

Recent results from the MAGIC telescopes

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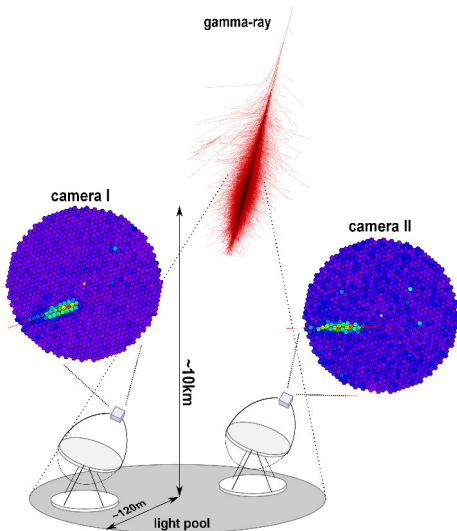
For the MAGIC Collaboration

**Magellan Workshop - Connecting Neutrino Physics and Astronomy,
DESY Hamburg, 03-18-2016**

MAGIC: Major Atmospheric Gamma-Ray Imaging Cherenkov Telescopes

- Two IACTs of 17 m diameter mirror dish
- MAGIC I since 2004, MAGIC II since 2009 → stereo system
- Energy range: ~ 50 GeV – 50 TeV
- Collaboration: ~ 170 scientists from 10 countries in Europe & Asia

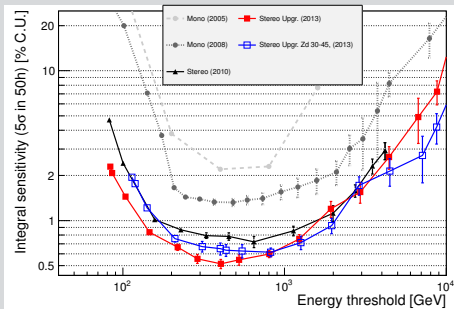




- Cherenkov radiation from charged particles in air showers
- Spectrum in optical-UV range (blue)
- Fast flashes (~ 5 ns) \rightarrow fast readout
- Faint emission \rightarrow PMTs or G-APDs and large mirrors

- Sensitivity: $\sim 0.6\%$ Crab nebula flux 5σ in 50 h (for $E > 400$ GeV)
- Angular resolution: $\sim 0.1^\circ - 0.07^\circ$ (energy dependent)
- Energy resolution: $\sim 15 - 20\%$ (energy dependent)

Improvement of the sensitivity in ~ 10 years



Aleksić et al. *Astropart. Physics*, 72, 2016

- 2004 - MAGIC I built
- 2007 - new MAGIC I readout
- 2009 - MAGIC II built
- 2011-2012 - upgrade of both readouts and MAGIC I trigger and camera

Pulsars, PWN, SNR, Novae ...



Image credit: Wally Pacholka (AstroPics.com, TWAN)

Active Galactic Nuclei

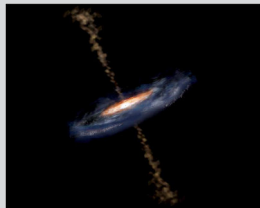
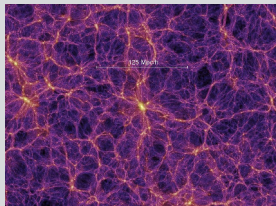


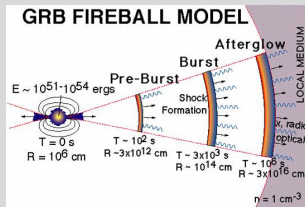
Image credit: Aurore Simonnet, Sonoma State University

DM, LIV, EBL, IGMF & cosmology



<http://wwwmpa.mpa-garching.mpg.de>

Gamma Ray Bursts



<http://www.swift.ac.uk/grb.shtml>

Pulsars, PWN, SNR, Novae ...



Image credit: Wally Pacholka (AstroPics.com, TWAN)

Active Galactic Nuclei

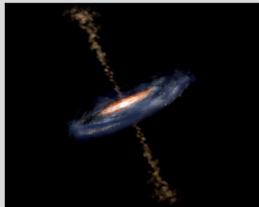
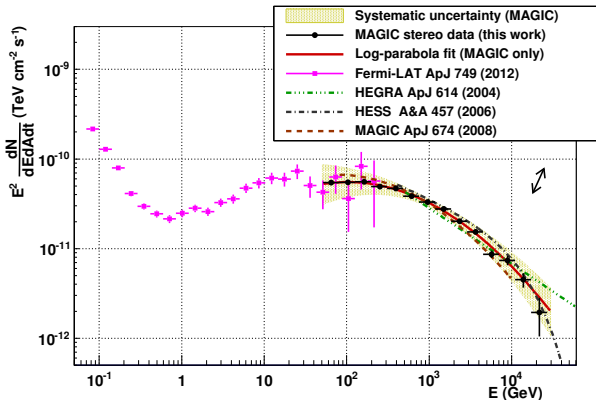
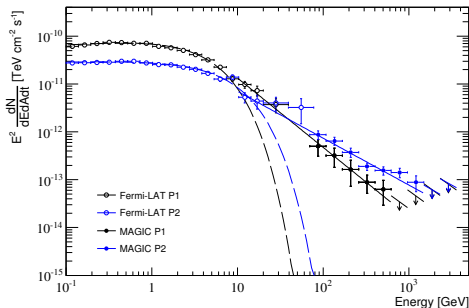
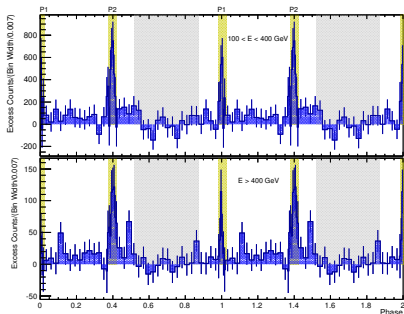


Image credit: Aurore Simonnet, Sonoma State University

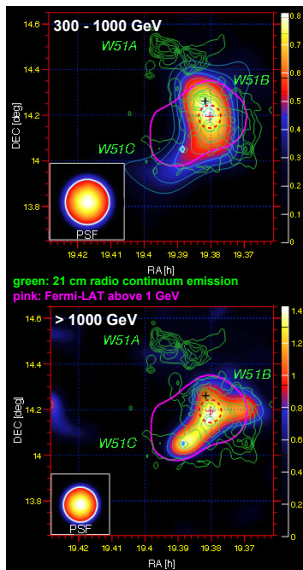
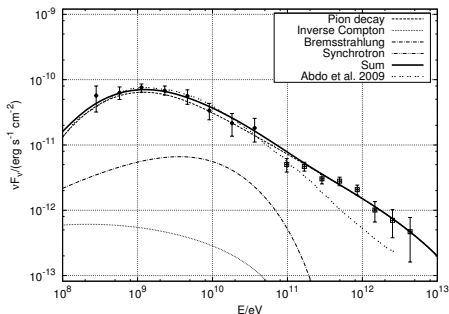
- Spectrum from 50 GeV to 30 TeV
- Combination with *Fermi*-LAT data: flat and broad Inverse Compton peak at $53^{+3_{\text{stat}}+31_{\text{syst}}}_{-3_{\text{stat}}-13_{\text{syst}}}$ GeV
- Broadness of IC peak disfavors constant B-field model
- Measurement over three decades in energy



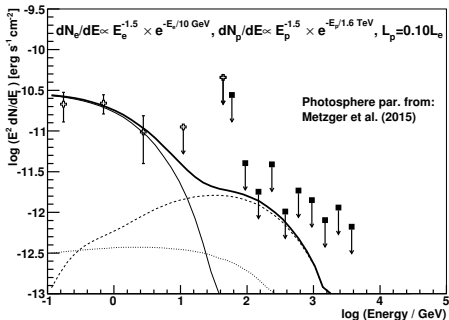
- First detection above 25 GeV by MAGIC reported in 2008 (Aliu et al. 2008 *Science*)
- ~ 320 h of observation: pulsed emission between 70 GeV and 1.5 TeV
- Probably, inverse compton scattering off low energy photons and γ -rays produced in vicinity of light cylinder
- **Most energetic pulsed emission to date**



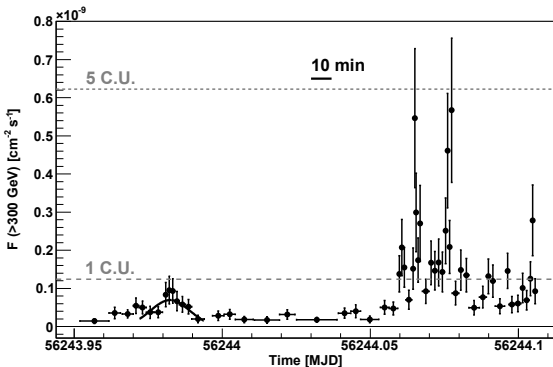
- Spectral and morphological studies of complex region W51
- γ -ray emission most probably hadronic
- Ongoing cosmic ray acceleration at least up to ~ 50 TeV



- **Shedding light on acceleration processes of leptons and hadrons in nova explosions**
- GeV γ -rays detected from novae produced by IC processes of e^- accelerated in shocks; p could be accelerated to higher energies
- Follow-up observations of novae and dwarf novae: e.g. classical nova V339 Del in Aug. - Sept. 2013



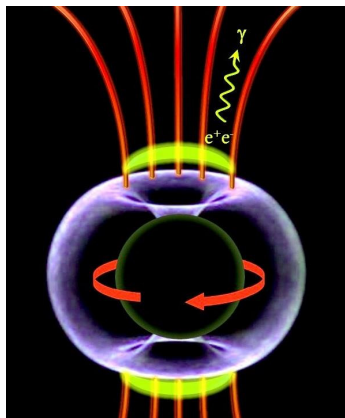
Ahnen et al. *A&A* 582, 2015



Aleksić et al. *Science* 346, 2014

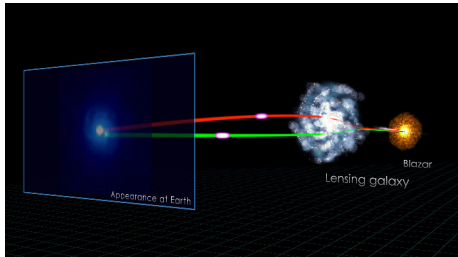
- Impressive TeV flare of IC 310 → ATel #4583, #4581
- Active galaxy with inclination angle of $10^\circ \lesssim \theta \lesssim 20^\circ$
- Minute variability inconsistent with shock-in-jet model

- “Magnetospheric models”:
by e.g. Levinson & Rieger 2011;
Aleksić et al. 2014, *Science*
- Similar to “aligned magnetic
rotator models” for pulsars
- **New clues on particle
acceleration in AGN from ultra
fast variability**

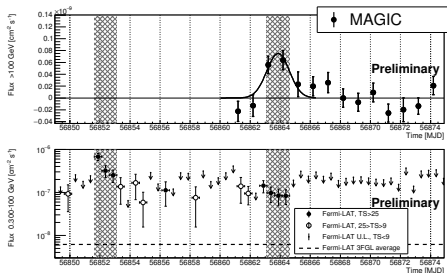


Aleksić et al. *Science* 346, 2014

- Gravitationally lensed blazars at $z = 0.944$ (lens at $z = 0.684$)
- Flare observed by *Fermi*-LAT in mid of July 2014 (full moon)
- MAGIC detection of delayed emission ~ 12 d after
→ ATel #6349
- **Unprecedented distance scale for ground-based gamma-ray astronomy**

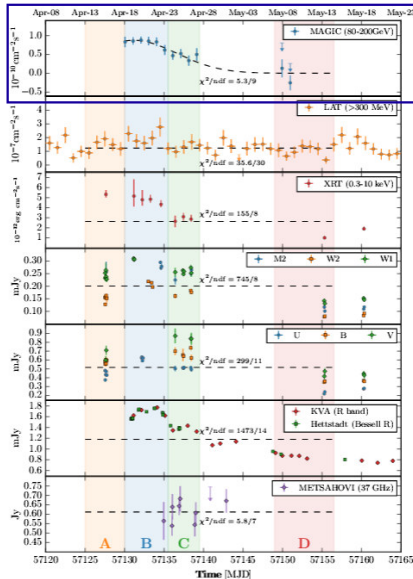


Credit: NASA/ESA, Hubble Legacy Archive

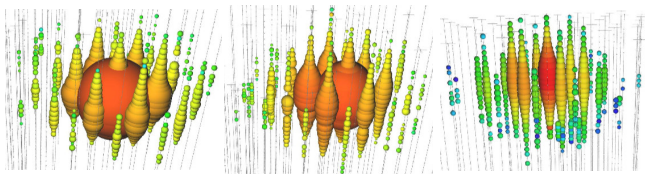


Sitarek et al. 2015, arXiv:1508.04580

- Flat-spectrum radio quasar at $z = 0.939$
- Outburst in April 2015 seen by *Fermi*-LAT
- MAGIC detection between 40 and 250 GeV with 25.5σ in April/May 2015
- MWL spectral energy distribution during different flux states
- Location of emission region outside BLR during high state and partially within during low state
- **Again γ -rays from the middle ages of the universe**



- Many candidate neutrino sources may be transient
- On-line triggers from IceCube to MAGIC/VERITAS
- Send alerts of interesting neutrino events to IACTs for follow-up observations (Bernardini arXiv:0509396)
- Precedent in AMANDA to MAGIC alerts (IceCube & MAGIC Coll. arXiv:0709.2640)
- **Real-time multi-messenger astronomy**



IceCube Coll. *PRL* 111, 2013; 113, 2014

- First twelve years of scientific operation: 32 new VHE detections (24 AGNs); > 100 peer reviewed papers, 5 in Science Magazine
- Scientific highlights:
 - Precision measurement of spectrum from Crab Nebula
 - Most energetic pulsed photons from pulsar
 - Ultra fast variability questions standard acceleration model in AGN
 - γ -rays from the middle ages of the universe
- Collaboration efforts with VERITAS, HESS, HAWC and many MWL instruments and follow-ups of gravitational waves & neutrinos

