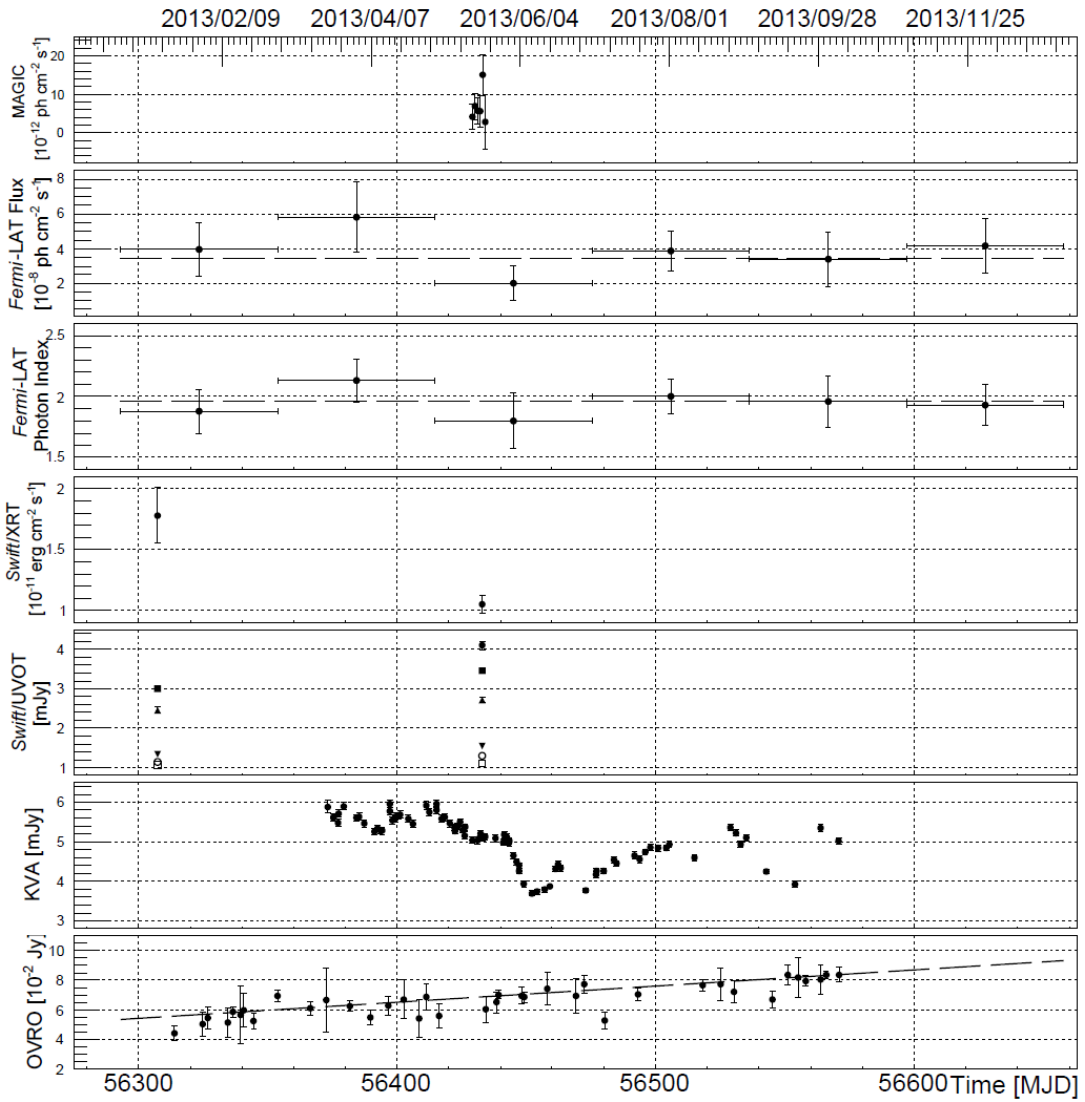
BL Lac with unknown z

Observed by MAGIC (triggered by optical high flux) in May 2013 (~12.5h data)

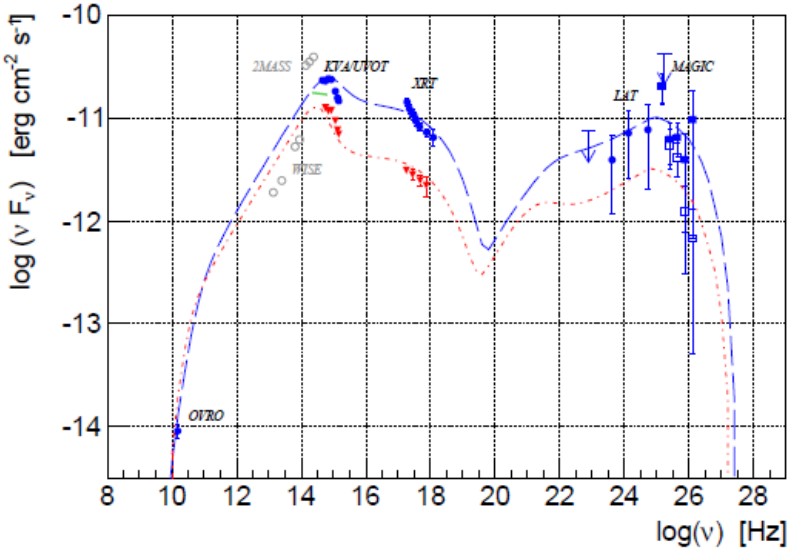
Estimated flux from MAGIC data: 2% Crab

Estimated redshift (using a method from *Prandini et al., MNRAS 405, L76, 2010)* z=0.34+-0.15

H1722+119



Ahnen et al., MNRAS 459, 3271 (2016)



Ahnen et al., MNRAS 459, 3271 (2016)

Data from 2013 modelled by inhomogenous helical jet synchrotron self Compton (blue line – the fit of simultaneus data)

Suprising behaviour between $3*10^{14}$ – 10^{18} eV

Cosmology and fundamental physics

- Testing extragalactic background light (EBL) models
- Dark Mater
- MAGIC as neutrino detector
- Lorentz Invariance Violation study

Observations of GRB ...

Testing extragalactic background light (EBL) models

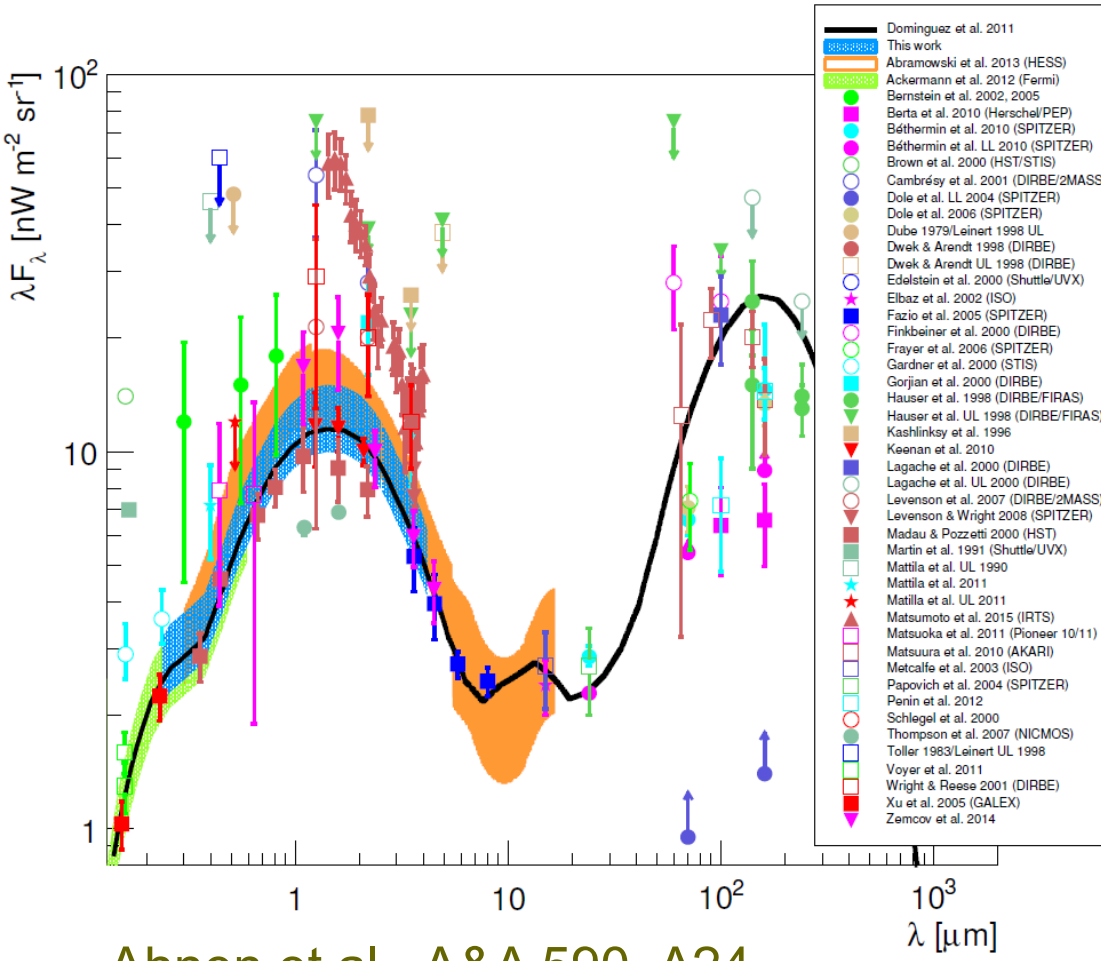
VHE γ-ray flux reduction due to the pair production on background photons (mostly IR or optical)

Results from Ahnen et al., A&A 590, A24 (2016)

Flare of BL Lac 1ES 1011+496 (z=0.212) in 2014

The constraint of the EBL density (for Dominguez 2011 model) in the wavelength range between 0.24 and 4.25 μm, with a peak at 1.4 μm of $F=12.27^{-2.29}_{+2.75}$ nW m^{-2} (one of the strongest EBL density constraints)

More study on EBL using using spectra of 12 blazars - Moralejo et al. (ICRC2017)



Ahnen et al., A&A 590, A24 (2016)

DM searches

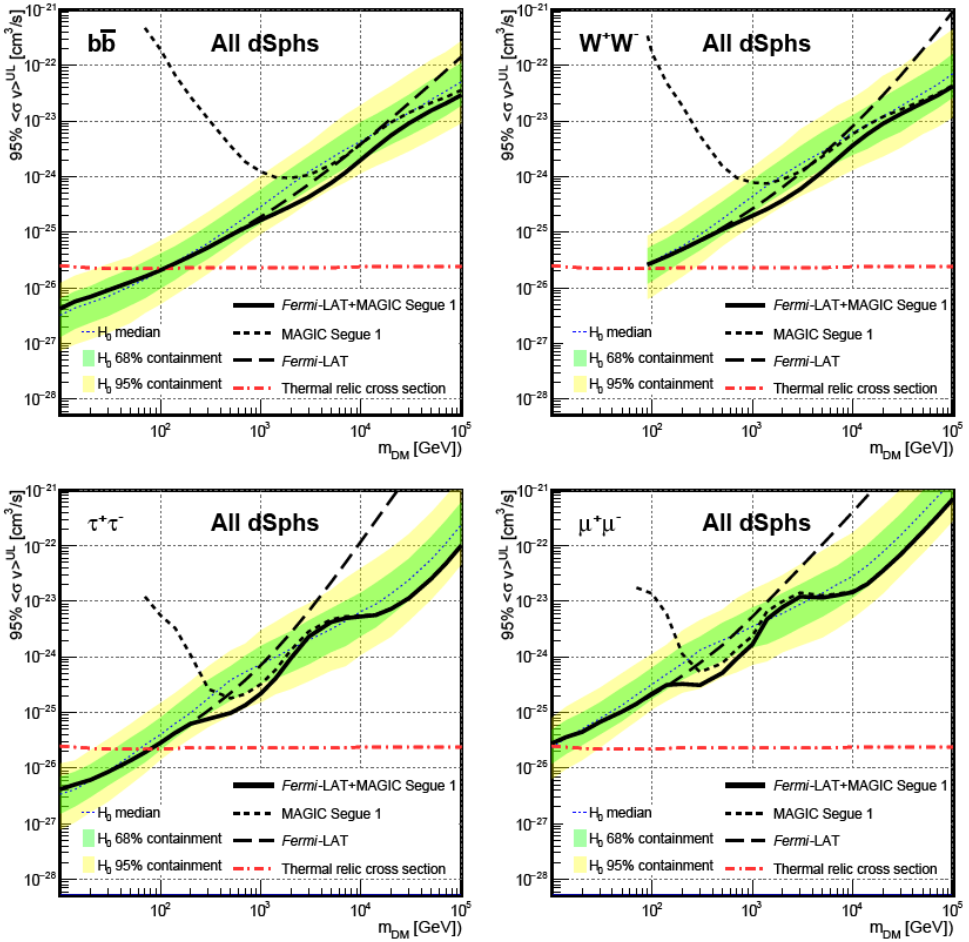
Results from Ahnen et al., Journal of Cosmology and Astroparticle Physics 2, id039 (2016)

~170 h of data (dwarf galaxy Seque1)

No signal from DM has been found

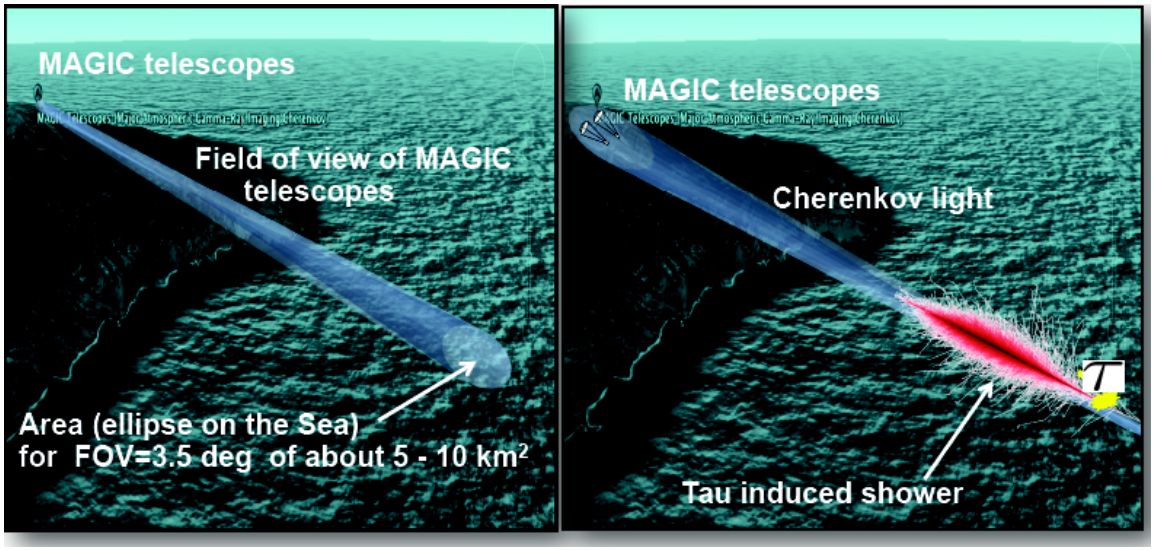
Limits for thermaly averaged cross sections for DM anihilation (Fermi data from 15 galaxies + MAGIC from Seque1)

Palacio et al. (ICRC2017) – limits of the DM lifetime – decay into pair of muons or taus (on Perseus data) - reached sensitivity ~8* 10^{25} s (at 20 TeV)



Ahnen et al., JCAP 2, id039 (2016)

MAGIC as neutrino detector



Satalecka TeVPa 20217

Idea described in D.Góra et al., EPS-HEP 2017

Preliminary results from Góra et al (ICRC2017, arXiv:1708.06147)

Looking for cosmic tau neutrinos arrising from the ocean at PeV (up to EeV)

This detection is background free!

Cheap - unique possibility to use very cloudy weather for observation

Results

-> no signal up to now (~30h of data)

->Upper limits for the flux of the diffuse tau neutrinios ~10^{-8} GeV cm^{-2} s^{-1}

->Sensitivity for point like source „in case of a strong flare is reaching the value $E^2\Phi(E) < 5.8\times10-6$ [GeV cm^{-2} s^{-1}] i.e. the level of so-called down-going analysis of the Pierre Auger Observatory"

Lorentz Invariance Violation study

The modified dispersion relation is postulated in theories of the Quantum Gravity

The group velocity of photon

$$u_\gamma(E) = \frac{\partial E}{\partial p} \approx c \cdot \left[1 - \xi_n \frac{n+1}{2} \left(\frac{E}{E_{QG_n}}\right)^n\right]$$

It depends on:

- the wavelenght (or photon energy)
- subluminal or superluminal (ξ=1 or -1)
- linear or quadratic case (n=1 or 2)
- an effective quantum gravity scale E_{QGn}

As a results an energy dependent shift in the pulsar phase is expected

from Gaug et al. ICRC2017

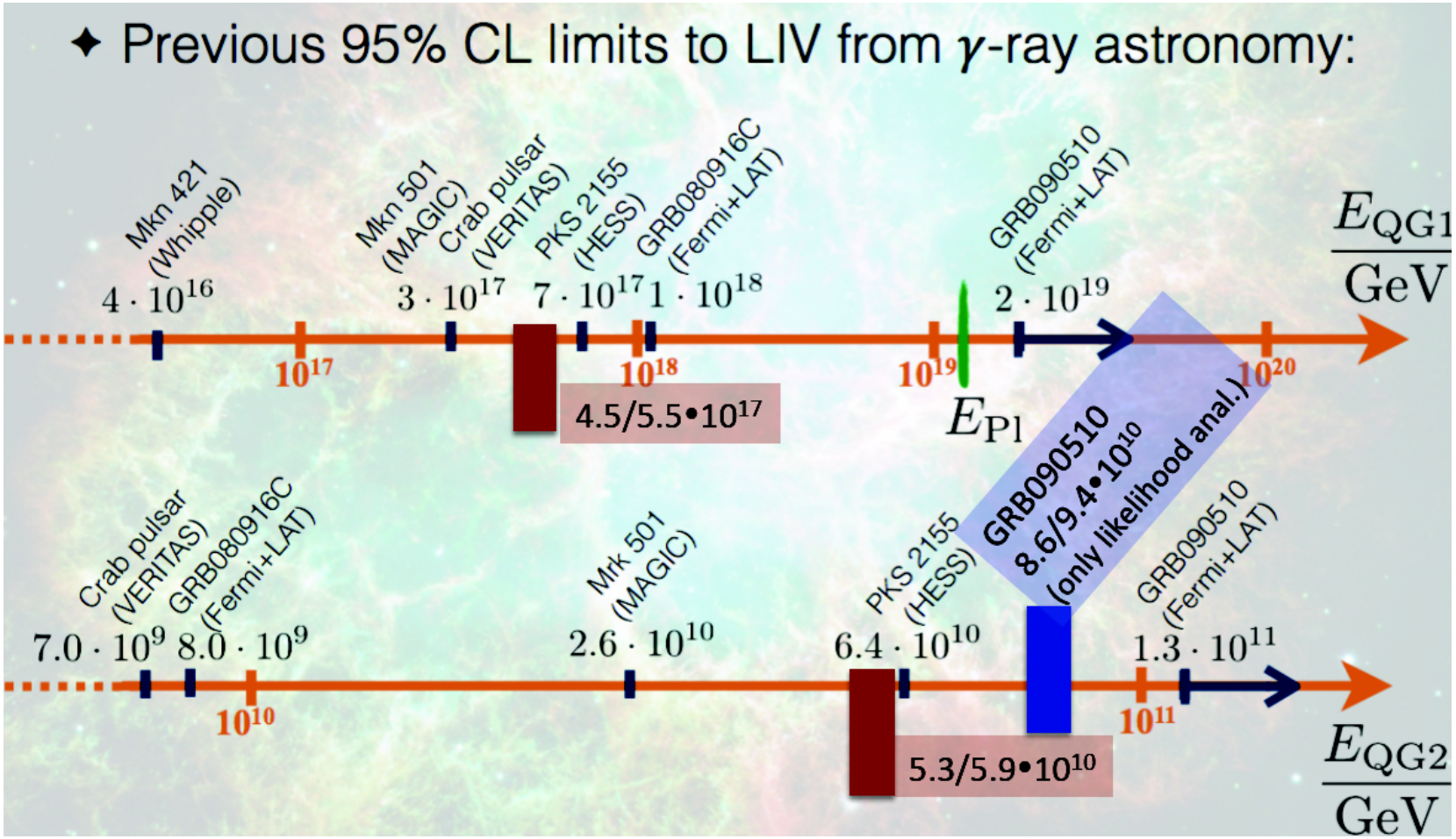
Lorentz Invariance Violation study

Results from Ahnen et al., ApJS 232,9 (2017)

- Crab data for pulsation above 400 GeV have been used
- Full Profile Likelihood Method was used in order to get an effective quantum gravity scales limits
- Pulsar case more interesting for quadratic case E_{QG2}
- With current data – almost world-best limits on E_{QG2}
- Future analyses (and combintions of likelihood method) should reveal nature of the Crab pulses and possibly better limits than GRBs!

Gaug et al. (ICRC2017)

Lorentz Invariance violation study



from Gaug et al. ICRC2017

MAGIC set almost world-best limits on E_{QG2} !

Summary

MAGIC is nicely operating since the latest major upgrade in 2011 – 2012

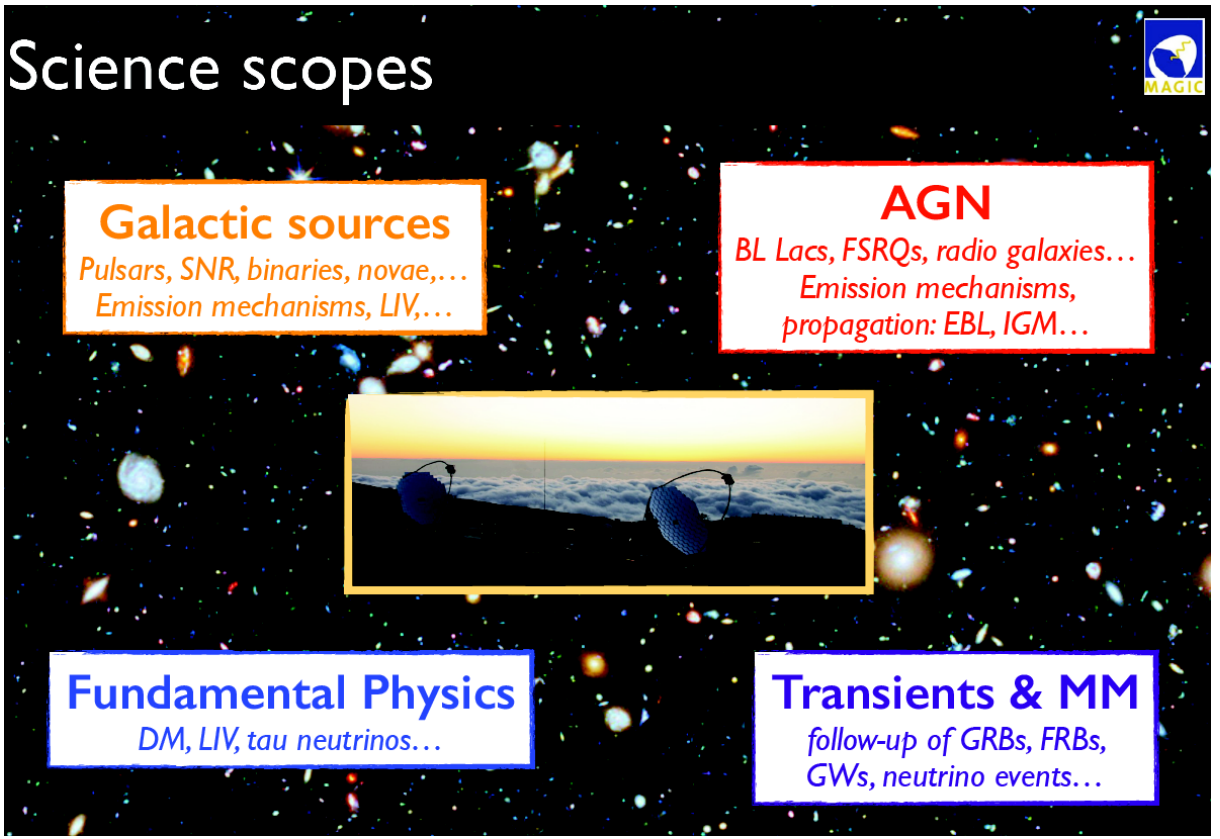
Collaboration with:

H.E.S.S., VERITAS and HAWC

Fermi-LAT, X-ray, optical and radio observatories in MWL campains

IceCube – neutrino alerts

....



from Satalecka K. TeVPa 2017

MAGIC opening to external scientists!

https://magic.mpp.mpg.de/outsiders/magicop/

The MAGIC Telescopes

Gamma-ray astronomy at low energies with high sensitivity

HOME | GENERAL INFORMATION | SCIENCE WITH MAGIC | MAGIC MEMBERS | MAINTENANCE

MAGIC > MAGIC observation proposals

MAGIC OBSERVATIONS PROPOSED BY EXTERNAL SCIENTISTS

The MAGIC collaboration encourages individual external scientists to propose observations to be performed with the MAGIC telescopes. Observation time will be granted by the Time Allocation Committee based on scientific merit. **The deadline for the next call is tentatively set to 2017/11/03, and the observation cycle spans from January to December 2018.**

MAGIC is not an open observatory and, because of the complexity in the analysis of the data (which requires specific expertise and tools that are not publicly available), the external scientists will need the help of some members from the MAGIC team, who will be supporting their projects throughout the entire procedure of proposal submission, and (if the observation time is granted) data reduction and publication. The details on the authorship of the publications should be discussed and agreed before the submission of the observation proposal, with the general constraint that the full MAGIC collaboration should be included in the authors' list of the publications reporting these data results for the first time.

PERFORMANCE OF THE MAGIC TELESCOPES

The performance of the MAGIC telescopes during regular dark-time observations is reported in full detail in **Aleksic et al 2016**, while the performance of MAGIC during moon-light is reported in **Ahnen et al 2017**. The main performance plots are reported **in this page**, and a few key numbers are given below:

- **Sensitivity for point-like sources (<0.1 deg)**: 0.8% the flux of the Crab nebula above 0.2 TeV in 50 hours of observation (using Sigma Li&Ma 1983, and 3 background regions), which is about 5% the flux of the Crab nebula in 1 hour. The numbers from the differential sensitivity plot can be retrieved from **this page**.
- **Sensitivity for extended sources (>0.1 deg)**: the sensitivity of MAGIC reduces with the source extension approximately as sqrt((0.1deg)^2 + (Source_Radius)^2), and the analysis becomes difficult (yet not impossible) for extensions larger than 0.6 degrees radius.
- **Analysis energy threshold**: ~75 GeV x pow(cos(Zenith_Angle),-2.3) for a Crab-like spectrum. We note that, for strong and/or steep sources, it is possible to measure gamma rays below such threshold, as shown in **Ahnen et al 2015a** and **Ahnen et al 2015b**, where spectra starting at 40-50 GeV are reported.
- **Energy resolution**: about 20% per incoming gamma ray.
- **Angular resolution**: better than 0.1 deg per incoming gamma ray.

OBSERVATION PROPOSAL DETAILS

The amount of observations performed yearly with the MAGIC telescopes are about 1000 hours, depending on weather conditions and technical access during that year. Additionally, moon observations can add up to 400 hours.

Starting from this year, external scientists can apply for MAGIC observation time

Deadline for the call:

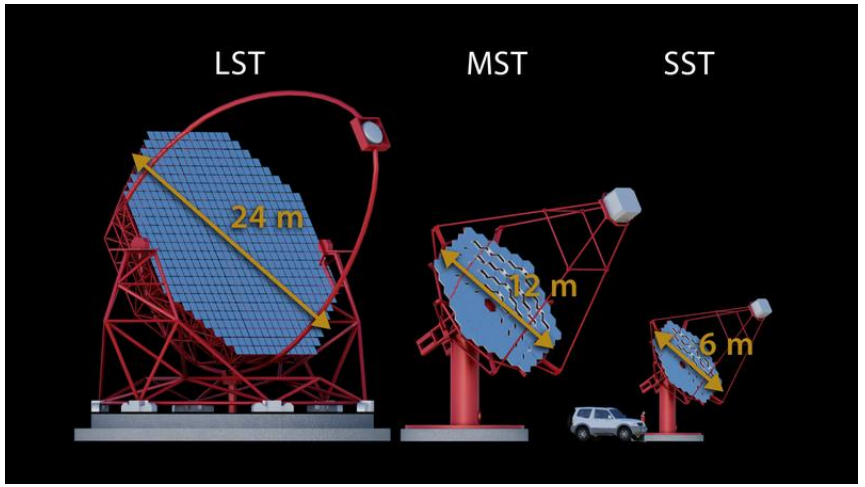
03-Nov-201, but if you would like to apply contact us as soon as possible

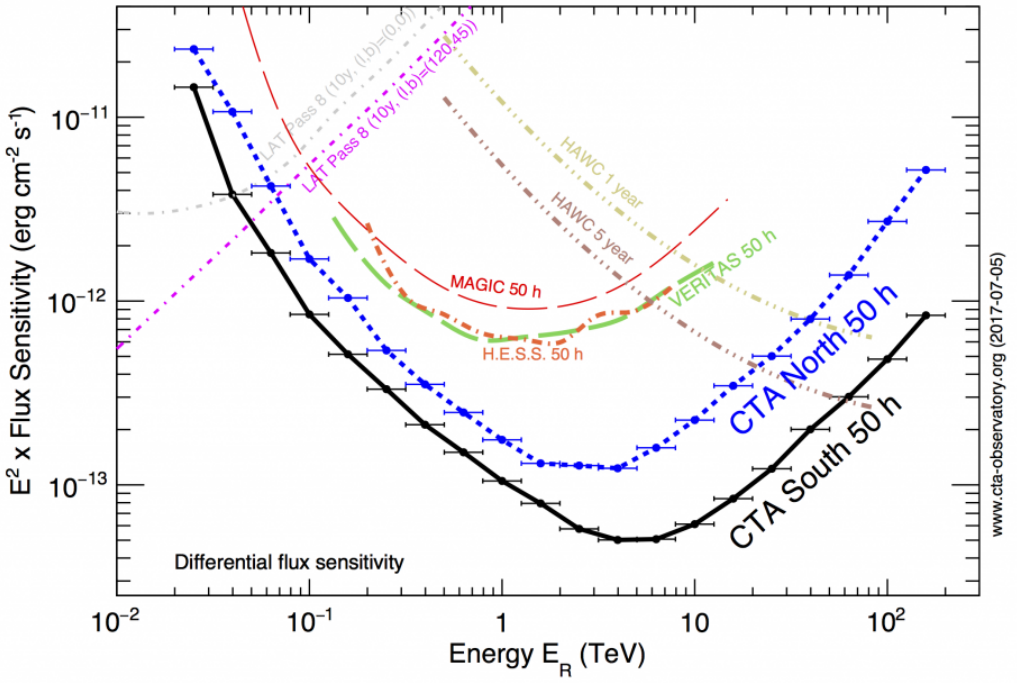
Future (CTA) ?

New project: Cherenkov Telescope Array (CTA)

https://www.cta-observatory.org/

North (at the same site as MAGIC) and South Observatories with Large, Middle and Small Size Telescopes





www.cta-observatory.org/science/cta-performance/


Isn’t the moon to bright for observation?
No, we can use a UV-pass filter..
Today is to cloudy for observation.
Yes, but we may hunt for tau neutrino.
Can we observe during fog, rain, strong wind or daytime?
No. Let our MAGIC people work on data analysys...
Daniel López / IAC