Results from MAGIC

M. Teshima
MPI für Physik, München
(Werner-Heisenberg-Institut)
MAGIC Telescope

New technologies to lower the threshold energy

- 17m diameter world largest cherenkov tel.
- 0.1° High resolution camera
- Hemispherical PMT with enhanced QE
- Analogue signal fiber transmission
- 2GS/sec Ultra Fast FADCs

Current MAGIC-I Performance

- Fast rotation for GRB < 40secs
- Trigger threshold ~50GeV → 25GeV
- Sensitivity ~1.6% of Crab (50hrs)
- Angular resolution ~0.1 degrees
- Energy Resolution 20-30%

MAGIC-II is under construction and will be completed in summer (September 18, 19)

- Improve sensitivity by a factor of three
- Effectively lower the threshold energy (upgrade with HPD 55%QE photodetectors)
Atmospheric Imaging
Cherenkov Telescope

Observe Cherenkov light from gamma ray showers

Effective area $\sim 10^5 m^2$

$\sim 50$ photons/m$^2$ at 1 TeV
Gamma-Ray Emission Processes (1)
Astrophysical process

Electron acceleration
- High-energy electron
- Magnetic Field $\propto E^{-2.2}$
- 2.7K CMB photon

Proton acceleration
- High-energy proton
- Gamma-ray $\propto E^{-2.2}$
- Nucleus
- $\pi^0$
- $\pi^+$

X-ray (synchrotron) $\propto E^{-1.6}$

Gamma-ray (IC) $\propto E^{-1.6}$

X-ray $\propto E^{-2.2}$

Gamma-ray (Proton) $\propto E^{-2.2}$

\[ E^2 \frac{dF}{dE} = \frac{4}{3} \sigma_T C \gamma_{\text{max}} U_{\text{photon}} \]

\[ \left( \frac{dE}{dt} \right)_{\text{I.C.}} = \frac{4}{3} \sigma_T C \gamma_{\text{max}} U_{\text{photon}} \]

\[ \left( \frac{dE}{dt} \right)_{\text{Sync}} = \frac{4}{3} \sigma_T C \gamma_{\text{max}} \frac{B^2}{2} \]
Crab Nebula
Synchrotron and IC
Gamma ray emission processes (2)
Exotic processes (DM, Mini-BHs)

Dark Matter Annihilations

Bergstrom et al.

New contribution: Internal bremsstrahlung
Scientific Objectives

SNRs
Pulsars and PWNe
Micro quasars X-ray binaries
AGNs
GRBs

Origin of cosmic rays
Dark matter
Space-time & relativity
Cosmology
Galactic sources

Crab Nebula
Crab Pulsar Discovery
Galactic Center
HESS J1813 PWN?
HESS J1834 $^{13}$CO cloud

LSI+61 303 Discovery
IC443 discovery
Cyg X-1 discovery
HEGRA Un-ID TeV2032
Cas-A
MAGIC Crab Nebula (PWN)
Gamma Ray Signals from Crab \(\sim 0.4\text{Hz}\)

\[ \text{IC peak is estimated to be} \]
\[ \text{IC\_peak} = 77 \pm 35 \text{ GeV} \]
Observation of Crab Pulsar

Optical light curve of Crab Pulsar observed by MAGIC central pixel readout.

Optical light intensity (not Cherenkov light)

Distribution of shower events in pulsar phase at ~65 GeV

95% Upper Limit for H.E. Gamma ray pulsed emission from Crab Pulsar
Sum Trigger (~25GeV)
 analogue sum pattern trigger after clipping signal

Improvement
One Siegen FADC rack was unmounted and filled with Sum Trigger electronics Flatfielded in time by cable lengths !!!

Riccardos patchboard
Detection of Crab Pulsar after 20 years long effort

Preliminary
Extragalactic sources
Extragalactic sources

AGNs

23 sources (1 x FR-I, 18 x HBL, 3 x LBL, 1 x FSRQ)

~700 sources with CTA
MAGIC Highlights in extra-galactic source observation (13)

- Mrk421 (z=0.031)
- Mrk501 (z=0.034)
  Very fast flare
- 1ES2344 (z=0.044)
- Mrk180 (z=0.045)
  Discovery
- 1ES1959 (z=0.047)
  Discovery
- M87 (z=0.0041)
- 1ES1218 (z=0.18)
  Discovery
- PKS2155 (z=0.116)
- PG 1553 (Z>0.25)
  Discovery
- 1ES1011 (Z=0.212)
  Discovery
- S5 0716 (z = 0.31)
  Discovery
- 3C279 (z = 0.536)
  Discovery
- BL-Lac (z=0.069)
  Discovery
The source was active in optical but the correlation is not clear, but good correlation with X-ray intensity (A. Marscher et al. 2008).
EBL Absorption

Extragalactic Background Light

Blazar\[\gamma_{VHE}\rightarrow e^+e^-\]

\[\gamma_{EBL}\rightarrow e^+e^-\]

IACT

Graphs showing spectral energy distribution and differential flux for 3C279, with different models and data sets compared.

3C279, z = 0.536

Intrinsic
EC / Hadronic

Wehrle et al. 1998

Sikora et al. 1998

Sikora et al. 1998
Blazar’s Sequence

Celotti & Ghisellini 2007

Fosatti et al. 1998
If Gravity is a Quantum theory, at a very short distance it may show a very complex "foamy" structure due to quantum fluctuation.

Use gamma ray beam from AGNs/GRBs to study the space-time structure:

Energy $1000\,\text{GeV} \sim 10^{-16}E_{pl}$
Distance $100\sim1000\,\text{Mpc} (10^{16-17}\,\text{sec})$

Visible time delay $\sim 1\sim10\,\text{sec}$

**Linear deviation:**

$$\xi_1 < 0; \quad v = c \left(1 - \frac{E}{M_{QG1}}\right); \quad n(E) = 1 + \frac{E}{M_{QG1}}$$

**Quadratic deviation:**

$$\xi_1 = 0; \quad \xi_2 < 0; \quad v = c \left(1 - \frac{E^2}{M_{QG2}^2}\right); \quad n(E) = 1 + \frac{E^2}{M_{QG2}^2}$$
Probing Q.G., Mrk501 very fast flare MAGIC + CERN Th. Group (J. Ellis et al.)

Mrk501 flare
09. July 2005

Energy Cost Function

ECF method
\[ M_{QG1} = 0.47(0.31-0.13) \times 10^{18}\text{GeV} \]
\[ M_{QG1} > 0.26 \times 10^{18}\text{GeV} \]

Likelihood method
\[ M_{QG1} = 0.30(0.24-0.10) \times 10^{18}\text{GeV} \]
New HE AGNs

- FR-1 M87, AGN with a misaligned jet
  - A lot of theoretical discussion on fast variation is ongoing

- FSRQ 3c279 z=0.56
  - EBL study
    - Good news; Universe is relatively transparent for gammas
    - Galaxy counts explain the major part of EBL ➔ bad news
      not many room for Pop-III stars (giant stars in the early epoch)

- FSRQ, LBL (BI Lacertae, W Comae, S50716)
  - Leptonics models, SSC, SSC+EC
  - Synchrotron Proton Blazars?
Preliminary: Pulsed gamma ray emission from Crab Pulsar was discovered by MAGIC at 25GeV
- Gamma ray emissions occur at far place from neutron star
- 25GeV $\Rightarrow$ 60GeV (dramatic change P1/P2 ratio)

The most distant 100GeV Quasar 3C279 was discovered by MAGIC
- EBL – very close to the lower limit obtained by the HST and Spitzer galaxy counts
- No big contribution from the extra components like Pop-III stars

MAGIC-II
- Completed this summer
- The start of the scientific operation (Stereo observation) is expected at the end of this year
- The upgrade with advanced photo-detector HPD($>50\%$ QE) in 2009