Recent Results On AGN Observations From The MAGIC Telescope

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Recent Results on AGN observations by the MAGIC Telescope

**Imaging Air Cherenkov Telescopes**

- **GLAST/FERMI (magnified)**
- **Cherenkov flash recorded by the PMT camera**
- **Reconstruction of primary particle**
  - particle id: hadron/\(\gamma\) discrimination
  - direction, energy

- **Gamma ray**
- **Particle shower**
- **~ 10 km**
- **~ 120 m**
Recent Results on AGN observations by the MAGIC Telescope

MAGIC telescope

- Largest single dish Cherenkov Telescope: 17 m Ø mirror dish, mirror surface (241 m²)
- 3.5° FoV Camera with 577 enhanced QE PMT’s
- Fast repositioning for GRBs: average < 40 s
- Low energy trigger threshold: 50 - 60 GeV
- Sensitivity: 1.6% Crab / 50 h
  improvement: 2GHz sampling - timing parameters in g/h separation
- γ-PSF: ~ 0.1° (E > 500 GeV)
- Energy resolution: 20 - 30%
- Observations during moonlight (duty cycle improved ~50%)
Recent Results on AGN observations by the MAGIC Telescope.

- AGNs detected by MAGIC:
  - Mrk421 (z=0.031)
  - Mrk501 (z=0.034)
  - IES2344 (z=0.044)
  - Mrk180 (z=0.045)
  - 1ES1959 (z=0.047)
  - 1ES1218 (z=0.18)
  - PG 1553 (z>0.25)
  - 3C279 (z = 0.536)
  - M87 (z=0.0043)
  - PKS2155 (z=0.116)
  - S5 0716+714

- Very fast flare:
  - 1ES2344

- Discovery:
  - Mrk180
  - 1ES1959
  - 1ES1218
  - PG 1553
  - 3C279

- S5 0716+714 (MAGIC PRELIMINARY)
  - Significance 6.8 σ

- M87 (z=0.0043)
  - Knot D
  - HST-1 knot
  - Nuclear region
  - X-rays
  - Chandra
Recent Results on AGN observations by the MAGIC Telescope

AGN - blazars

- Intense and variable emission up to ~10 TeV
  - Observed structures:
    - accretion disk; obscuring torus
    - Relativistic Jet
    - Broad/Narrow line regions (NLR, BLR)
- TeV emitting zone: jet with high relativistic bulk motion
  - Particle acceleration at shock boundaries bundled in a magnetic field (Fermi acceleration processes)
  - Gamma-ray emission from accelerated electrons (synchrotron and inverse-Compton scattering) or hadronic interactions
- Unified AGN model: different AGN classes depending on viewing angle
  - FRI, FR-II, Radio quasars, BL-Lac (HBL-LBL)
Recent Results on AGN observations by the MAGIC Telescope

γ-ray emission from AGN:
SSC a (minimal) standard model

- Blazar: collimated emission from jet (relativistic amplification)
  - Environment: B, δ, R
- Observed emission (SED) well described by leptonic models, such as SSC and EC.
  - Expected X-ray / Tev time correlation
- Synchrotron peak: IR to x-ray
- IC peak: UV to γ-rays
- LBL, IBL, HBL
- Outbursts of e.m. radiation

Synchrotron: IC

Emitted power

Energy

\[ E_{\text{min}} \] \[ E_{\text{max}} \]

\[ n_e(\gamma) = \frac{K\gamma_{\min}^{-1}}{\left(\gamma/\gamma_b\right)^{p_1} + \left(\gamma/\gamma_b\right)^{p_2}} \]

\[ \gamma \]

\[ \gamma_{\min}, \gamma_{\max} \]

\[ \gamma_{\text{tr}}, \gamma_{\text{max}} \]

\[ \gamma_{\text{tr}}, \gamma_{\text{max}} \]

\[ \gamma_{\text{tr}}, \gamma_{\text{max}} \]

\[ \gamma_{\text{tr}}, \gamma_{\text{max}} \]

\[ \gamma_{\text{tr}}, \gamma_{\text{max}} \]
Blazar Multiwavelength campaigns

- **Simultaneous Multifreq. Observations covering 15 decades in photon energy:**
  - **VHE:** H.E.S.S., MAGIC, VERITAS
  - **HE:** Agile, Fermi
  - **X-ray:** Suzaku, Swift, Chandra, Integral
  - **Optical:** KVA
  - **Radio:** Metsahövi, VLBI…

Methods:
- Monitoring (optical, x-ray, radio)
- Intensive planned campaigns
- **Target of Opportunity (ToO): react to alerts (internal/external)**
  - MAGIC Monitoring program of bright blazars (Mrk421, Mrk501, 1ES1959, 1ES2344+514….)

Some recent MWL campaigns:
- Mrk 421, Mrk 501, PG 1553+113, 1ES 1218+304, 1H 1426+428, M87
- …and other campaigns organized…

Recent Results on AGN observations by the MAGIC Telescope
Mrk 421 June ‘08 flare

- MWL campaigns on Mrk421 from optical to TeV energies: great cooperation between observatories
- High TeV states, > 40σ for MAGIC, VERITAS between May 27 and June 8
- Variability of X-ray data gives limit on source size: \( R < \frac{c t \delta}{20} \sim 5 \times 10^{16} \) cm

- TeV-X ray correlation
- No clear TeV-opt correlation
- SSC model parameters: \( B \sim 0.1 \) G, \( \delta \sim 20 \)

Recent Results on AGN observations by the MAGIC Telescope

IES 1959+650

HBL $z=0.047$

- MWL campaign (opt-UV-X-VHE) KVA, AIT, Suzaku, Swift, MAGIC
- Low TeV flux; medium opt
- High X-variability (x2)
- Low optical variability


SSC model
R=7.3e15 cm
B=0.25 G
D=18
Optical triggers

Regular optical monitoring of candidate TeV sources
Tuorla observatory

Mkn 180
Trigger point

1ES 1011+496
Trigger point

MAGIC Collab.,

March 2006
MAGIC
12.1 h
S=5.5 σ

MAGIC
18.7 h
S=6.2 σ
**Recent Results on AGN observations by the MAGIC Telescope**

**S5 0716+714**

*IBL  z=0.31 (?)*

- Bright in optical ⇒ trigger
- Clear signal in 2.6 h: 6.9σ
  - 1st VHE detection
  - $F_{(>400 \text{ GeV})} \approx 10^{-11} \text{ ph/cm}^2/\text{s} \approx 25\% \text{ Crab}$

**MAGIC collab. 2008, Atel #1500**

Preliminary
Recent Results on AGN observations by the MAGIC Telescope

S5 0716+714

IBL  \(z=0.31\)

- **High redshift** Nilsson, A&A 487(2008)L29 reports the detection of the host galaxy: \(z=0.31\pm0.08\)

- **Rotation of positional angle of polarization (EVPA) during maximum (60deg/day)** Larionov et al., ATel #1502
  - propagation of a polarized knot spiraling down the jet, following helical magnetic field
  - (e.g. BLLac, Marscher et al., 2008, Nature, 452, 966)

- **X-ray spectrum shows synchrotron component:** transition between LBL-HBL states?

*Discovery MAGIC paper - to be submitted*
Recent Results on AGN observations by the MAGIC Telescope

**M87**

\[ \text{RG } z=0.0043 \]

- “misaligned blazar” (20°-40°); 16 Mpc
- HEGRA hint; HESS/VERITAS detection
- Candidate nearby CR site (hadronic emission?)
- Variability?
- Site for TeV emission (core/HST-1)?
M87

- MWL campaign Jan-Feb 2008 (triggered by MAGIC detection on 1st February flare)
- 9.9σ detection; 8.0σ single night 1st-Feb
- First spectrum at E>100 GeV
  - Marginal hint of spectral hardening
- Clear <~daily variability at E>350 GeV
- Chandra observations \(\Rightarrow\) core/HST-1 contribution (core active / HST-1 dim)

(Crab nebula) \(\alpha=-2.2\)  \(\alpha=-2.6\)

Recent Results on AGN observations by the MAGIC Telescope

3C66A or B?

- 3C66A blazar at $z = 0.44$ (controversial)
- Sept. 2008, VERITAS detection $>100$ GeV ATEL # 1753
- 3C66B: a large FRI radio galaxy, 6’ away from 3C66A ($z = 0.0215$)
- Optical outburst in Aug. 2008 $\rightarrow$ MAGIC observations
  - Total time: 54.2 hrs
  - $6\sigma$ signal ($5.4\sigma$ after trial correction)
  - 2.2% Crab $>150$ GeV
  - Spectrum: $-3.1 \pm 0.31$
- Excess from 6.1’ from 3C66A
  From simulations of skymaps, exclusion probability from 3C66A is 85.4% (including systematics in pointing accuracy)

Recent Results on AGN observations by the MAGIC Telescope

**3C279**

*FSRQ  z=0.536*

- Brightest EGRET AGN
- Gamma-ray flares in 1991 and 1996
- Fast time variations (ΔT~6h in 1996)
- At the edge of γ-ray horizon (z=0.536)

**EGRET**

*3EG

**FERMI**

96h exp.

Wehrle et al. 1998
**Recent Results on AGN observations by the MAGIC Telescope**

**3C279**

*FSRQ  z=0.536*

**MAGIC observations**

- **9.7 h over 10 nights**
  - (WEBT campaign, Jan-Apr 2006)
- **Clear detection on 23th Feb ‘06**
- **First FSRQ in the TeV sky**

**Science**, (2008) 320, 1752

- **Low optical state**
- **...but active in X-ray**

Boettcher et al. arXiv:0810.4864
Interaction with Extragalactic Background Light (EBL)

**EBL**

$\gamma_{HE} \gamma_{EBL} \rightarrow e^+ e^-$

$E_{HE} \epsilon_{EBL} = 3.6(m_e c^2)^2 \quad \lambda = 1.24 \mu m \left( \frac{E_\gamma}{1 \text{ TeV}} \right) / (1 + z^2)$

$\Phi_\gamma^{\text{observed}} (E) = \Phi_\gamma^{\text{unabsorbed}} (E) \cdot e^{-\tau(E_\gamma, z)}$

$\tau(E,z)$: Optical Depth

Gamma Ray Horizon (GRH): $\tau = 1$

**EBL**

$2.7 \text{ K CMB, IR}$

$\Rightarrow$ energy dependent $\gamma$-ray absorption

$\Rightarrow$ modification of original spectrum
**Recent Results on AGN observations by the MAGIC Telescope**

**3C279**

**EBL**

- Source Intrinsic spectrum depends on EBL models
  - Stecker+07 (fast) (high density)
  - Primack+05 (low density)
  - Kneiske (tuned $\alpha^*=1.5$)

- Intrinsic spectrum slope is constrained by (leptonic) emission models (max slope of electrons): $\alpha^* \geq 1.5$
  - Upper limit to EBL density
  - Allowed region for EBL

*Science, (2008) 320, 1752*
MAGIC-II

First light ceremony
24th-25th April 2009

- Stereoscopic mode:
  - Improved sensitivity
  - Better angular and energy resolution
- Parallel mode:
  - Observation of simultaneous sources (AGNs monitoring)
- New technologies:
  - lower energy threshold
  - Camera: Photo-detectors with higher QE (HPDs in near future)
  - Faster Digitalization: 4 GHz Analogue to Digital Converts (Domino)
MAGIC-II

- Overall sensitivity will be improved by a factor of 2-3
- Energy resolution ~25% → 15-20%
- Angular resolution Substantial improvement

Energy resolution

Angular resolution
Recent Results on AGN observations by the MAGIC Telescope

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