MAGIC Highlights

Rubén López-Coto on behalf of the MAGIC Collaboration - IFAE, Barcelona

Rome International Conference on AstroParticle Physics - Noto - 02/10/14

Overview

The MAGIC telescopes

Galactic sources

- Crab nebula and pulsar
- The PWN 3C 58

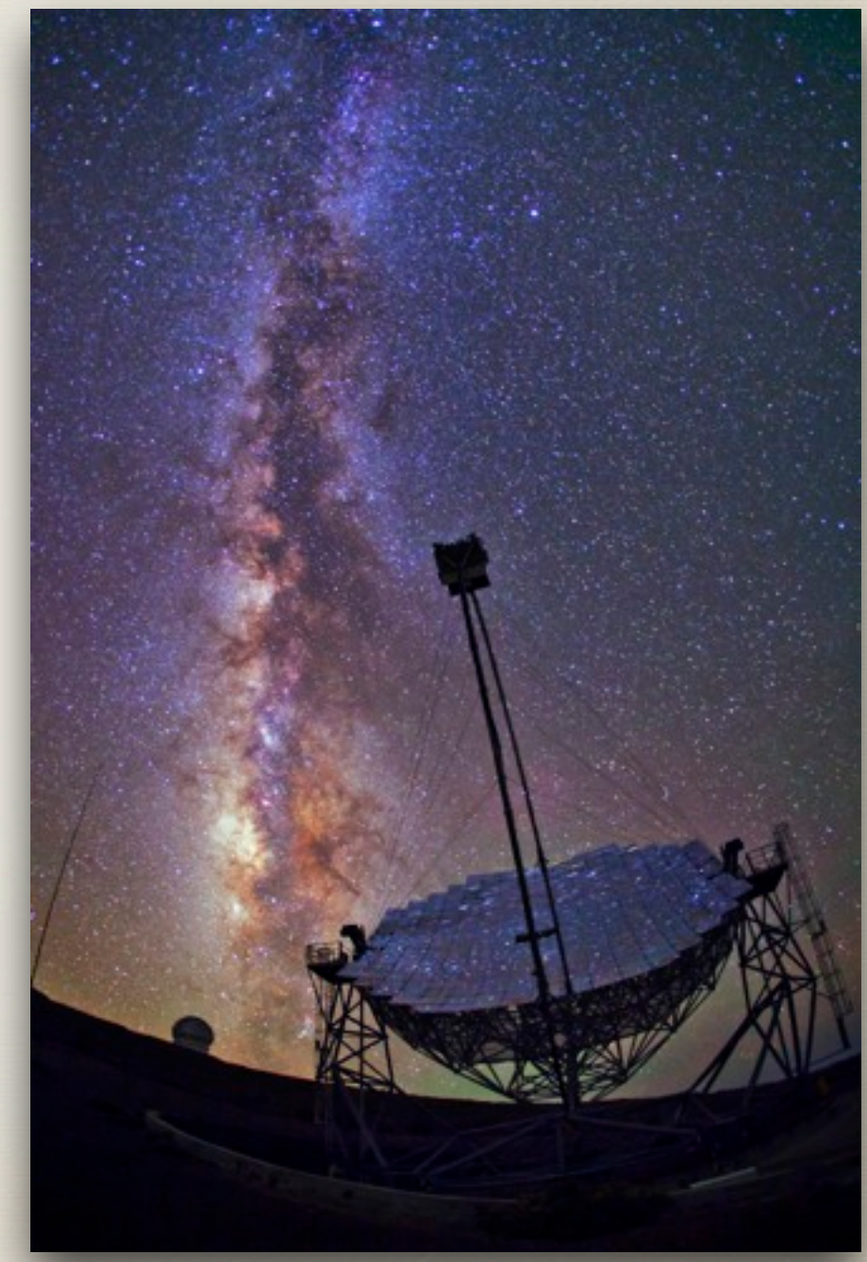
Extragalactic sources

- IC 310 radiogalaxy

Dark matter searches

- Segue1

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/180º).
The telescopes were recently upgraded to homogenize the system.

The MAGIC location

The Canary Island of La Palma (Spain) hosts one of the best astronomical observatories in the world.

The Observatory “Roque de los Muchachos” is at 2200 m a.s.l. It has one of the clearest skies in the world.

Observatory

MAGIC Upgrade

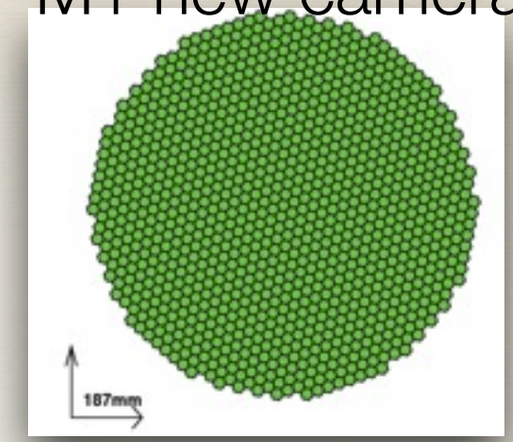
We had two different telescopes making the maintenance and operation twice as difficult
We exchanged:

- M1 camera (577 pixels (different sizes) -> 1039 pixels)

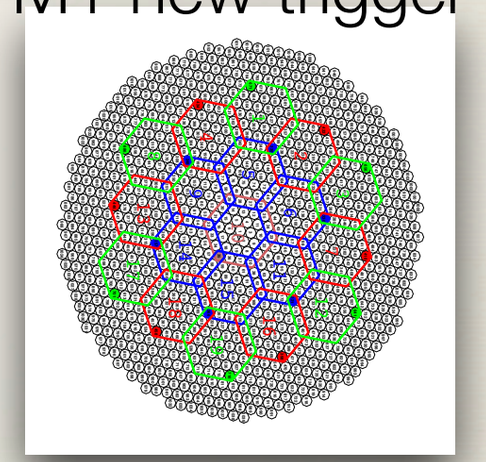
- M1 trigger region size was increased by 70%

- Readout system (dead time reduction from 500 μs to 26 μs)

M1 new camera



M1 new trigger



DRS4 readout

MAGIC Performance

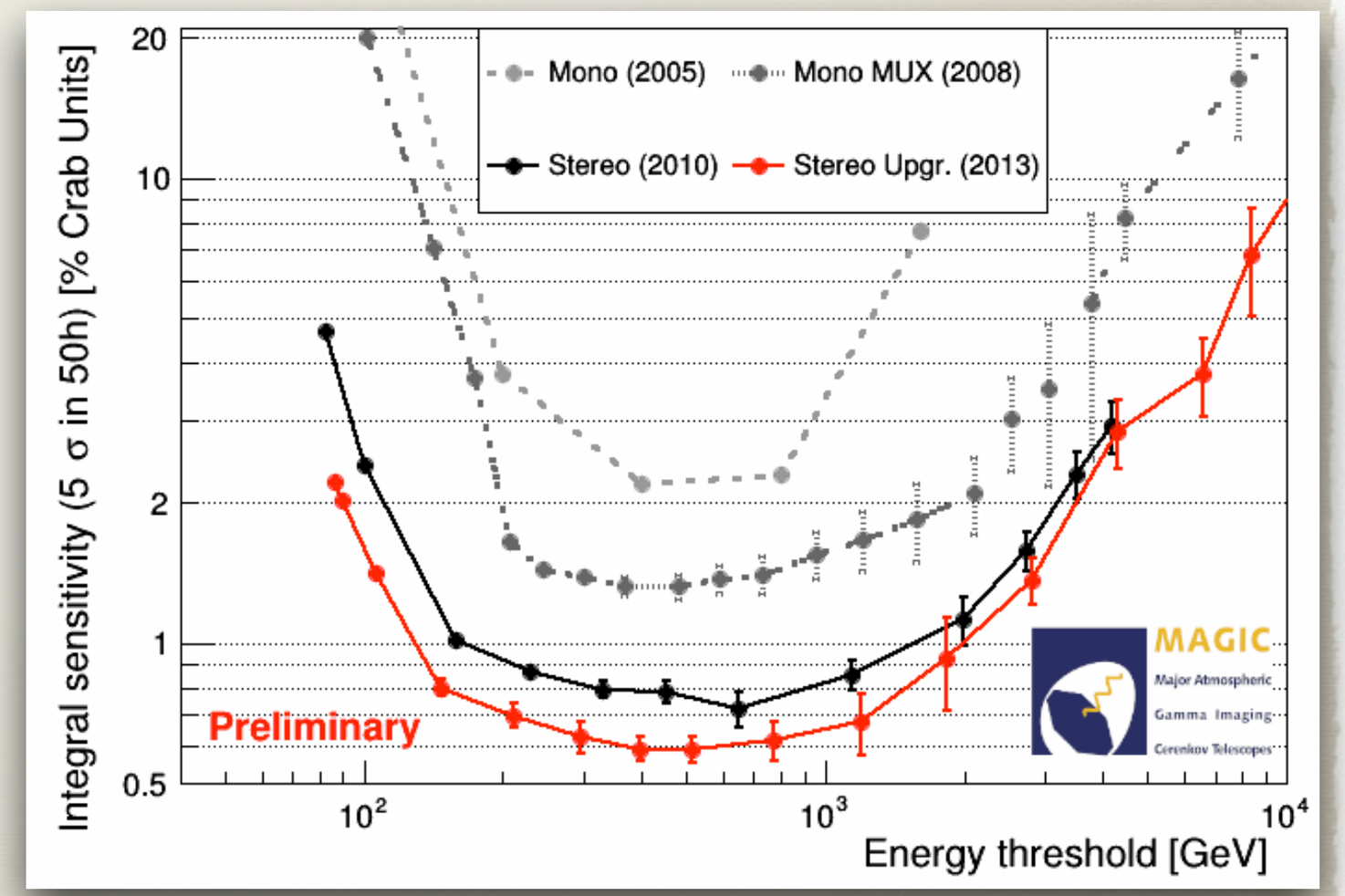
Performances of upgraded system today:

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

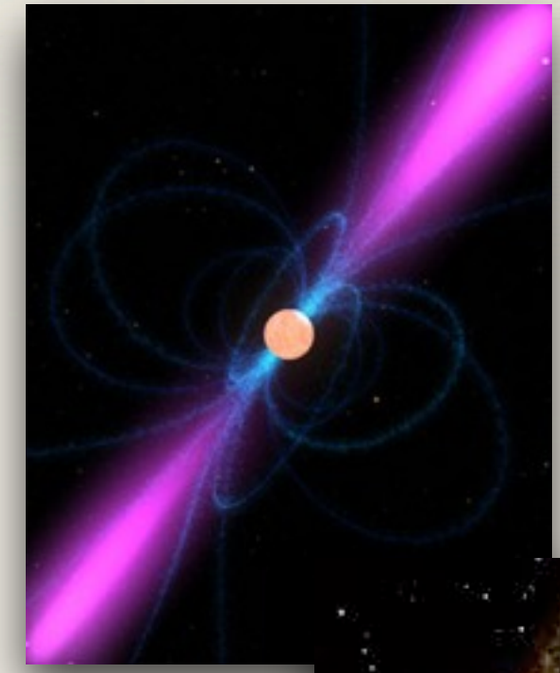


Forthcoming publication

SCIENTIFIC HIGHLIGHTS

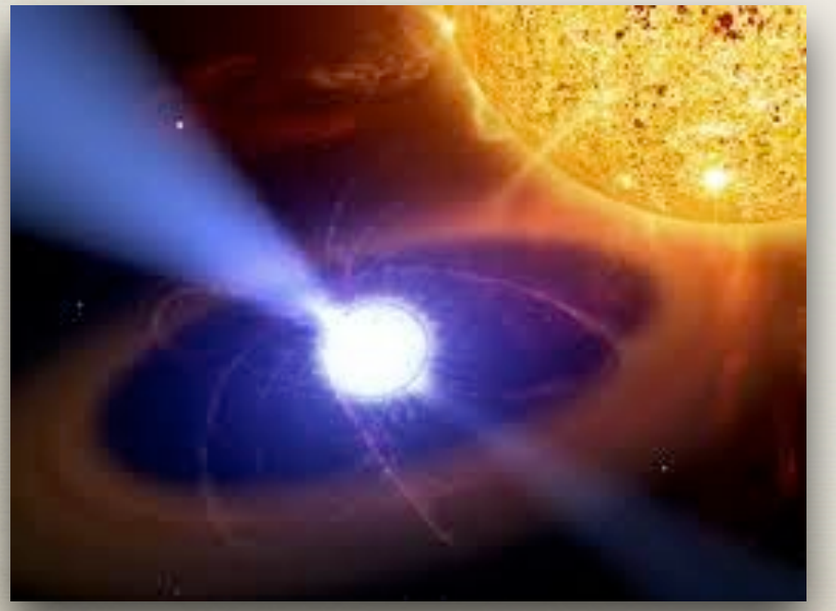
GALACTIC SOURCES

SNRs



Pulsars

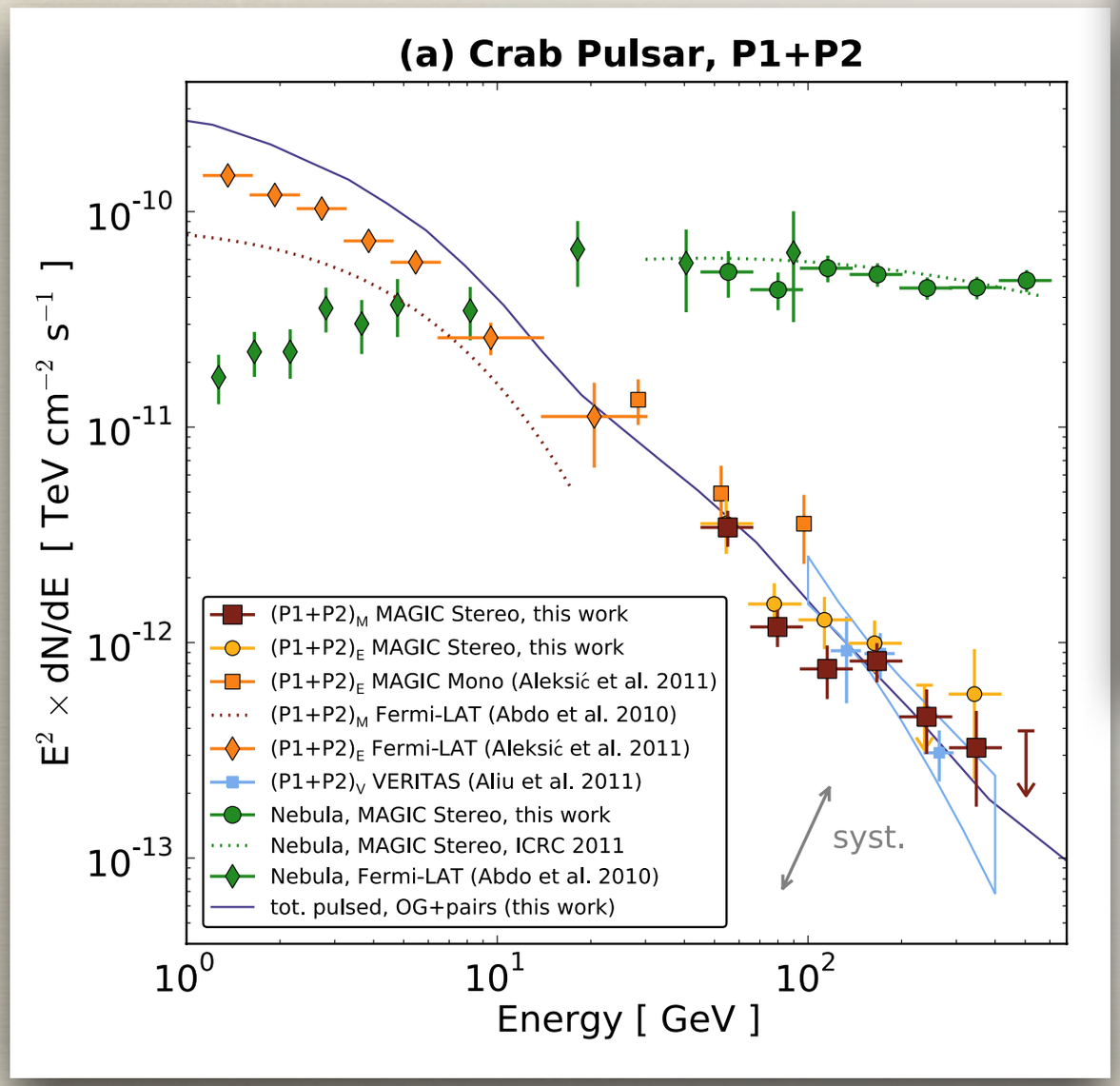
PWNe



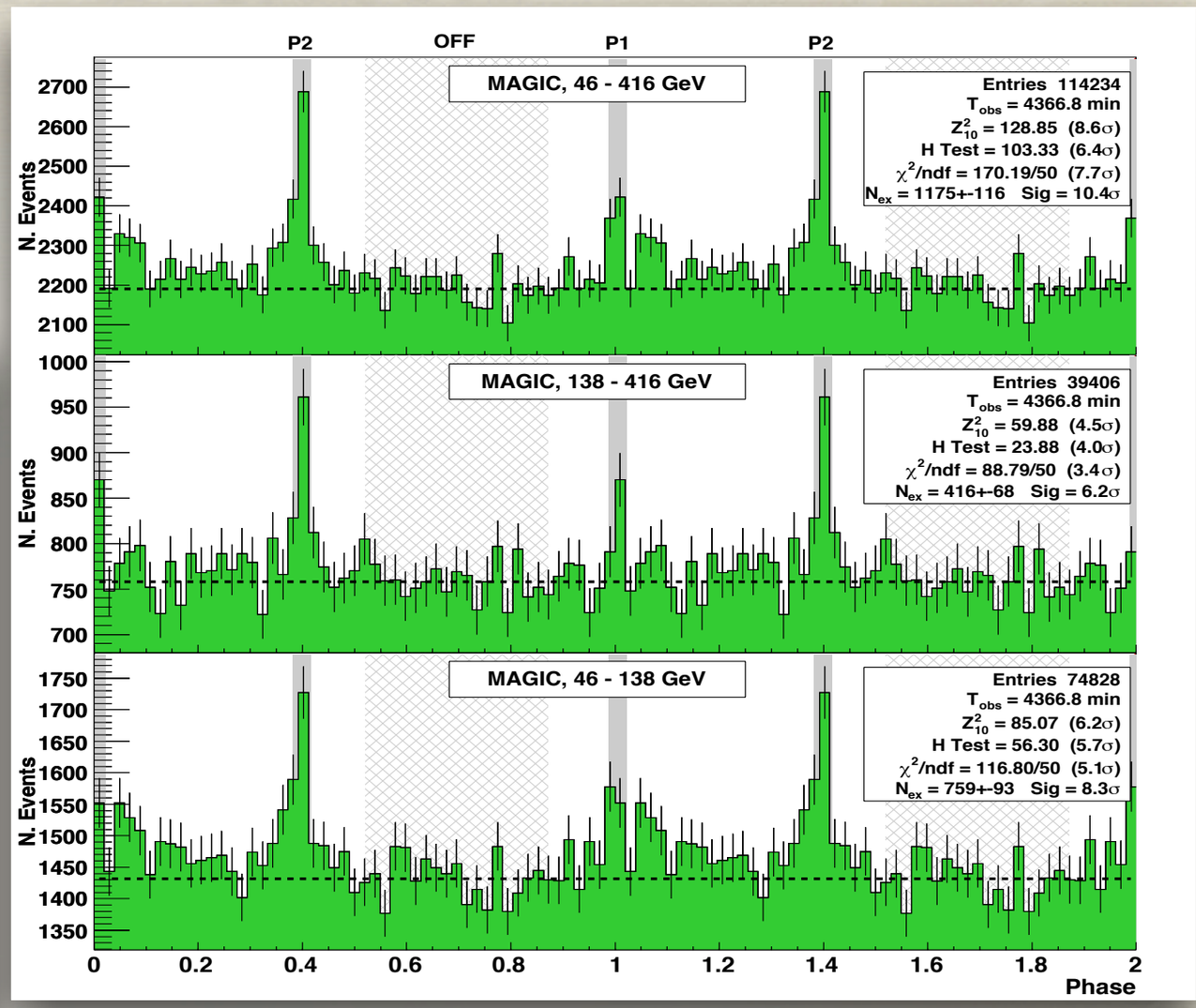
Binary systems

Crab Pulsar

MAGIC discovered pulsed gamma-ray emission above 25 GeV (Science, 2008, 322, 1221).



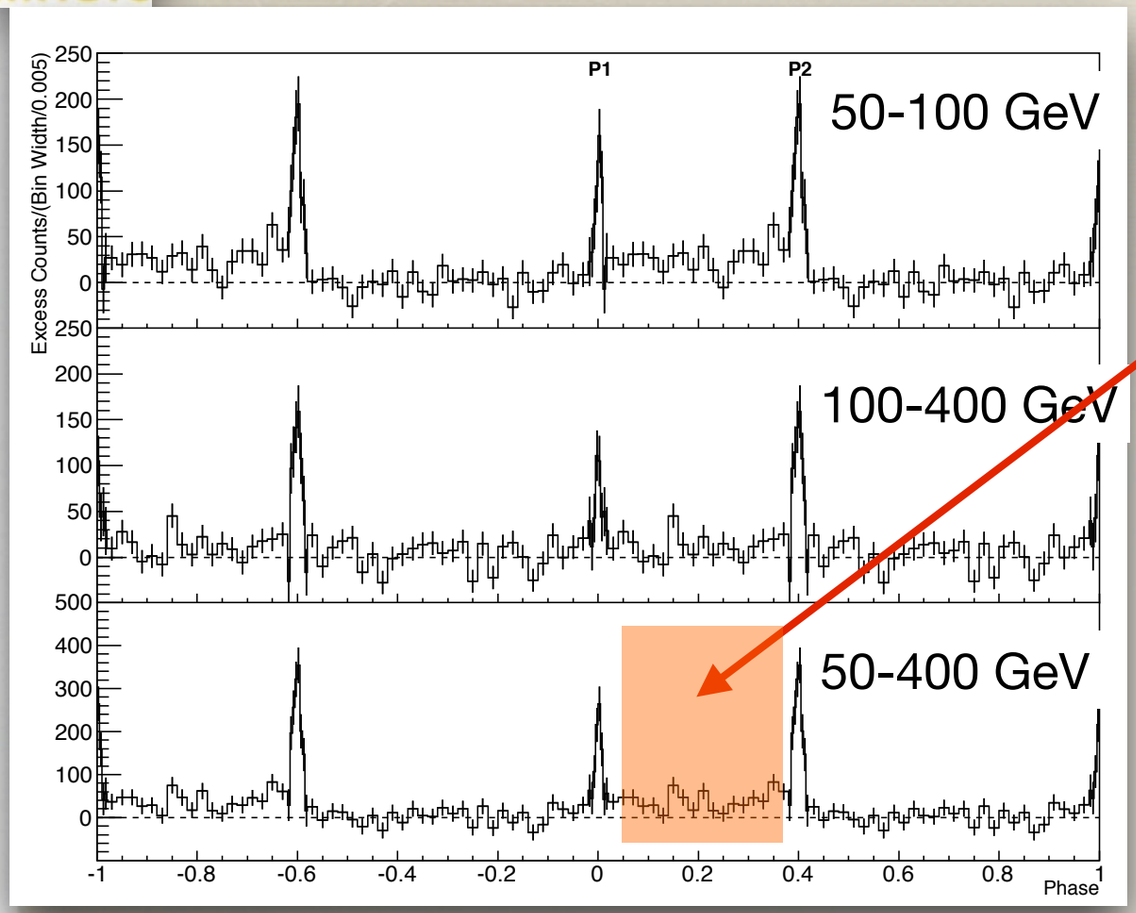
J. Aleksić et al. (MAGIC Coll.), A&A. 540 (2012) 69



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.

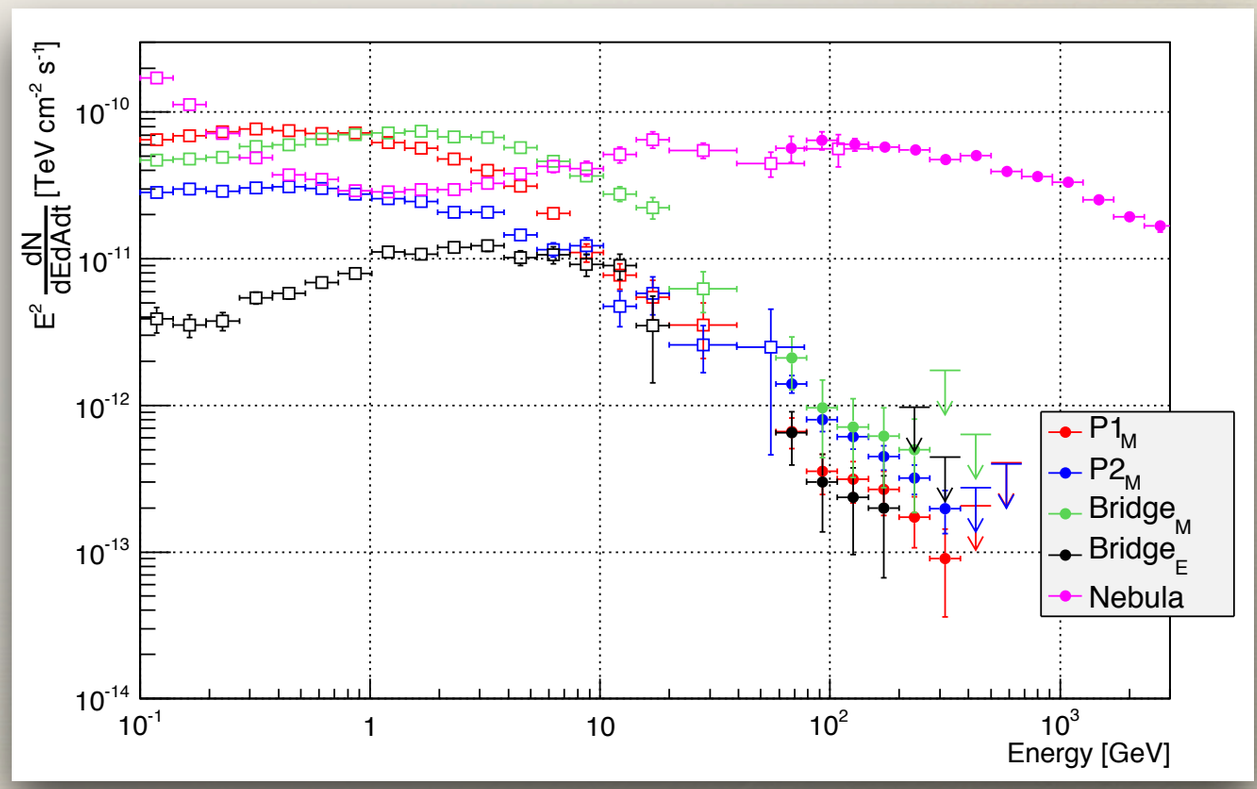
Crab Bridge



J. Aleksić et al. (MAGIC Coll.), A&A, 565 (2014) L12

Recently, MAGIC has discovered VHE emission from the bridge region between the two peaks extending beyond 100 GeV

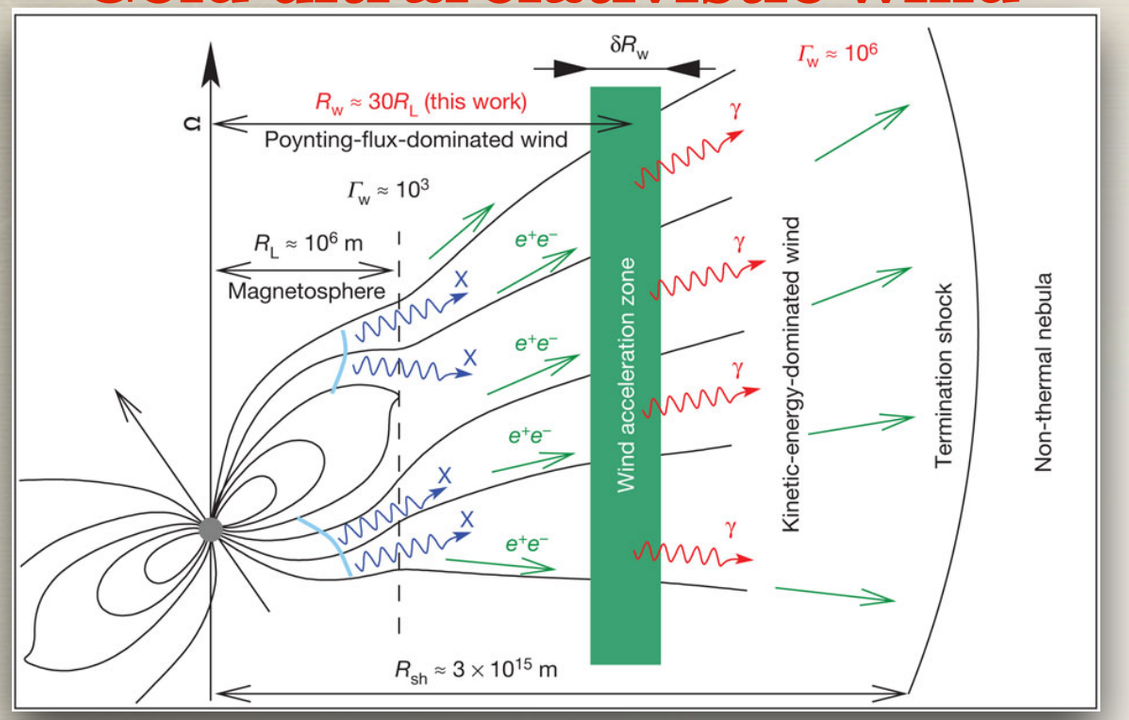
The bridge emission was detected with a significance above 6 σ for energies above 50 GeV



J. Aleksić et al. (MAGIC Coll.), A&A, 565 (2014) L12

(A couple of) VHE pulsar models

Cold ultrarelativistic wind

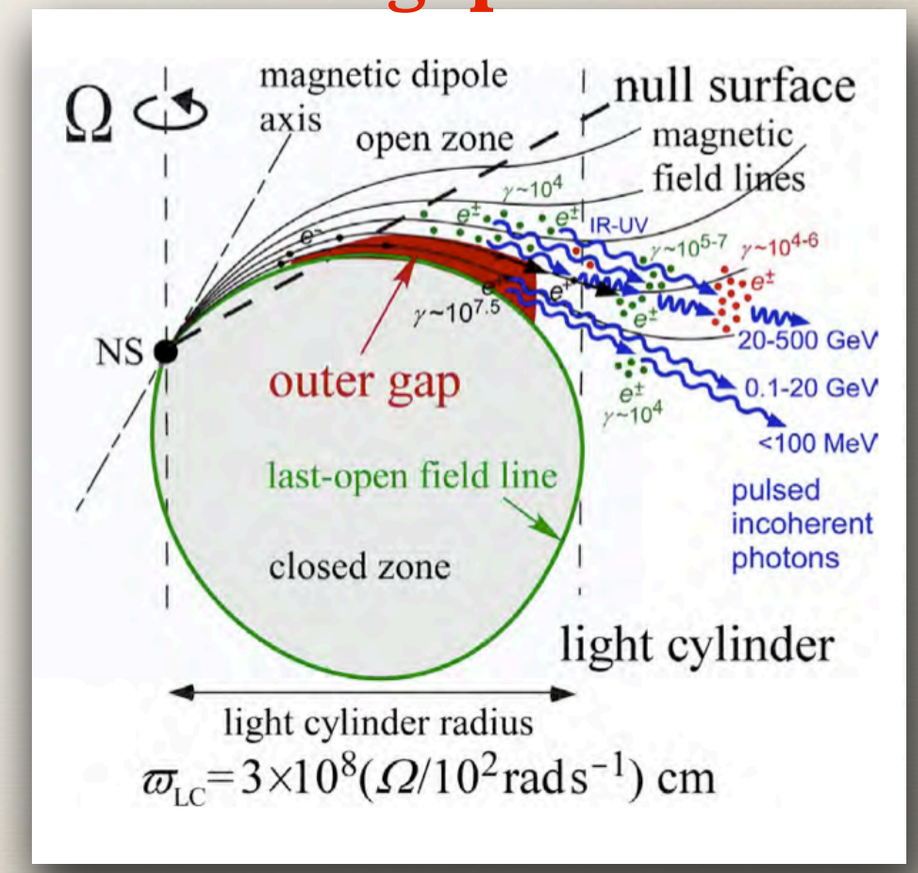


Aharonian, F. et al., Nature 482 (2012) 507

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

Predicts bridge emission but broader peaks than observed.

Outer gap



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

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.

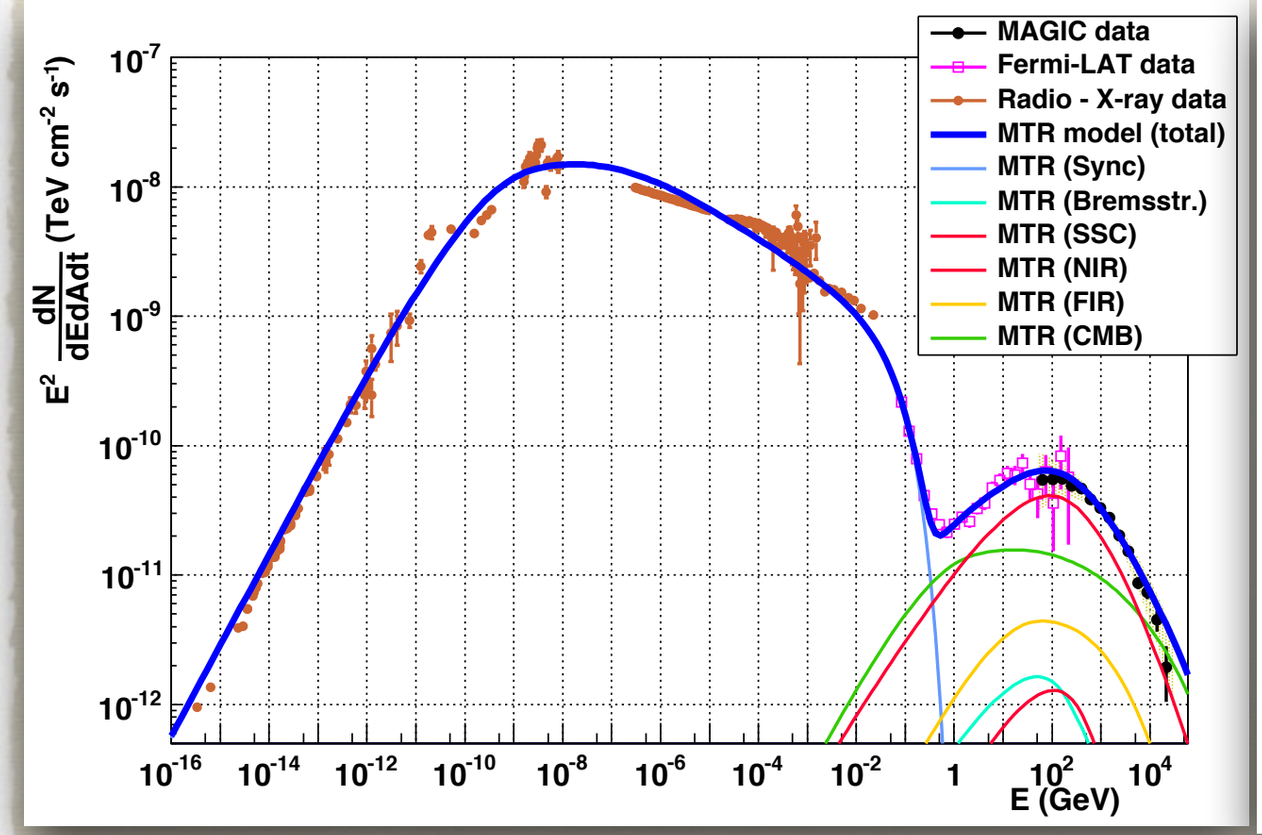
The Crab Nebula

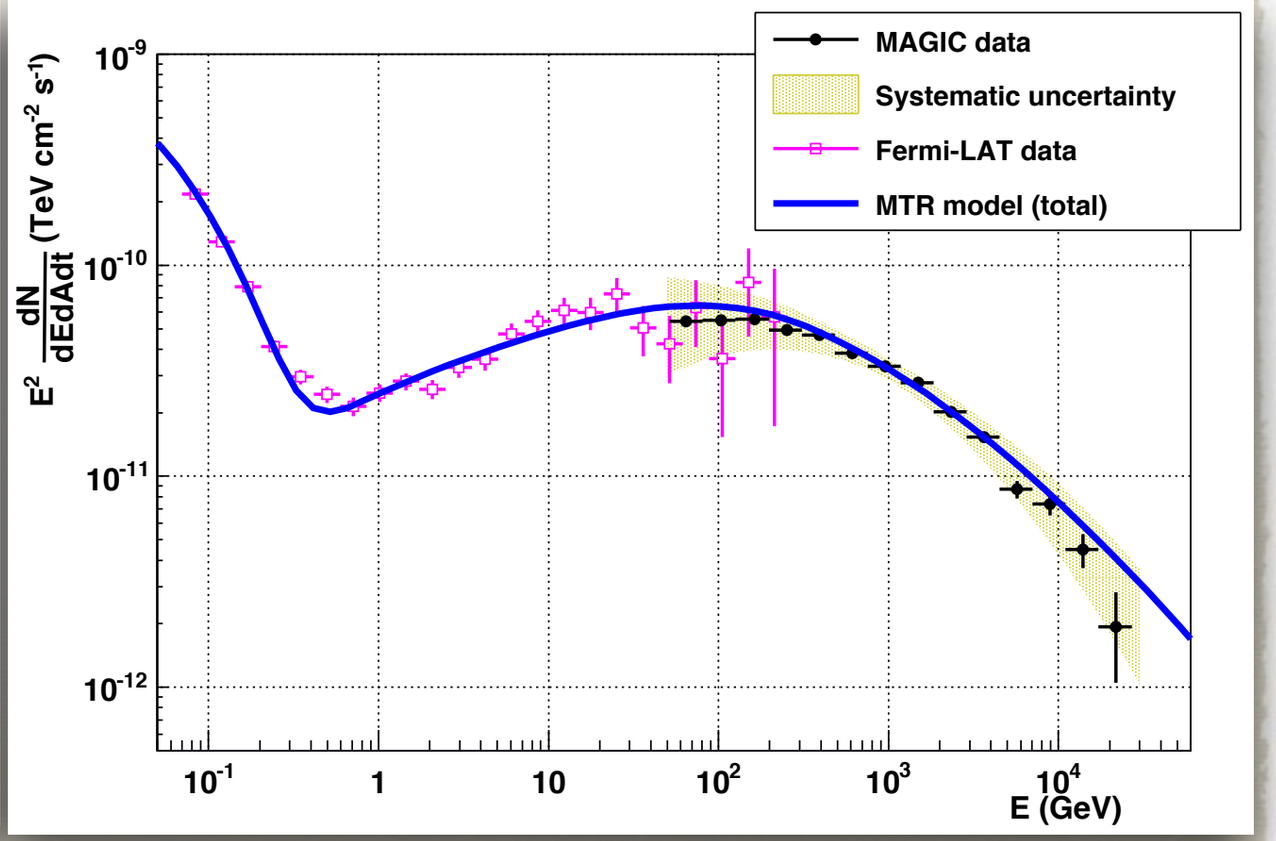
New results with 70 hours of stereo observations (2009-2011)

Spectrum extends from 50 GeV to ~30 TeV (statistical error 5% at 100 GeV)

In combination with Fermi-LAT, the IC peak is measured at $53 \pm 3_{stat}$ GeV with a bad χ^2, showing that the log-parabola is not a good representation of the IC peak

All the tested models have too simplistic assumptions and none of them can explain the MW spectrum of the Crab nebula





Aleksić et al. JHEAP submitted (arXiv:1406.6892)

The PWN 3C 58

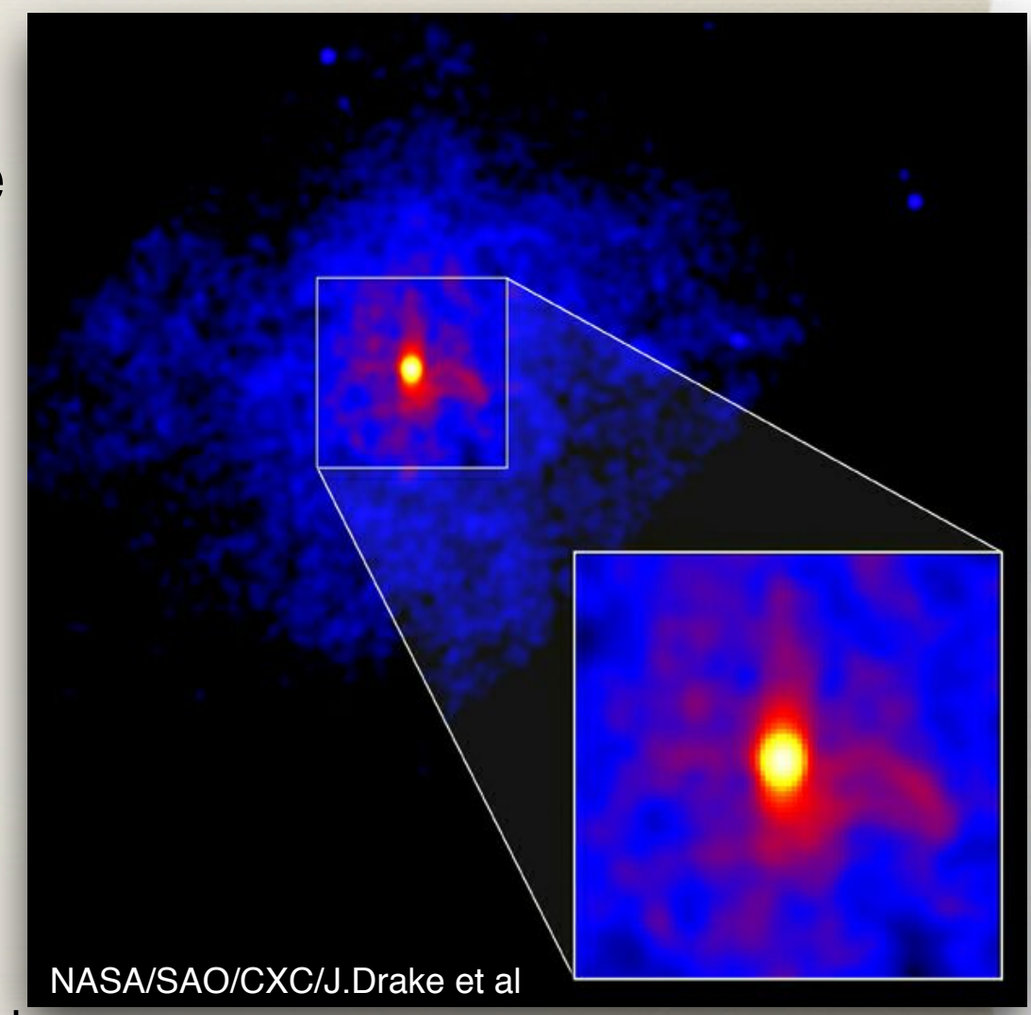
Centered in PSR J0205+6449 ➜ One of the highest spin-down pulsars in the sky: E(dot)=2.7×10^{37} erg s^{-1} (5% Crab pulsar).

3C 58 has been compared to Crab due to the jet-torus morphology ➜ One of the classical sources considered to emit gamma rays.

Distance 3.2 kpc or 2kpc
Age: 2.5 kyr?

Discovered by Fermi at gamma rays in 2013 with a spectrum extending beyond 100 GeV.

Up to now, there were only upper limits (lowest at 2.3% Crab) at VHE by Whipple, VERITAS and MAGIC

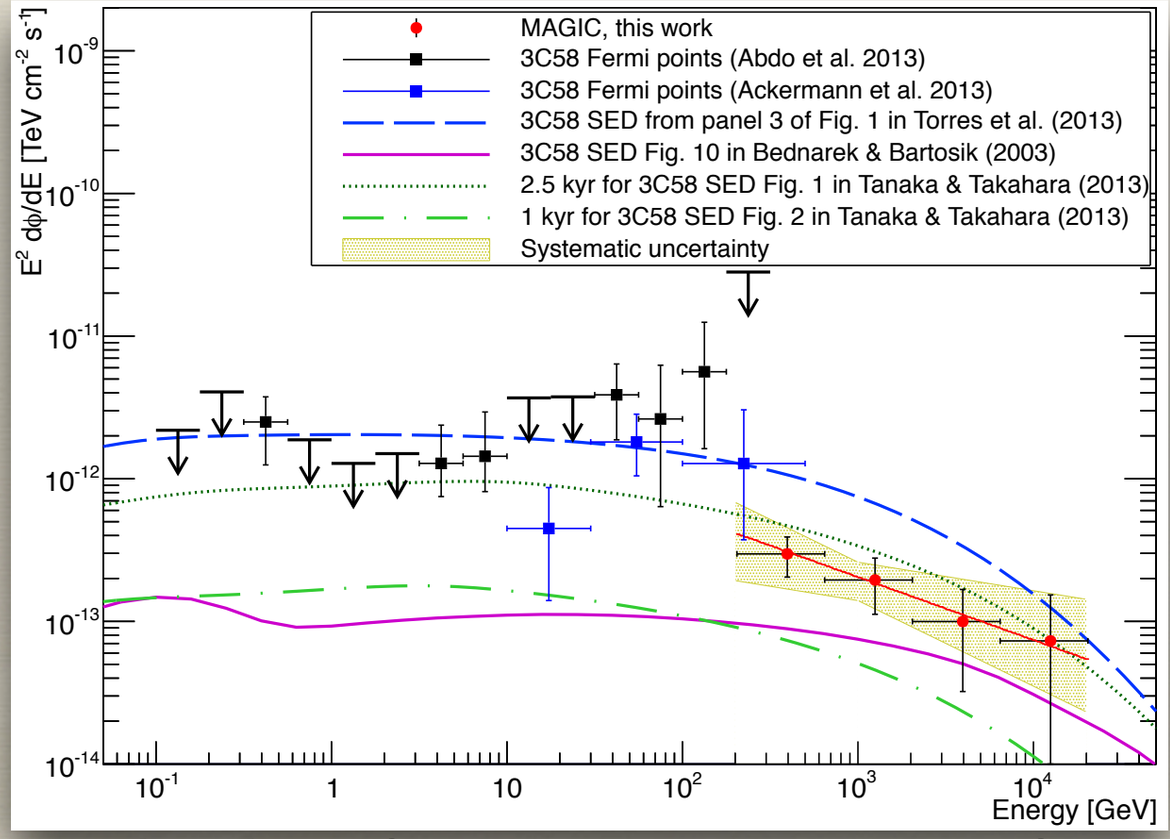

NASA/SAO/CXC/J.Drake et al

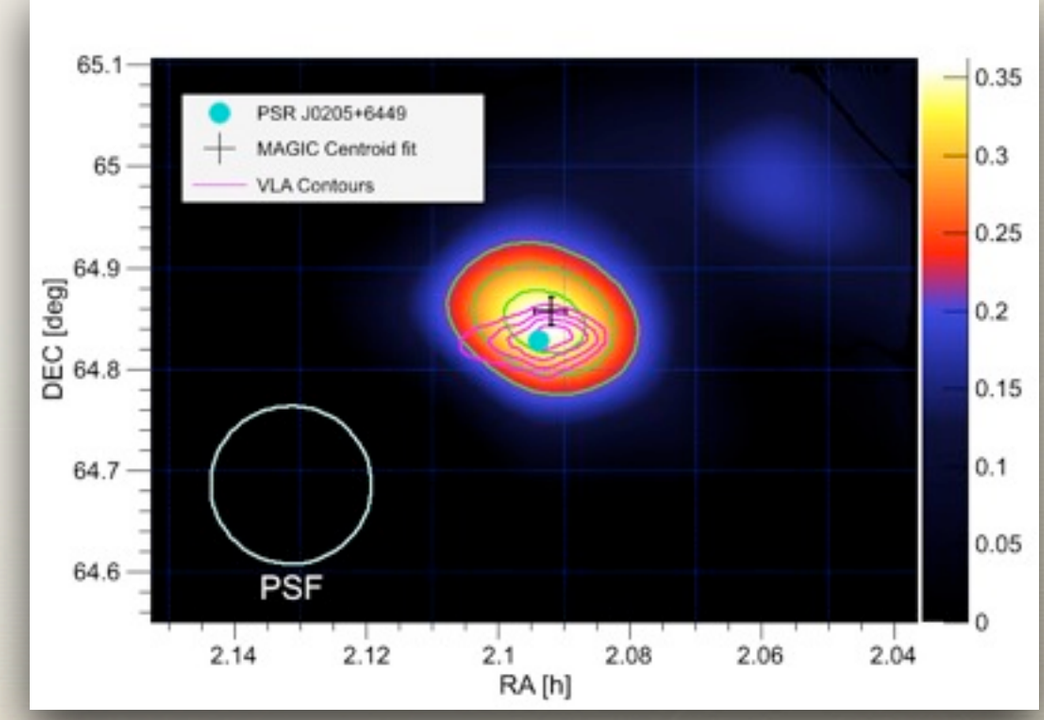
MAGIC got it!

MAGIC discovered a VHE gamma-ray source at the position of 3C 58 (MAGIC J0205+6451) after 81 hours of observations in 2013-2014

We extended the spectrum up to a few tens of TeV.
Above 400 GeV the spectral index is 2.4

Integral flux above 400 GeV is 0.65% Crab (weakest PWN detected at TeV).





Aleksić, J. et al., A&A 567 (2014) L8

MAGIC got it!

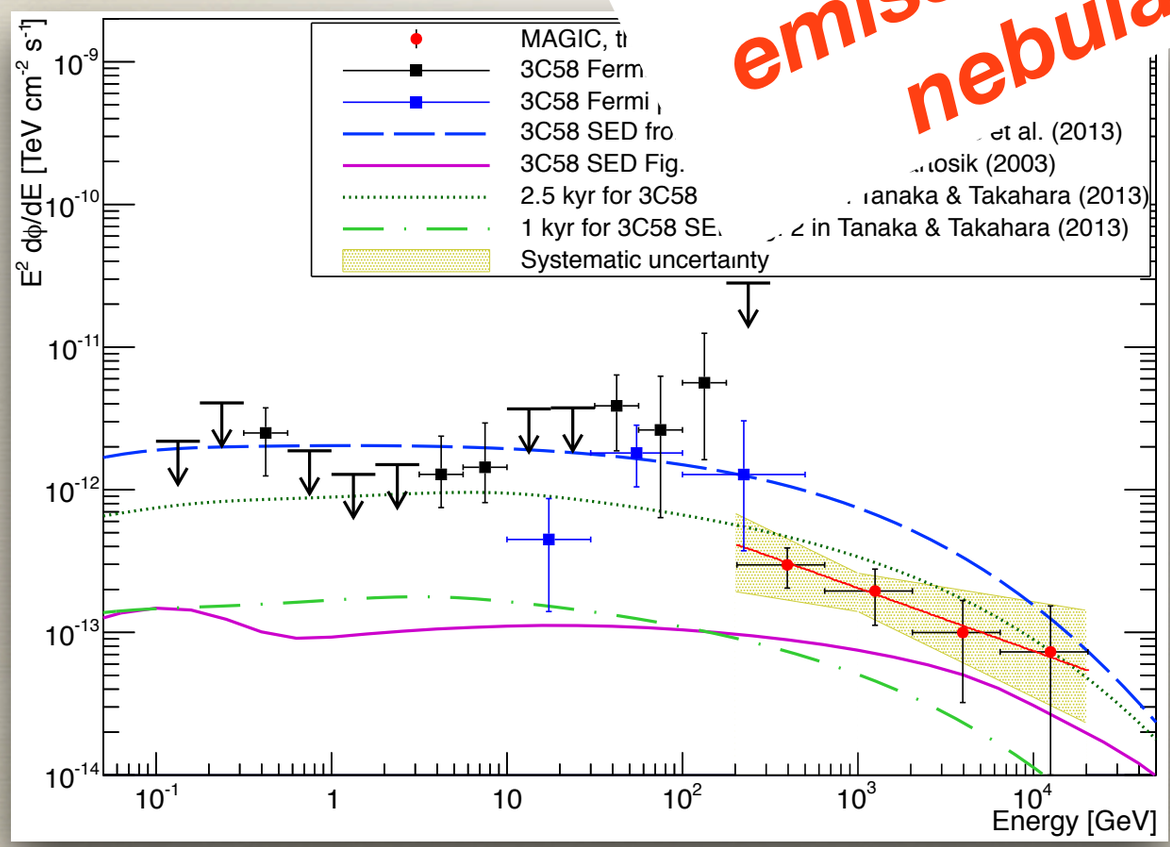
MAGIC discovered a VHE gamma-ray source [illegible] 3C 58 (MAGIC J0205+6451) after 81 hours of observat[illegible]

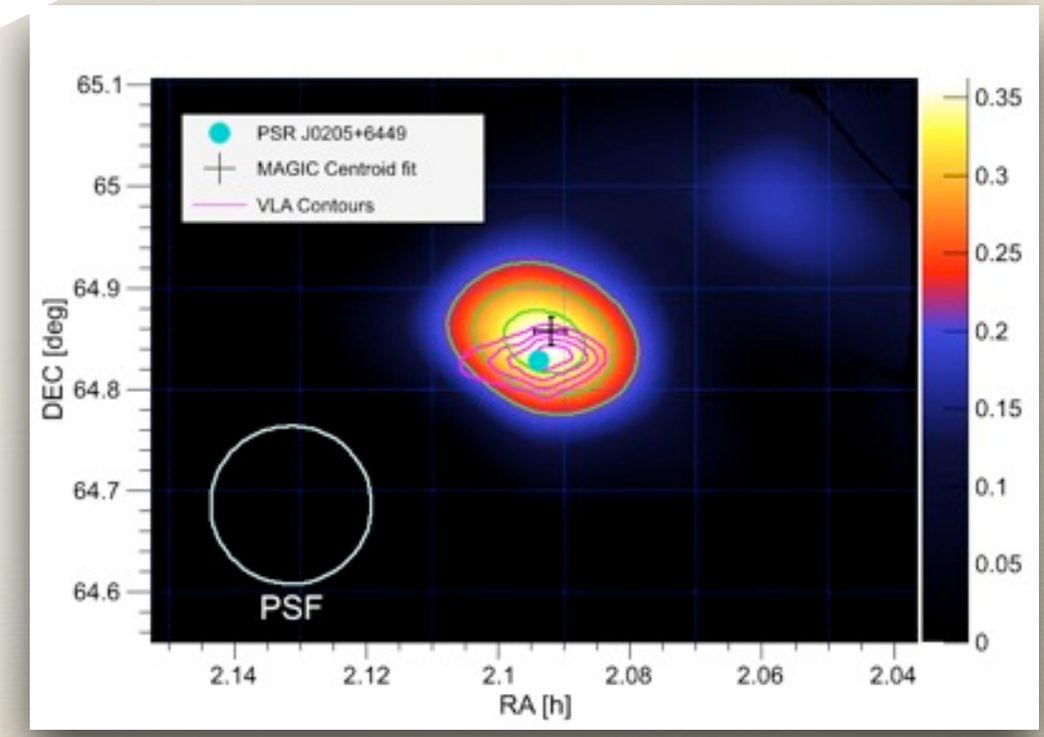
We extended the spectrum [illegible]
Above 400 GeV the sp[illegible]

Integral flux above [illegible] (weakest PWN detected at TeV).

See talk at the Parallel Session F:

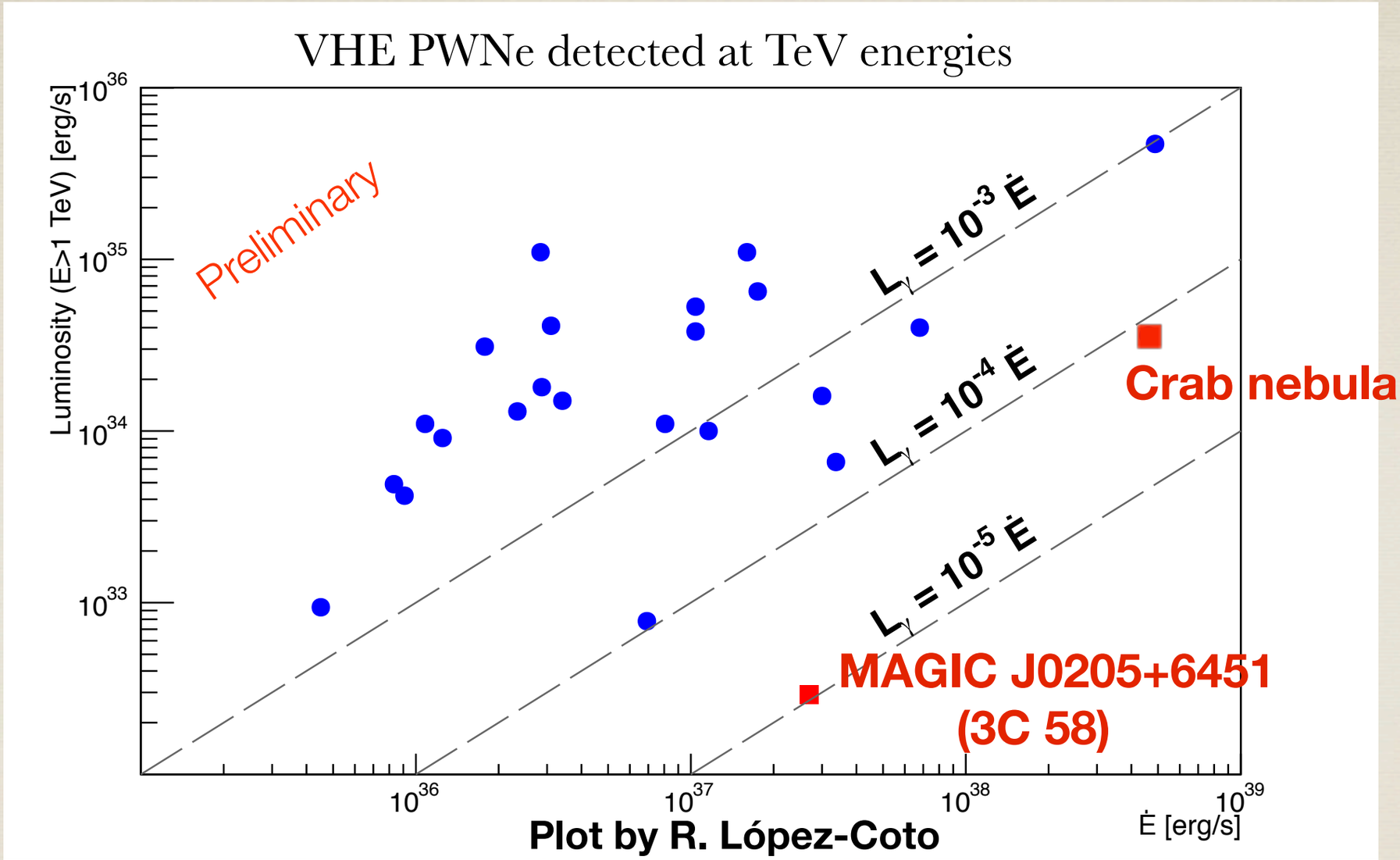
Discovery of TeV gamma-ray emission from the pulsar wind nebula 3C 58 by MAGIC





Aleksić, J. et al., A&A 567 (2014) L8

PWNe detected at VHE



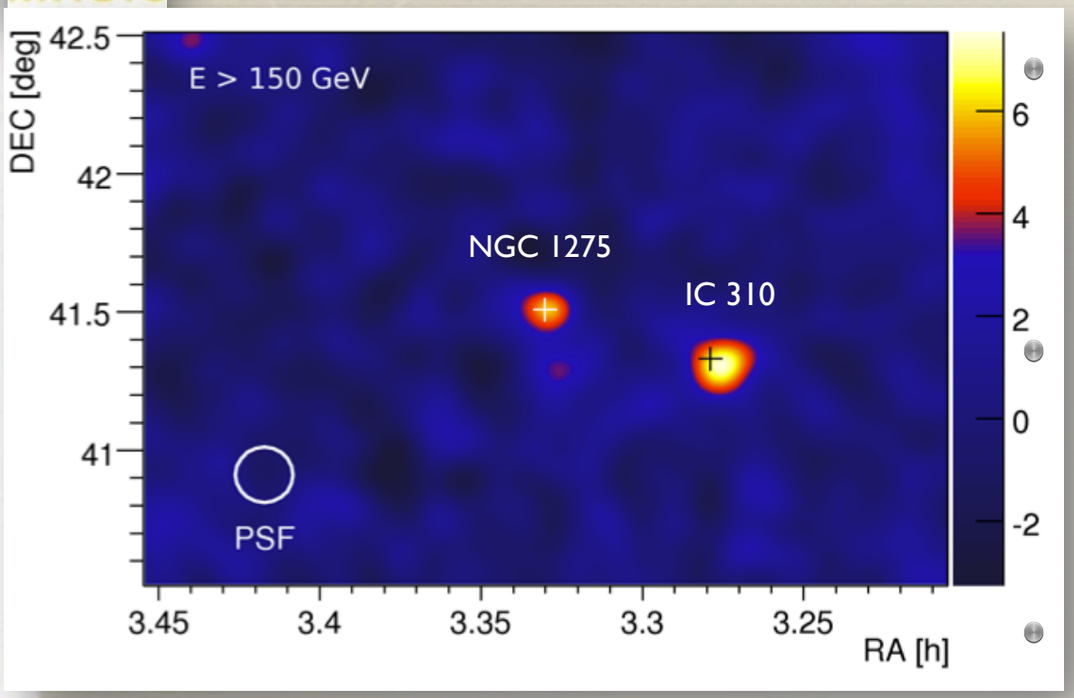
Only models assuming a 2 kpc distance to 3C 58 or an unexpectedly high FIR energy density fit the gamma-ray data → We favor 2 kpc distance

All the models derive magnetic fields lower than 35 μG.

3C 58 is the PWN with the lowest luminosity and the less efficient PWN ever detected at TeV energies to date.

EXTRAGALACTIC SOURCES

The Radiogalaxy IC 310



Aleksić, J. et al., A&A, 541 (2012) 99.

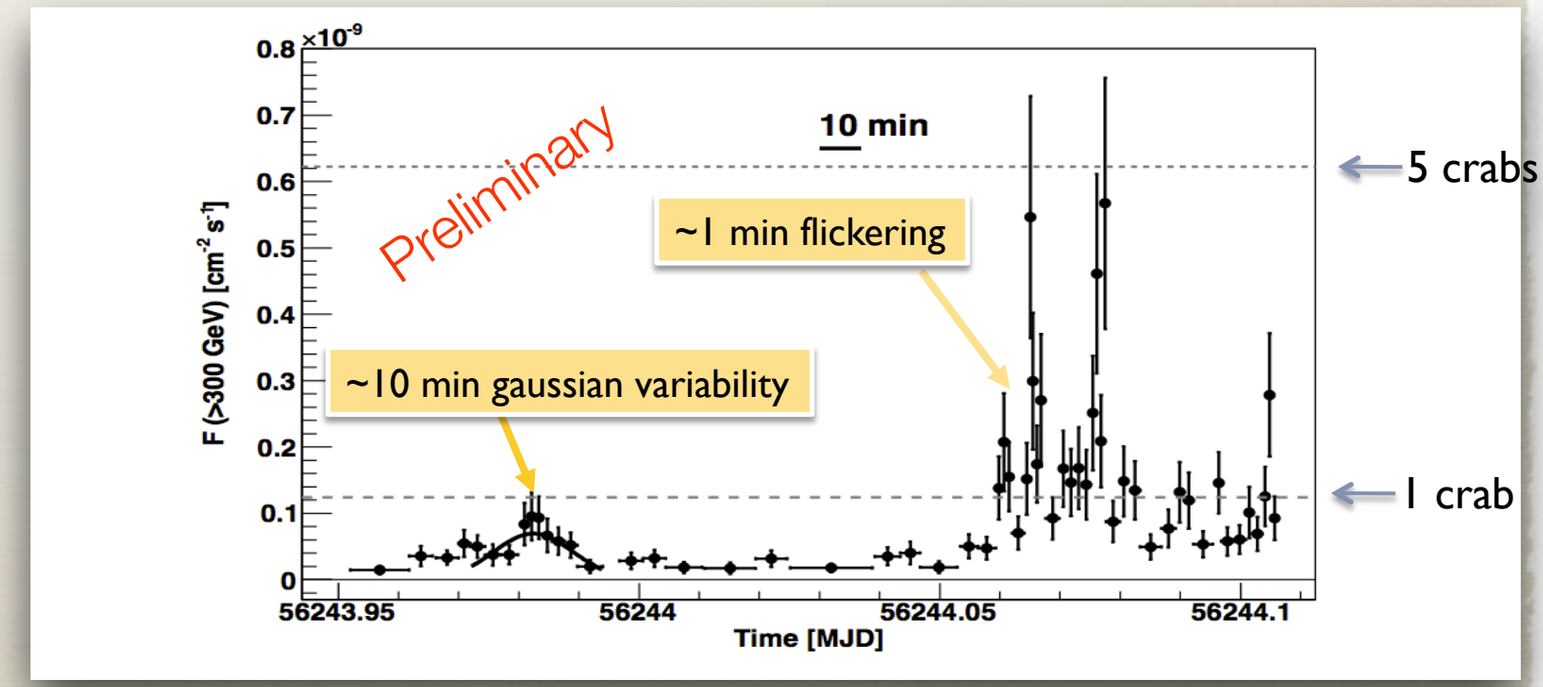
Discovered at VHE on Fermi data (Neronov, A., Semikoz, D., & Vovk, I.2010, A&A, 519) and MAGIC (ApJ, 723 (2010) L207)

Same field of view as the radiogalaxy NGC1275 (also discovered at VHE by MAGIC) -> Both of them in the Perseus cluster.

IC 310 showed day-to-day variability in 2011(A&A 563 (2014) A91).

During flare in 2012 variability was observed with a timescale of 9.5±1.9 min and large amplitude flickering in time scales of the order of minutes

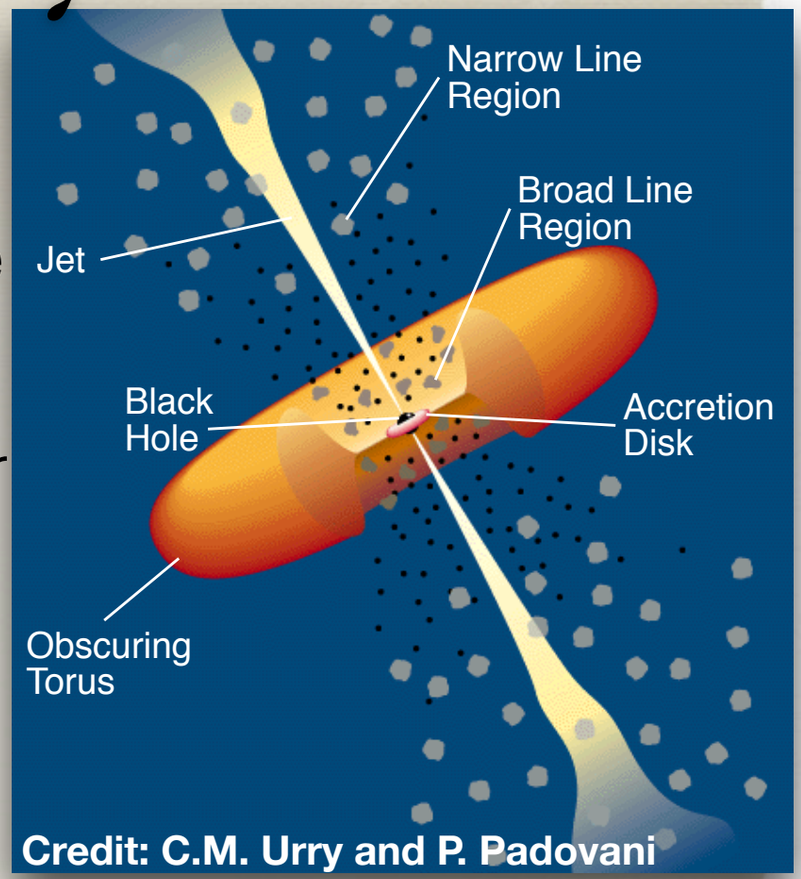
MAGIC: Submitted



Fast variability

For a 3×10^8 $M_\odot$ BH, time flickering of the order of minutes is below the event horizon light-crossing-time

Similar fast variability has been found in VHE Blazars like Mrk 501 or PKS 2155-304 but they have Doppler factors of ~50. IC 310 can have a Doppler factor of 3 – 4 with the jet at 10°-20° from the line of sight. Intrinsic variability is much shorter in IC 310.



Emission seen by MAGIC hard to explain by models:

- Shocks in the Jet? But difficult to explain the event horizon light-crossing-time measured
- Minijets in the Jet pointing towards the line of sight? But it would make luminosity of IC 310 huge
- Jets crossing dense matter clouds or stars? But crossing and pp cooling times are typically longer

S3 0218+357
Farthest AGN ever detected

Discovery of Very High Energy Gamma-Ray Emission From Gravitationally Lensed Blazar S3 0218+357 With the MAGIC Telescopes

ATel #6349; *Razmik Mirzoyan (Max-Planck-Institute for Physics) On Behalf of the MAGIC Collaboration*
on ***28 Jul 2014; 14:20 UT***
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

S3 0218+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


DARK MATTER
Millenium Simulation, MPA Garching, V. Springel, S. White et al.

The Target: Segue 1

Ultra-faint satellite galaxy

The most dark matter dominated object known so far

The least luminous galaxy known

Close, no conventional gamma-ray sources expected, Northern Hemisphere

Segue 1	
Coordinates	$10^h\ 07^m\ 04^s$, $+16°\ 04'\ 55''$
Distance	23 ± 2 kpc
Number of resolved stars	71
Magnitude	$-1.5^{+0.6}_{-0.8}$
Apparent magnitude	13.8 ± 0.5
Luminosity	$340\ L_\odot$
Mass	$5.8^{+8.2}_{-3.1} \times 10^5\ M_\odot$
M/L	$\sim 3400\ M_\odot/L_\odot$
Half-light radius	29^{+8}_{-5} pc
System velocity	208.5 ± 0.9 km/s
Velocity dispersion	$3.7^{+1.4}_{-1.1}$ km/s
Mean [Fe/H]	-2.5

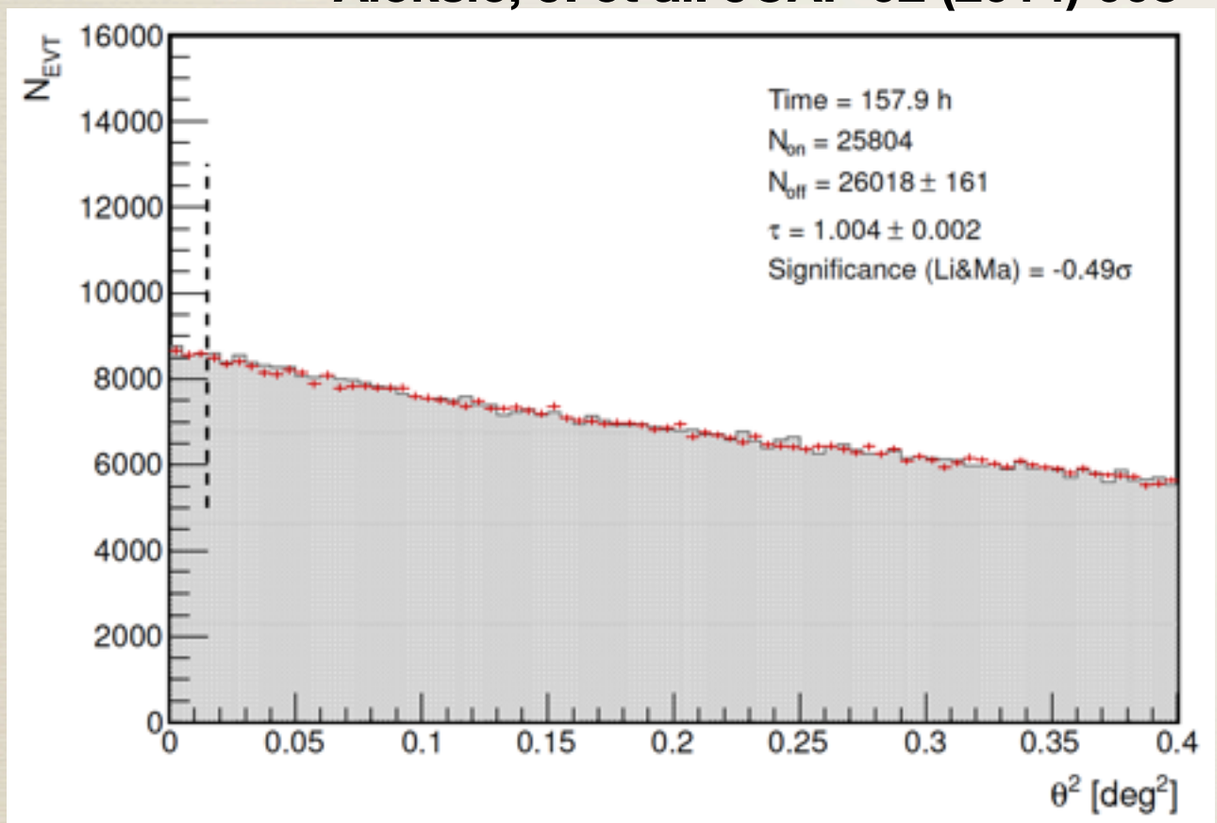
MAGIC Observations

MAGIC observed Segue 1 for 158 h during 2011-2013 (JCAP 02 (2014) 008).

→ Deepest observation of a dSph by an IACT to date.

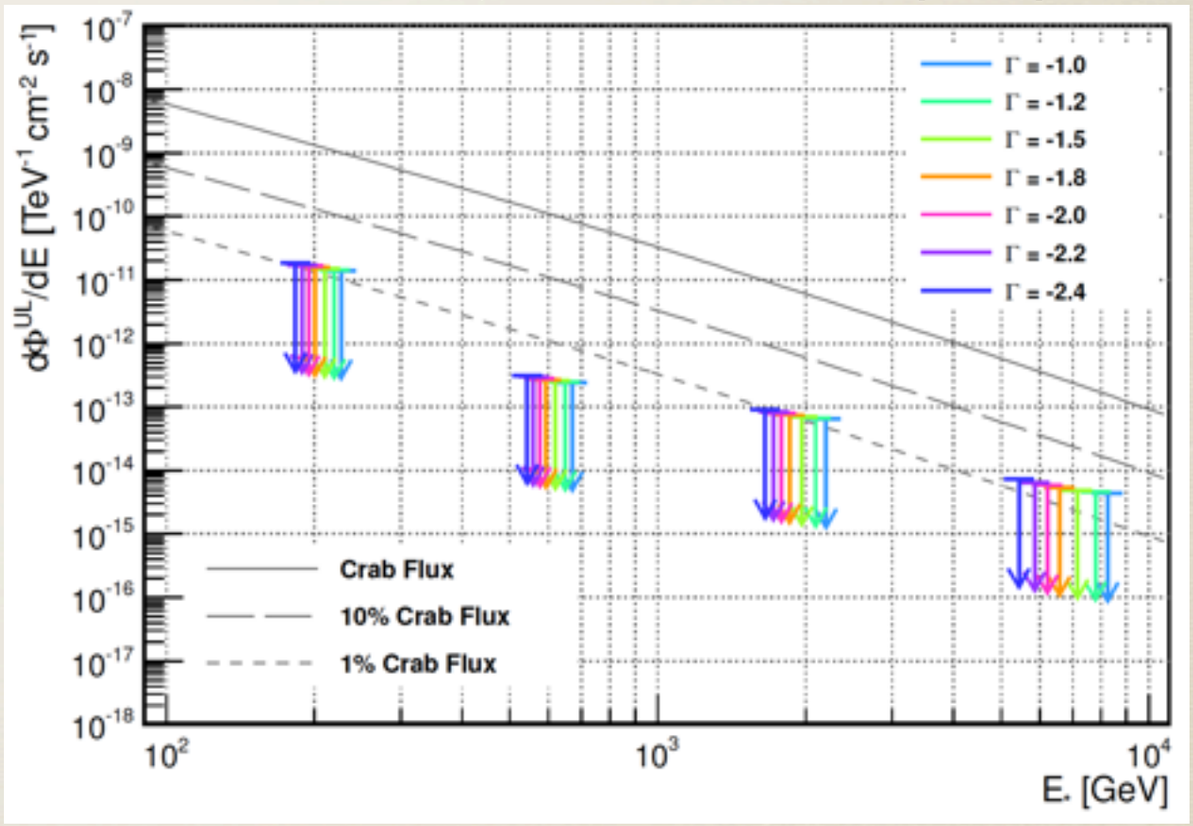
No hint of signal in the whole dataset.

Aleksić, J. et al. JCAP 02 (2014) 008



Distribution of events vs distance to signal/background region center

Aleksić, J. et al. JCAP 02 (2014) 008

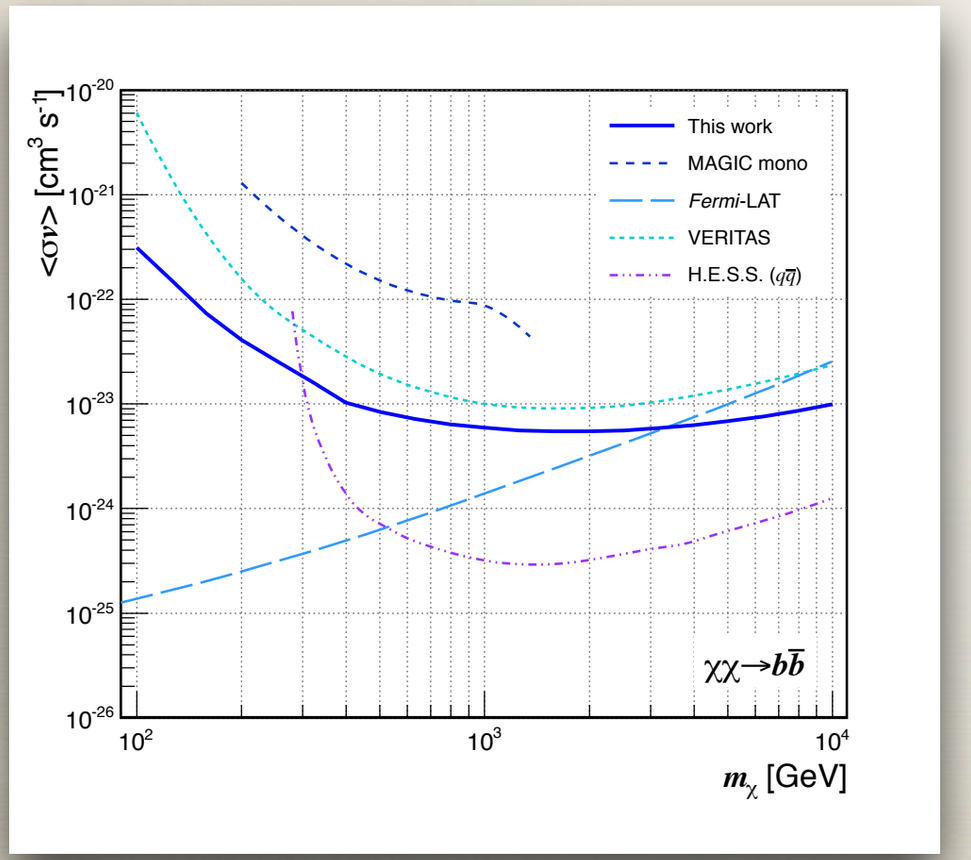


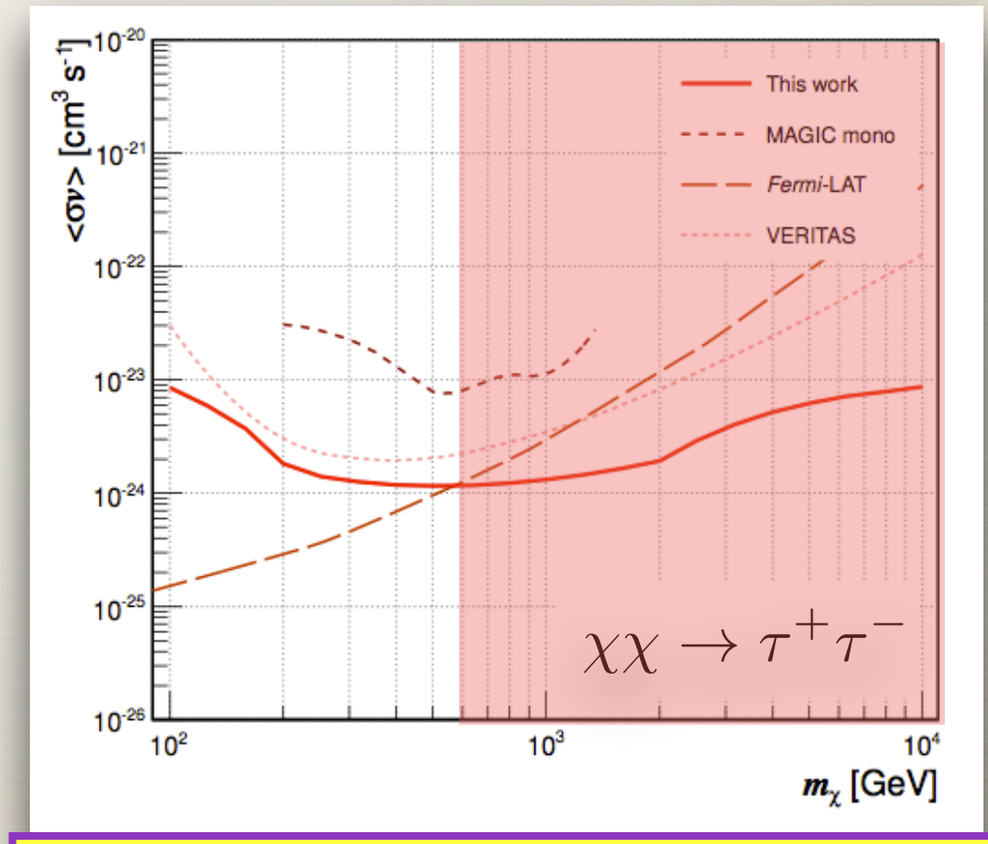
Upper limits to differential gamma-ray flux

Search for gamma-rays

Full likelihood analysis (Aleksić, Rico & Martinez, JCAP 10 (2012) 032) method optimized to recognize spectral features like those expected from DM annihilation and decay

Computed upper limits to the annihilation and lower limits to the decay into secondary standard model particles.





Strongest limit above 600 GeV from dSphs

The Future of MAGIC

Further improvements: We want to go to even lower energies!

STEREO SUM TRIGGER

Same concept as used for the Crab pulsar discovery.

Stereo trigger threshold down to 30 GeV.

Already installed and currently being commissioned.

SUM TRIGGER-II

TOPO-TRIGGER

New concept of stereo trigger based on the NSB rejection using the position of the showers in each camera.

Allows reduction of the discriminator threshold improving the collection area at the lowest energies.

Also installed and being commissioned.

TOPO-TRIGGER BOARD

To sum up...

Telescopes in good shape to continue producing scientific results for several years. System with a better performance than ever.

Currently running more ambitious Key Science Programs → They will be the MAGIC legacy for the scientific community.

We are currently having very **exciting** and **novel** results:

Source discoveries: 3C 58, S3 0218+357, MS1221.8+2452, RBS 0723, RX J1136.5+6737.

Deep studies of known sources: Crab nebula, LS I +61° 303, Mrk 421, Mrk 501, DM searches...

Surprises as IC 310 extreme variability...

What has the future waiting for us?

GRB detection?

→ Stay tuned!!

Let's hold the torch together...

...Before giving it to our Big Sister

Thanks!!!