The MAGIC Experiment: Highlights, Recent Results and Future Perspectives

L. Angelo Antonelli
INAF – OAR & ASDC
on behalf of the INAF – MAGIC Team
and the MAGIC Collaboration

The MAGIC Experiment

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescope

- Active from 2004
- In stereo configuration since 2009
- New MAGIC1 camera since 2012
- New mirrors for MAGIC 1 from august 2014
- At least 5 more years foreseen

New technologies to lower the threshold energy:

- 2x17m diameter (A=472 $m^{2)}$
- High resolution cameras (PSF ~0.06°, **FoV = 3.5°**)
- Hemispherical PMT with enhanced QE

Fast repointing capability: ~8 degree/s

The MAGIC Collaboration

~170 Collaborating Astro-Physicists from 10 Countries

Bulgaria Sofia

Croatia Consortium (Zagreb, +...)

Finland Consortium (Tuorla, +...)

Germany DESY Zeuthen, TU Dortmund, MPI Munich, U. Würzburg

India Saha Inst. of Nuclear Physics, Kolkata

Italy INFN & U. Padova, INFN Pisa & U. Siena, INFN Como/Milano Bicocca, INFN Udine/Trieste & U. Udine, INAF

Japan Consortium (Kyoto, +...)

Poland Lodz

Spain U. Barcelona, UAB Barcelona, IEEC-CSIC Barcelona, IFAE Barcelona, IAA Granada, IAC Tenerife, U. Complutense Madrid, CIEMAT Madrid

Switzerland ETH Zurich

INAF participation to MAGIC

Official entrance June 2007
Admittance to Full-membership April 2008

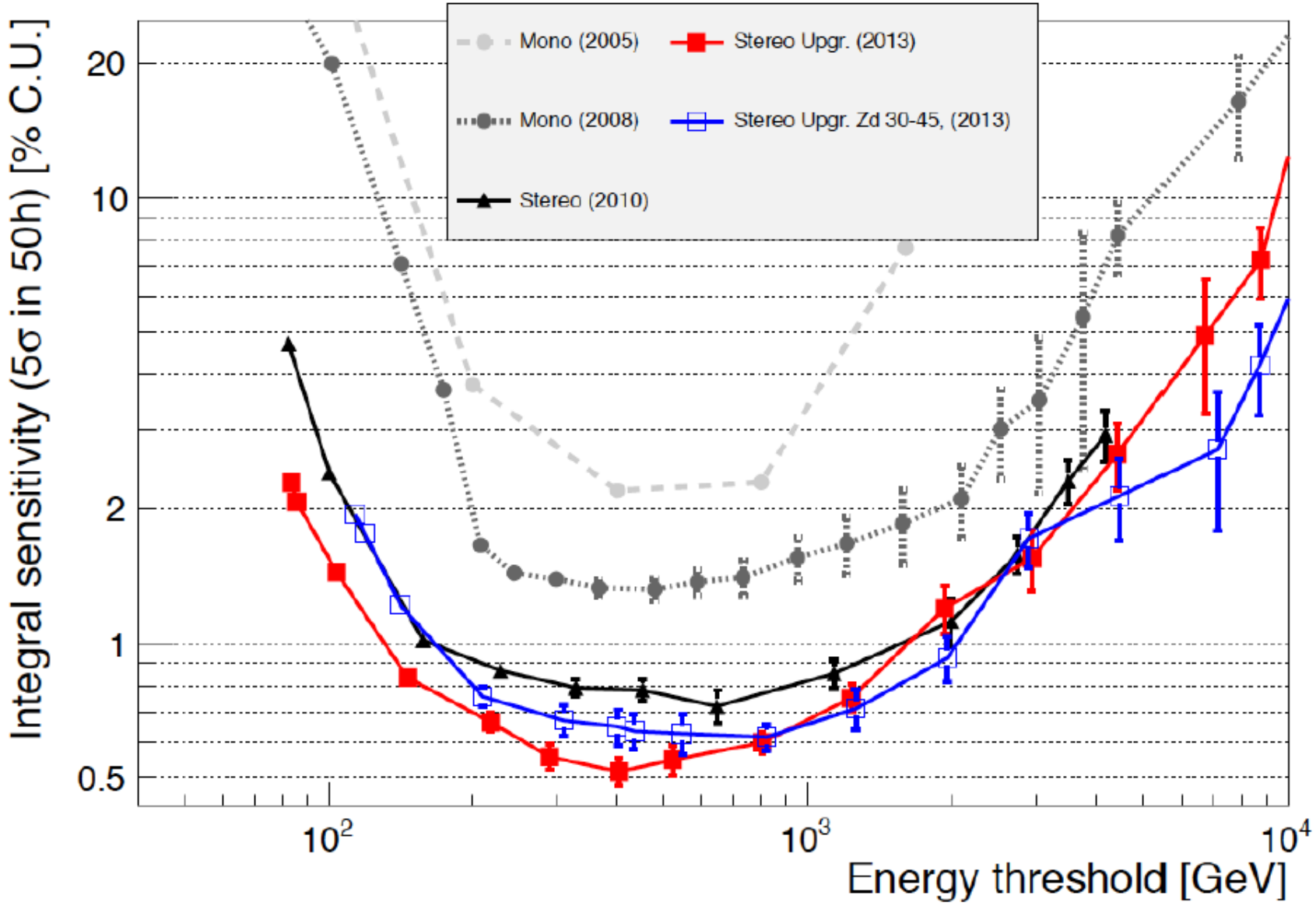
INAF contributes to MAGIC with:

- M2 and new M1 Mirrors
- Data Taking and Analysis
- Software development & maintenance
- Science and MWL activities
- Logistic support by TNG staff
- WEB Management
- Public Outreach

L. A. Antonelli, G. Bonnoli, A. Carosi, S. Covino, F. Di Pierro, S. Gallozzi, P. Giammaria, S. Lombardi, L. Maraschi, L. Perri, C. Righi, A. Stamerra, F. Tavecchio

MAGIC sensitivity

Aleksić et al. (MAGIC) Astropart.Phys, 72, 2016

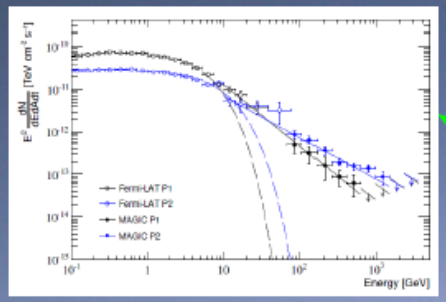


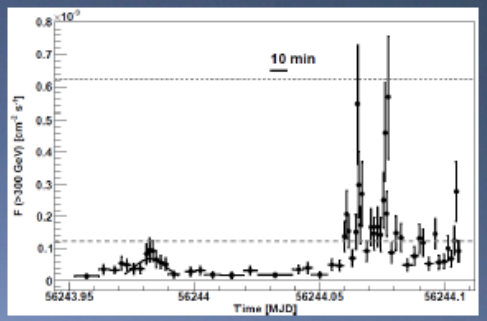
MAGIC Science

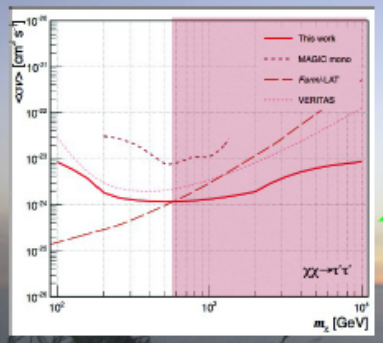
MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescope

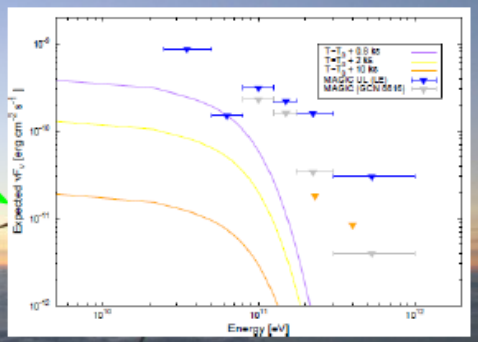
Galactic sources:
Pulsars, PWN, SNR, Binaries

AGNs:
BL Lacs, FSRQs, Radio galaxies









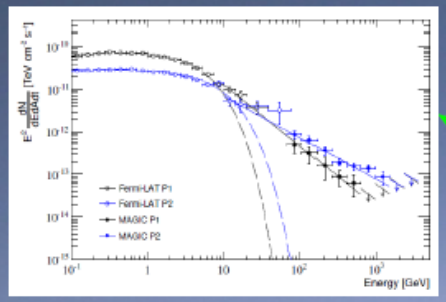
Fundamental physics:
Dark matter, LIV, EBL, IGMF & cosmology

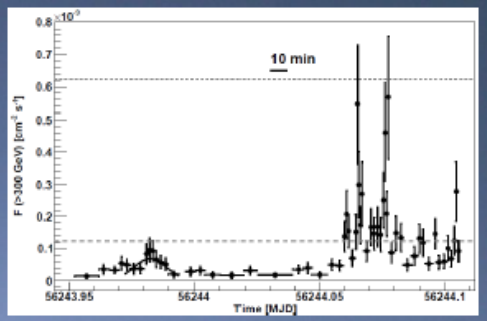
GRBs

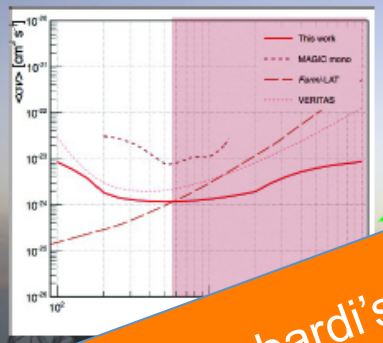
MAGIC Science

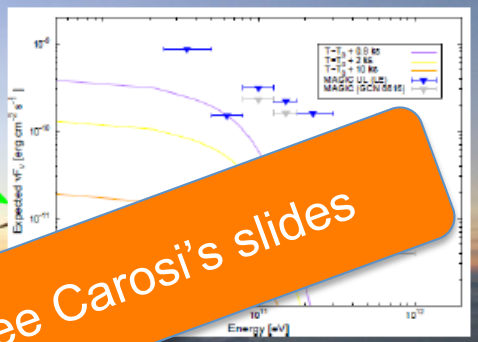
Galactic sources:
Pulsars, PWN, SNR, Binaries

AGNs:
BL Lacs, FSRQs, Radio galaxies









see Lombardi's talk

see Carosi's slides

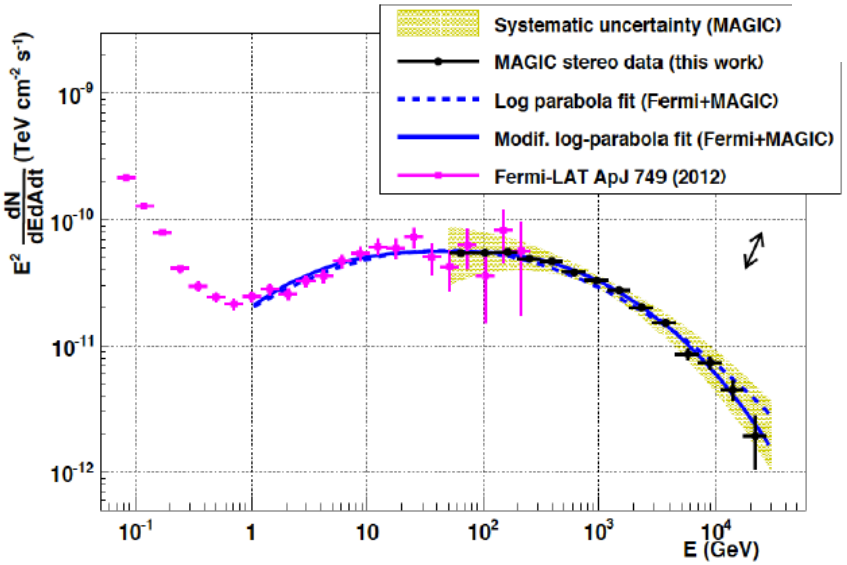
Fundamental physics:
Dark matter, LIV, EBL, IGMF & cosmology

GRBs

Exploring CRAB with MAGIC

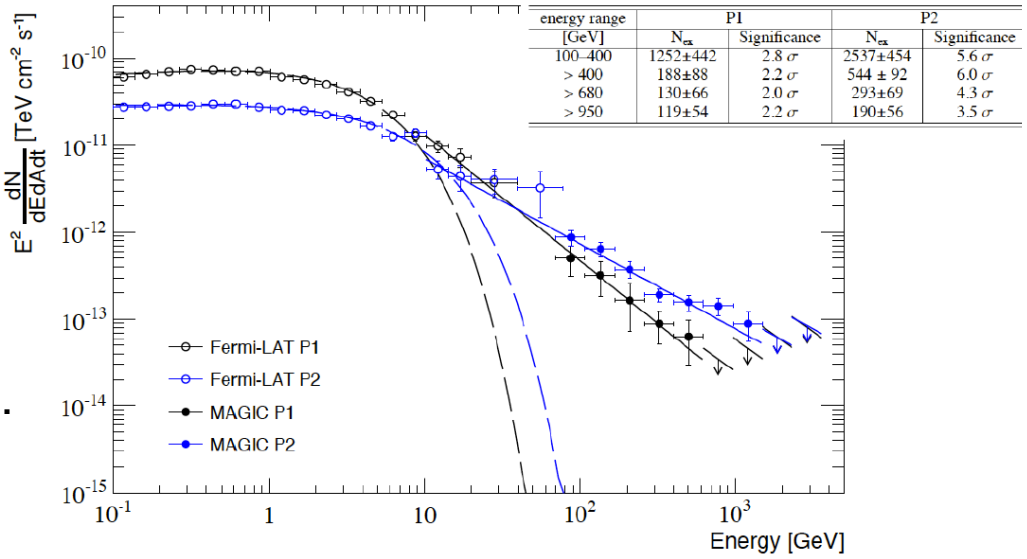
CRAB Nebula:

- High precision energy spectrum: 50 GeV to ~30 TeV, 5 bins per decade.
- Observations at E > 80 TeV (high-Zd) are allowing the K-N regime exploration.
- Combined fit with Fermi data yields the most precise measurement of the IC peak: 52.5 +/- 1.6 GeV



CRAB Pulsar:

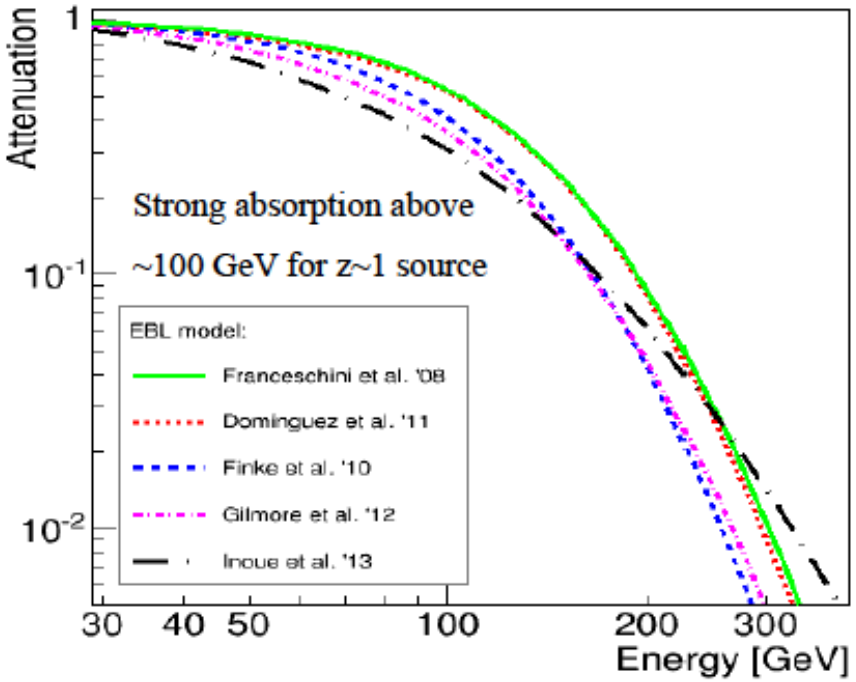
- First detection of Crab Pulsar at VHE back in 2008 (E>25 GeV).
- 320 hours of observation led to the detection above 400 GeV with spectrum extending up to TeV energies.
- A VHE emission “bridge” also detected up to 400 GeV.+++



energy range	P1		P2	
[GeV]	N_{ex}	Significance	N_{ex}	Significance
100–400	1252±442	2.8 σ	2537±454	5.6 σ
> 400	188±88	2.2 σ	544 ± 92	6.0 σ
> 680	130±66	2.0 σ	293±69	4.3 σ
> 950	119±54	2.2 σ	190±56	3.5 σ

Extragalactic Astrophysics

- The MAGIC Low-Energy Threshold allows to observe also objects at high redshift otherwise absorbed by Extragalactic Background Light.
- Farthest objects ever observed at VHE are FSRQ, most part of them has been discovered by MAGIC.
- At present the farthest FSRQ detected at VHE is at z=0.939.



FSRQ	*Redshift*	*First VHE detection by:*	*Year*
3C 279	0.536	**MAGIC**	2006
PKS 1510-089	0.361	HESS	2009
PKS 1222+216 (4C +21.35)	0.432	**MAGIC**	2010
B0218+35	**0.944**	**MAGIC**	**2014**
PKS 1441+25	**0.939**	**MAGIC**	**2015**
S4 0954+65*	0.368	**MAGIC**	**2015**

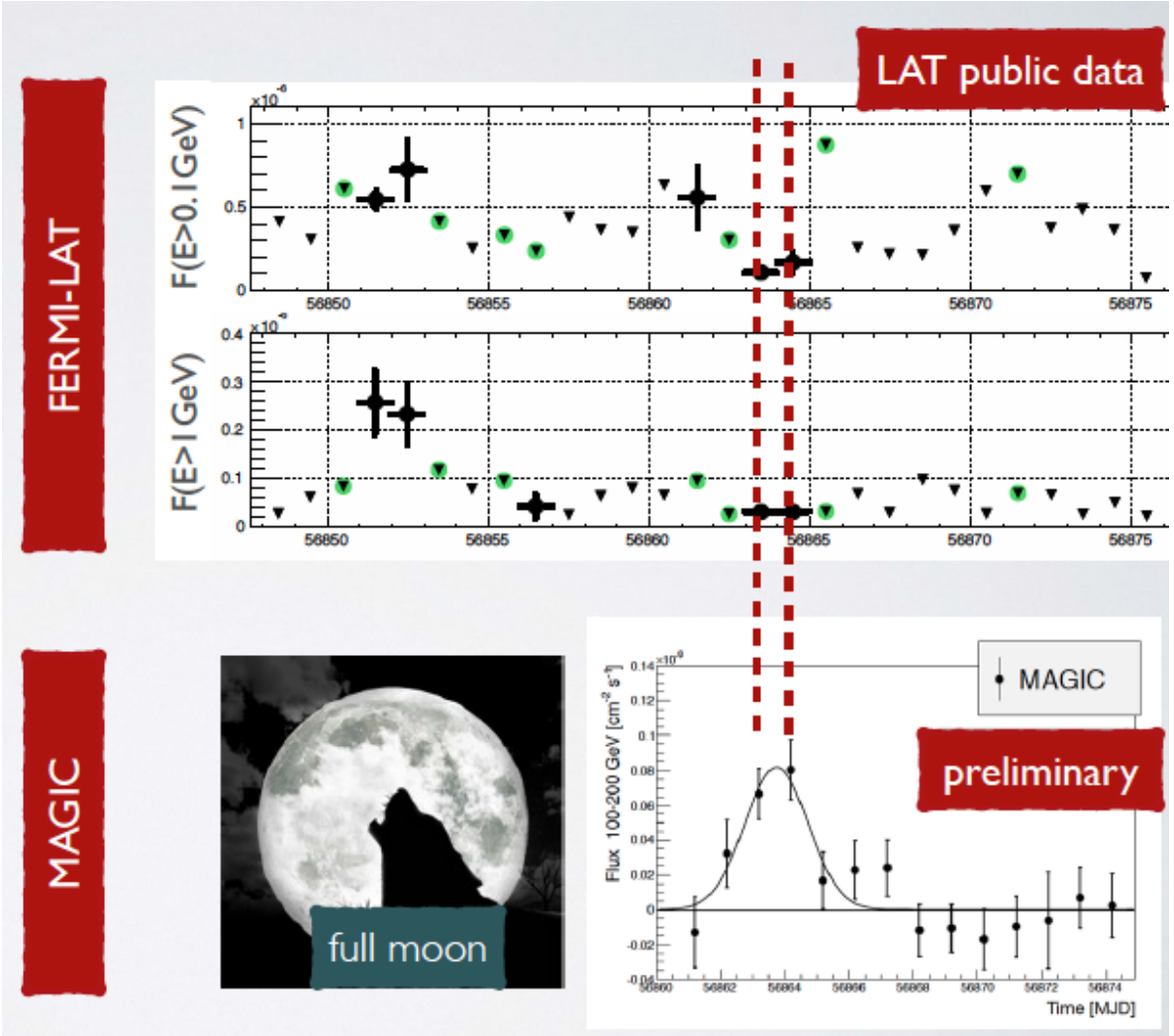
Detection of the first gravitationally lensed VHE emission: the blazar S3 0218+357

LAT-observations in July '14:
spectral hardening
(Buson et al. ATel #6316)

A real pity:
no MAGIC observations right at the flare (full moon)

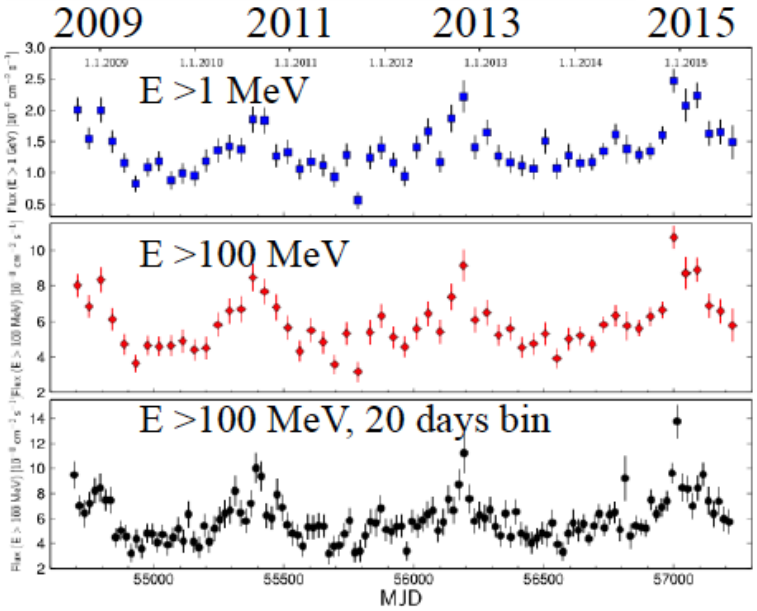
but ~10 days later:
=> delayed emission!
signal with >5σ
in 4 consecutive nights,
point-like source

ATel#6349
MAGIC discovery



Periodic signal from a BH? PG1553

Ackermann et al., ApJL 813, 2015

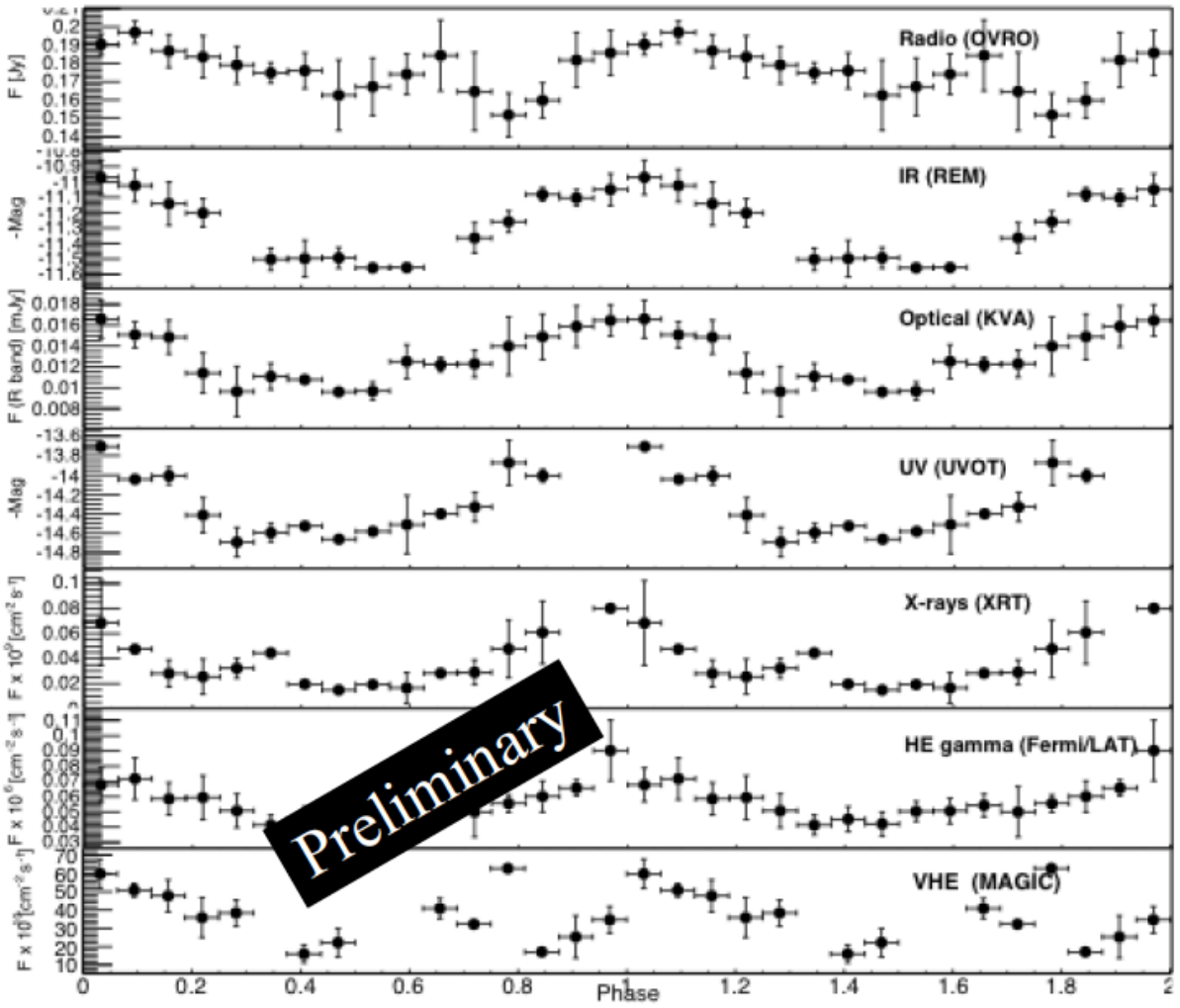


Fermi Collaboration has reported the detection of periodic signal (T=798 d)

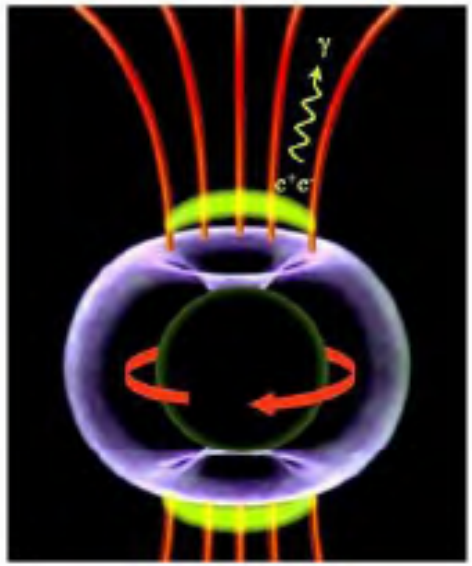
Since 2014, intense MWL campaign

Well known at VHE, sparse sampling since 2005

Folded MWL Light Curves



Extreme Flares: the case of IC310

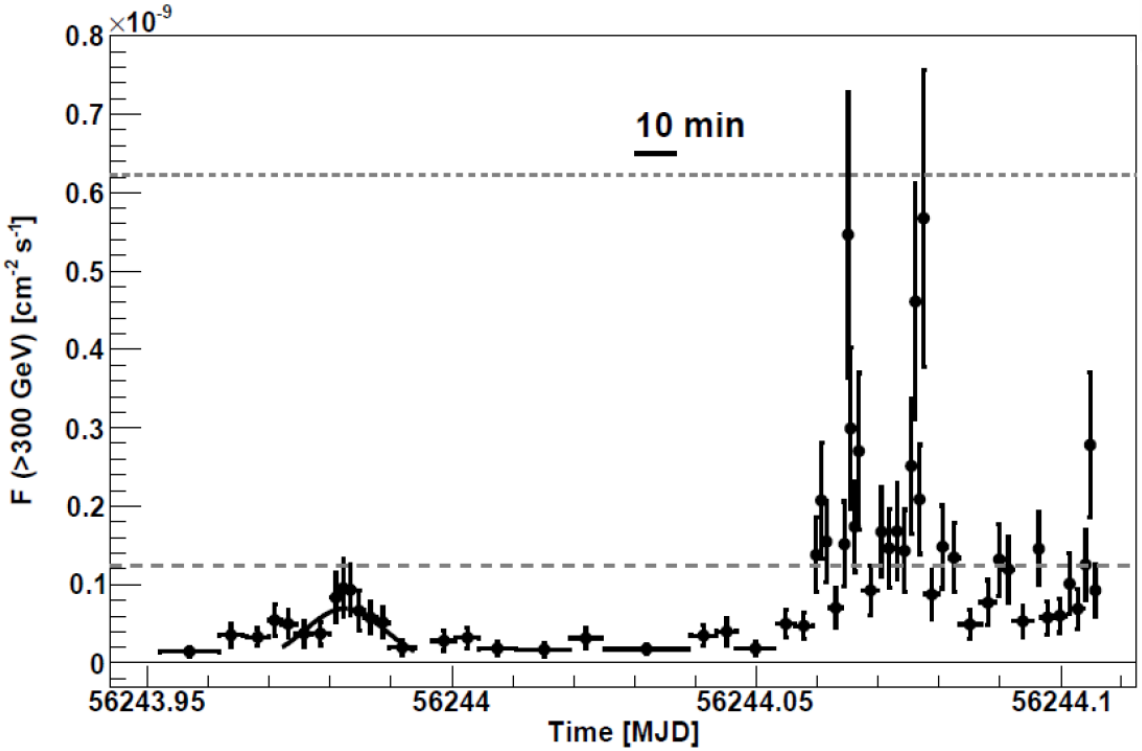


Flaring activity with ultra-fast variability (< 5 min) detected in 2012 => sub-horizon variability challenges shock-in-jet models.

Possible scenarios:

- mini-jet
- jet-cloud interactions
- magnetospheric origin of gamma-rays

Aleksić et al. (MAGIC) Science 346, 2014



Very High Energy Sky

161 sources in 2016 (vs 3 in 1996, 12 in 2003)

32 new sources detected by MAGIC (24 AGNs)

110 peer reviewed papers (5 Science)

Conclusion

MAGIC is at its most productive time in terms of physics. MAGIC sensitivity allows the/to:

- Comprehension of acceleration mechanism in pulsars
- Detailed broad band studies of Crab Nebula,
- Long term behaviour of binary systems and AGNs
- Access the ultra fast variability in AGNs (minute scale)
- Increase the accessible volume of the Universe (up to z~1)
- Measurements on the EBL density at different redshifts
- Dark matter searches leading to best limits on dark matter cross-section from dSph.
- Effectively search for GRBs or fast transients.