Highlight results from the MAGIC telescopes

Pierre Colin for the MAGIC collaboration
Max-Planck-Institut für physik (Munich)
colin@mppmu.mpg.de
Outline

- From one to two telescopes
- Performance in stereo
- Recent results
  - Galactic
  - Extra-galactic
  - Astroparticle physics
- Final remarks
MAGIC phase I

World Largest IACT
- 17 m diameter
- 3.5° FOV
- 577 pixels
- 2 GSample/s
- Repositioning <40s

Site: Canary Island La Palma, 2200 m asl.

Performance
- Energy threshold: 55 GeV
  (pulsar trigger: 25 GeV)
- Sensitivity: 1.6% Crab in 50 h
- Angular resolution: 0.1°
- Energy resolution: ~20%
Two 17m telescopes observing in stereoscopic mode

- Improved drive system: repositioning <20s (both telescopes)
- MAGIC-2 camera:
  - 3.5°FOV with 1039 pixels
  - Higher PMT QE
  - Larger Trigger area
  - Readout: DRS2 - 2 GSample/s
- Stereo Trigger (Level 3)
  - Energy threshold: ~50 GeV

MAGIC-2 = Improved clone of MAGIC-1
Improvement from Stereo observation

Stereo trigger:
- Reduce dramatically the background at low E

New parameters:
- Geometrical reconstruction (axis crossing)
- Shower impact parameter
- Height of the shower max

Double reconstruction:
- Energy (using lookup tables)
- Direction (DISP method)
Angular Resolution

Crab: 50-110 GeV

Crab: E>250 GeV

MAGIC Crab Nebula, 50 - 110 GeV

MAGIC Crab Nebula > 250 GeV

2D Gauss fit, Data
2D Gauss fit Monte Carlo
68% containment, Data
68% containment, MonteCarlo

Angular resolution [degree]

Estimated Energy [GeV]
Sensitivity

Most sensitive observatory in the range: 50-200 GeV

M-stereo performance paper in preparation...
Galactic sources

- pulsars
- Supernova Remnants
- X-ray binaries
Crab Nebula: full HE-VHE coverage

Smaller error bars with MAGIC in 3.2h

Fermi (8 months)
MAGIC phase-II (3.2 hrs)
Crab Pulsar

- Special trigger (sum trigger) with threshold = 25 GeV
- First detection of a pulsar above 25 GeV.
- Flux Compatible with Fermi
- Recently confirmed by VERITAS and extended to higher energies
- Challenging result of pulsar models

MAGIC: E >25 GeV
59 h of data from Oct-2007 to Jan-2009
4.3σ 7.4σ

The SNR W51C

One of the most luminous star forming regions (dist ~6 kpc)
W51C is a medium age (~30 kyr) supernovae remnant
The SNR shell is intersecting with the surrounding molecular clouds
Discovered by Fermi/LAT (~GeV) and HESS (4.4σ above 1 TeV)

Promising candidate to study CR acceleration in SNR

Detection with MAGIC:
- 8σ above 150 GeV
- extended emission
MAGIC results for W51C

- Observation: 31.1 h in 2010
- Extended emission: 0.16°
- Maximum of the emission coincides with the shocked cloud regions
- Models based on Fermi / LAT + radio data predict a too softer spectrum than MAGIC sees: spectral index $= 2.4 \pm 0.14$
- Morphology suggests hadronic or other mechanisms:
  - particle spectrum hardens at high energies
  - High energy particles penetrate more effectively dense regions
  - other sources $> 100$ GeV

PRELIMINARY!
Binary systems

**LS I +61 303**
- Discovered by MAGIC in 2006 (Periodic VHE emission)
- Correlation between X and VHE gamma-ray in 2008 suggests leptonic processes are at work.
- Faint VHE state detected in 2009

**Cygnus X-3**
- Large MWL efforts!
- 56.7 hours of MAGIC-phase I data results in upper limits at every X-ray or $\gamma$-ray states

**HESS J0632+57**
- Variable source at VHE
- Detection by MAGIC in 2011 (ATEL #3161), coincident with high X-ray activity period

---

*Figures showing data and graphs.*
Extragalactic objects

- Dwarf Galaxies
- Galaxy Clusters
- Radio galaxies
- BL lacs
- FSRQs
- GRBs
MAGIC discoveries during phase-II

6 new extragalactic objects in 12 months!
- 3 BL lac objects
- 1 Flat Spectrum Radio Quasar
- 2 radio galaxies (or unclear classification)
Optical trigger discoveries

Monitoring of good VHE candidates with the KVA telescope. MAGIC observation during high optical state (ToO)

**MAGIC phase-I:**
- Mrk180: HBL (z = 0.045)
- 1ES1011+496: HBL (z = 0.212)
- S5 0716+714: LBL (z = ~0.31)

**MAGIC phase-II:**
- B3 2247+381: HBL (z = 0.119)
- 1ES1215+303: HBL (z=0.130 or z=0.237)
- (Flare of 1ES0806+524, HBL z=0.138)

KVA light curve of 1ES1215+303

Significance sky map of 1ES1215+303 observation with MAGIC in 2011
Flat Spectrum Radio Quasars

3C 279
- Discovered by MAGIC in Feb 2006
- The farthest TeV object (z=0.54)
  (Best object to constrain EBL models)
- Another flare detected in Jan 2007
  (during a optical high state)

PKS 1222+21 (4C21.35)
- Discovered by MAGIC in June 2010
- Second farthest TeV object (z=0.432)
- Fast variability: doubling time=8.6 min
- No sign of any cutoff
- Very challenging for emission models
Multiwavelength campaigns

- Long term monitoring of bright VHE sources: Mrk 421, Mrk 501, 1ES 1959+650, 1ES 2344+514

- Example with Mrk 421 results:
Joint HESS-MAGIC-VERITAS campaign of the radio galaxy M87

- Shared monitoring between HESS, MAGIC, VERITAS
- Day-scale variability at VHE.
- Evidence of correlation with the nucleus in X-ray and Radio.
- Evidence of central origin of the VHE emission (60Rs to the BH)
Perseus cluster galaxies

About 80h of observation with MAGIC in stereo (2009-2010)
Detections of 2 radio-galaxies inside the cluster:

- **NGC 1275**
  - Central galaxy of the cluster (like M87)

- **IC 310**
  - First Head-tail radio-galaxy detected at VHE
  - Variable flux (Blazar-like object)

**Spectral Energy distribution of IC310 in 2009**

**Significance sky map of Perseus cluster observation with MAGIC in 2009-2010**
Extended emission from Perseus

Cosmological models of galaxy cluster formation predict concentration of:
- Dark Matter (80% of the mass)
- Cosmic Rays

**VHE gamma-ray emissions:**
- DM Annihilation / decay
- CR interaction with ICM gas (neutral pion decay)

Emission concentrated near the cluster center (NGC 1275).
Extension:
- CR model: 60% within 0.15°
- DM model: 0.2°- few degrees

Constraint on CR models with MAGIC-phase-I
Dark Matter search in dwarf galaxies

DM annihilation or decay can produce VHE gamma rays

Dwarf galaxy:
- High mass-to-light ratio
- No other VHE emitters expected

Observed galaxies (phase-I):
- Draco
- Willman 1
- Segue 1 (best candidate)

With current astrophysical factors of dwarf galaxy, we are 3 decades from models, but uncertainty in the astrophysical factor are high
MAGIC Telescopes upgrade

New MAGIC-1 camera: (clone of Magic-2 camera)
- 1039 pixels (PMT with higher QE)
- possibility of using HPD

New readout system for both telescopes:
- DRS4 running at 2 GSample/s

Improved trigger:
- Larger trigger area for MAGIC-1
- New ‘sum’ trigger for both telescopes (threshold= ~25 GeV)

Easier maintenance with 2 identical telescopes

Upgrade scheduled for Summer 2011
Conclusion

The MAGIC telescopes in phase-II
- Stereo observation since fall 2009
- Sensitivity $>300$ GeV twice better (0.8% crab in 50h)
- Sensitivity 50-200 GeV 3 times better (best world instrument)
- Improved off-axis performance

Some Recent results:
- Multiple discoveries and results (10 ATELs in one year)
- Detections of distant blazars (FSRQ)
- Very successful optical trigger (5 discoveries +AGN flares)
- Increase TeV radio galaxy catalogue (NGC-1275, IC-310)
- Extended MWL campaigns: Mrk-421, M87, LSI-61, etc.
- Morphological study of SNR (W51C)
- Study of Crab pulsar above 25 GeV