MAGIC and Multi-Frequency Observations of the nearby Blazar Markarian 421

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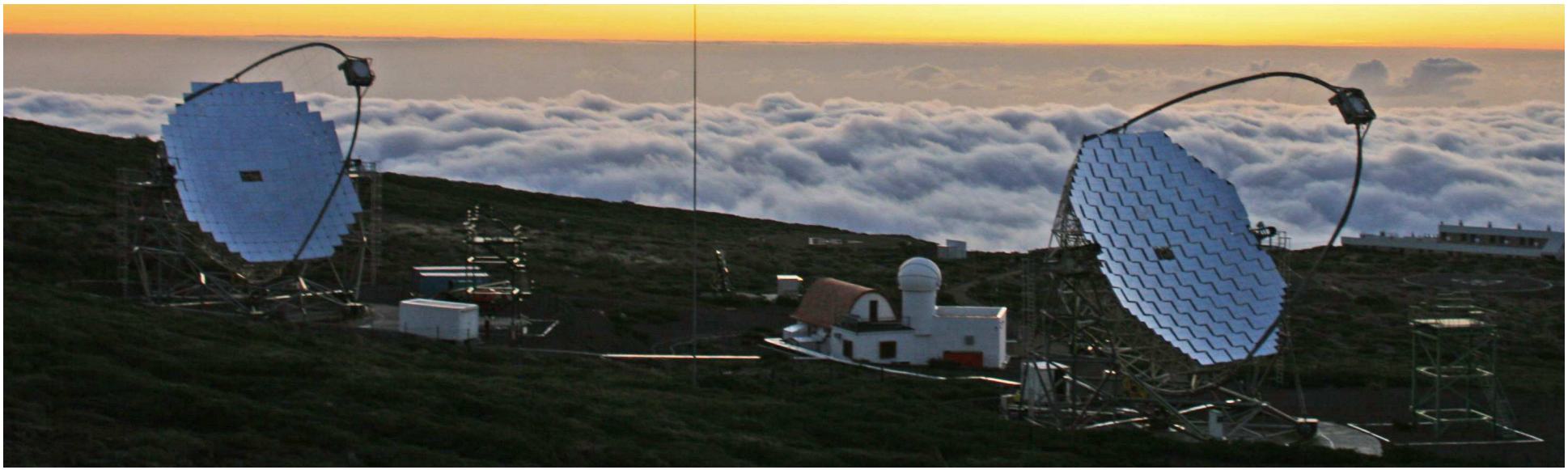
Contents

The MAGIC Telescopes

- Two Imaging Atmospheric Cherenkov Telescopes
- Located on the canary islands of La Palma at 2220 m a.s.l.
- Detection of cosmic Gamma-rays with energies between $\sim$ 50 GeV (25 GeV with a special trigger) and $\sim$ 30 TeV

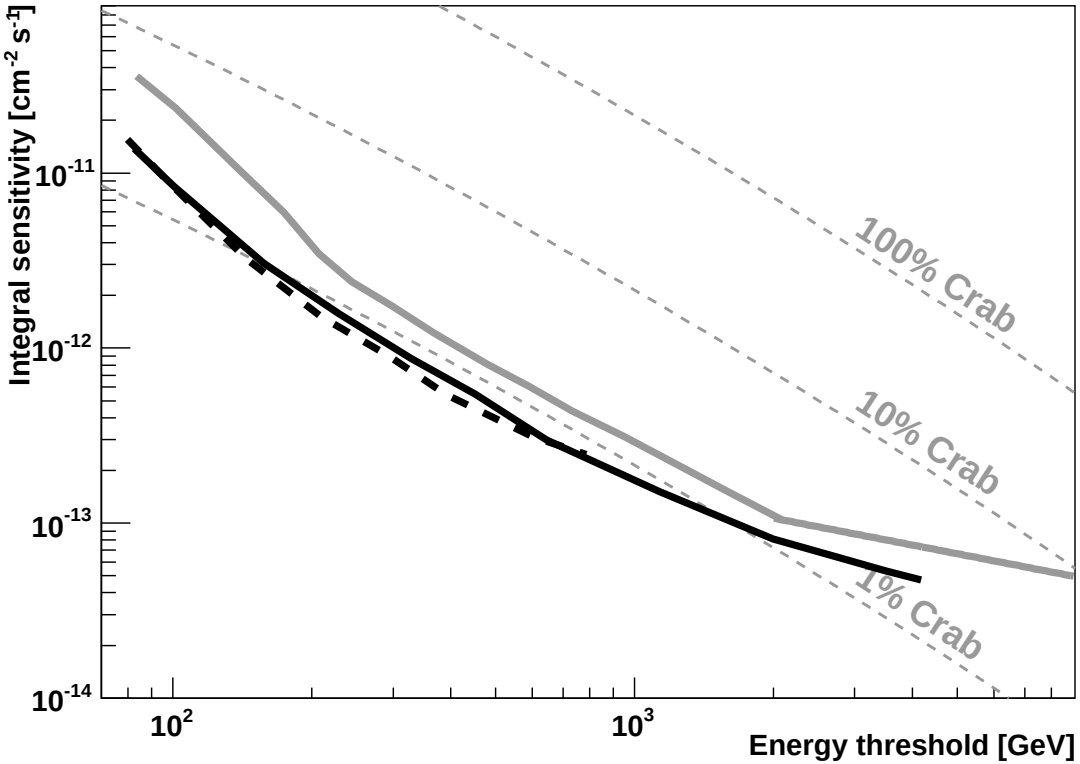


MAGIC Characteristics

- MAGIC-I in operation since 2004, MAGIC-II since 2009 $\longrightarrow$ stereo observations
- Light-weight carbon fibre telescope frame $\Rightarrow$ Fast repositioning < 20 - 40 s
- 17 m diameter mirror dishes $\Rightarrow$ Active Mirror Control
- Cameras: 577 pixel (MAGIC-I), 1039 pixel (MAGIC-II), 3.5° FOV
- Analog signals transferred via optical fibres to counting house
- Fast (2 GHz) readout electronics
- $\Rightarrow$ Currently lowest energy threshold

Stereo Performance

⟶ ((http://arxiv.org/abs/1108.1477, submitted to Astroparticle Physics)



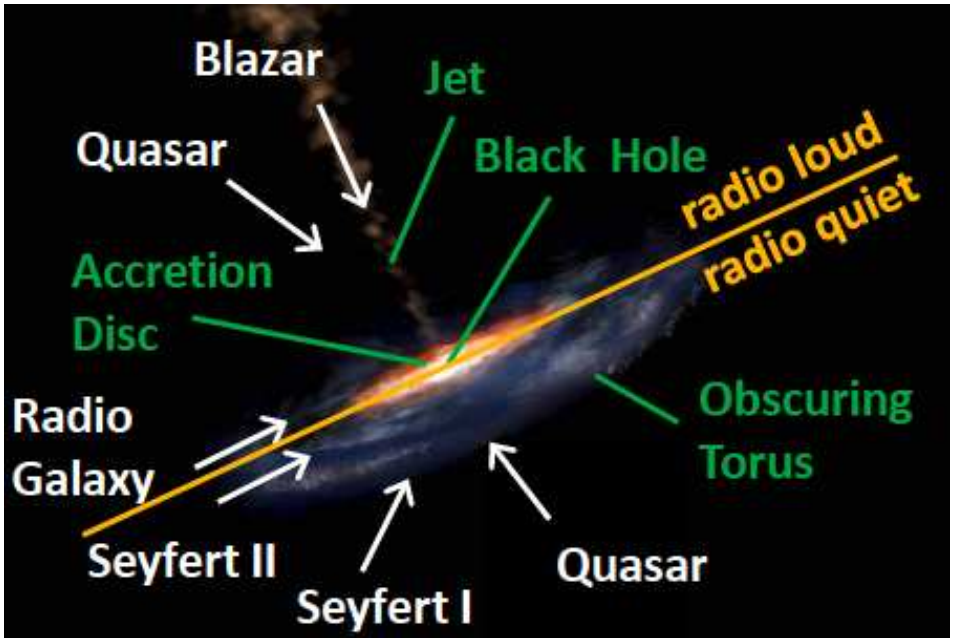
Integral Sensivity: Source flux detectable with 5 σ confidence within 50 hrs :

MAGIC-I: $\approx$ 1.6% Crab above $\approx$ 300 GeV

MAGIC Stereo: $\approx$ 0.8% Crab above $\approx$ 300 GeV

- Energy resolution above 300 GeV: Improved 25 to 16%
- Angular resolution above 300 GeV: 0.1° above $<$ 0.07°
- Trigger threshold:
  - $\sim$ 50 GeV with standard trigger
  - $\sim$ 25 GeV with sumtrigger

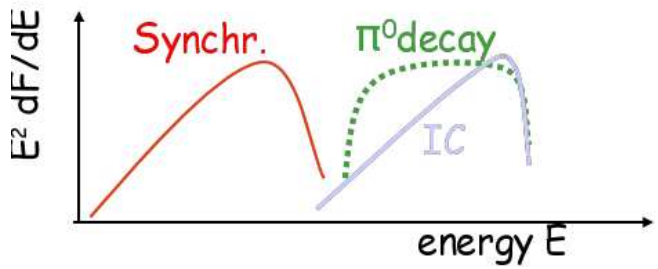
Active Galactic Nuclei (blazars, radiogalaxies,...)



- Powerful cosmic accelerators
- Engine: Supermassive black hole(s)
- Accretion disk and jets
- Different AGN types as an artefact of observation angle
- Blazar: Jet pointing toward observer

Active Galactic Nuclei: What we know

- Emitting at all accessible energies
- Variability at all timescales
- Double-peak spectrum



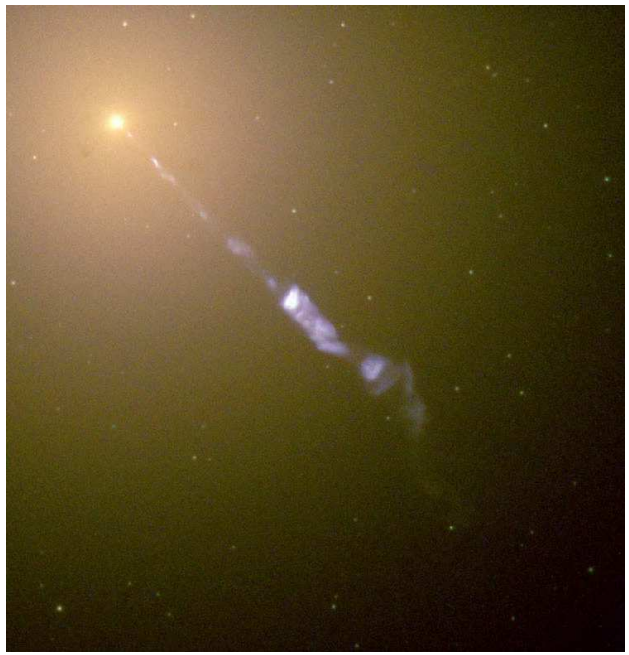
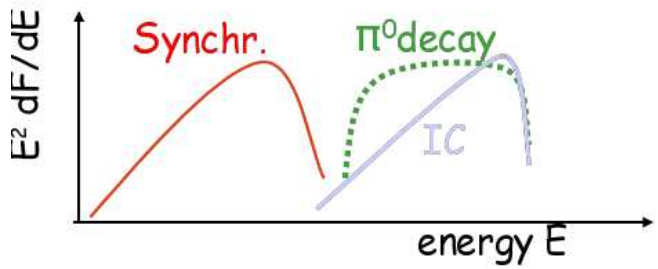


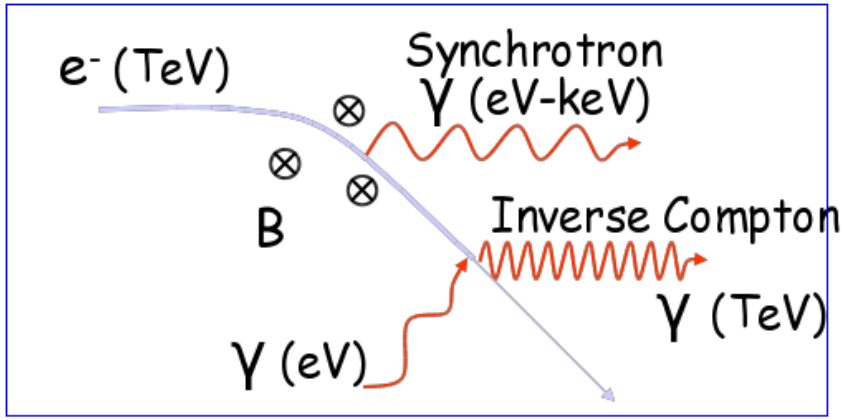
Figure: Hubble Space Telescope image of the active galaxy M87

Active Galactic Nuclei: What we don't know

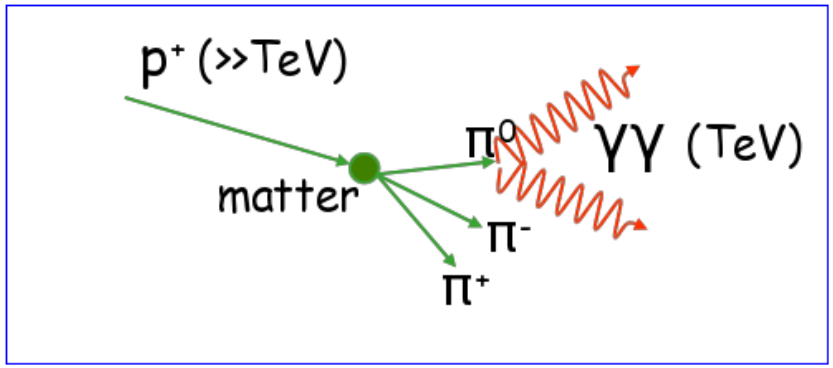
- Origin (type and location) of radiation
- Emitting particle species: Leptonic or hadronic model?



- Variability drivers
- Inter-band correlations



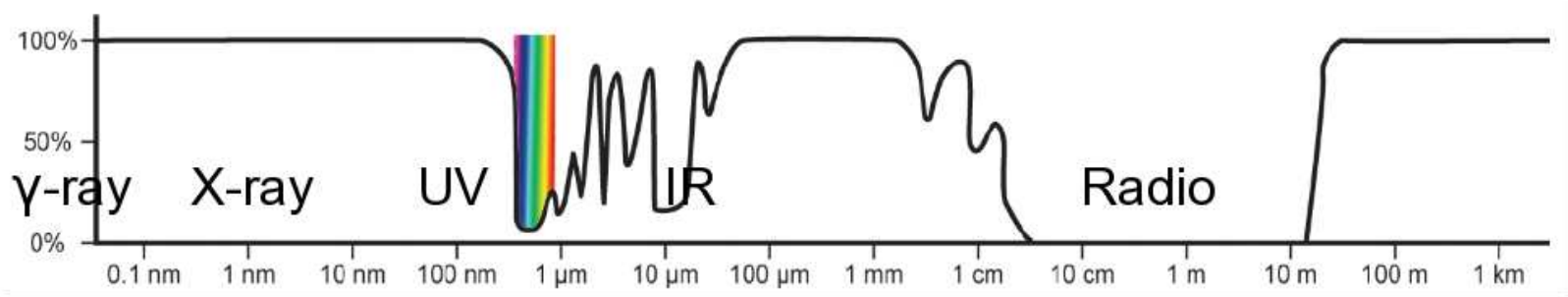
Example: Leptonic model



Example: Hadronic model

Multiwavelength Studies

- For strong, established AGNs, MAGIC is frequently participating in large synchronized multiwavelength campagins
- Organized over long time periods many observatories worldwide
- Multi-frequency SED and Lightcurve allow for deeper understanding of the source
- Some targets: Best studied nearby TeV blazars Mrk421 and Mrk501 (z$\sim$0.03), nearby radio galaxy M87



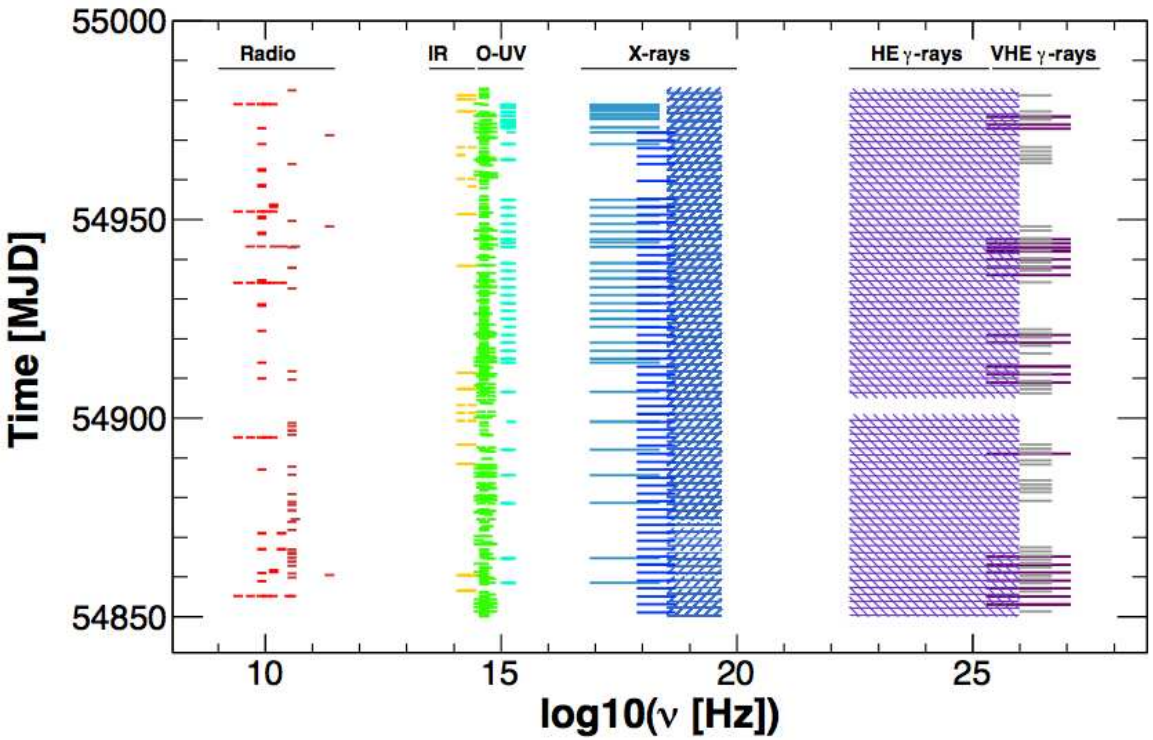
Mrk 421

- Blazar located in Ursa Major with redshift z $\sim$ 0.031
- Supermassive black hole at its center and a companion galaxy
- Very bright at TeV: $\approx$ 0.5-3 Crab Units
- Very fast γ-ray flux changes: Timescale from months down to minuts
- Nearby and strong source $\Rightarrow$ Excellent laboratory

Figure: Optical image of Mrk 421 and its companion galaxy 421-5, Aimo Sillanpaa/Nordic Optical Telescope

Multiwavelength study of Mrk 421 in 2009

- Observed by MAGIC during 4.5 months in 2009
- Monitored regardless of activity
- Over 25 instruments participated covering frequencies from radio to TeV



Time and energy coverage for Mrk 421, arXiv:/1106.1348

Broadband SED

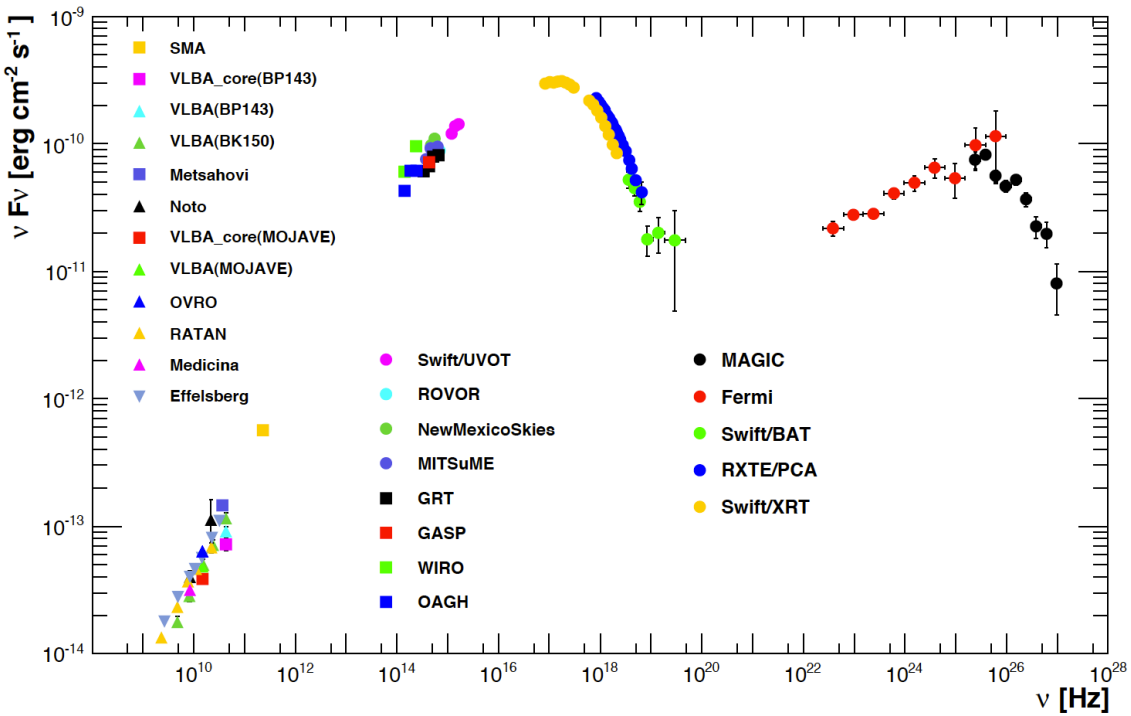


Figure: arXiv:/1106.1348, ApJ accepted

- → Most detailed SED yet collected
- Fermi-MAGIC: For the first time spectral coverage of the complete high energy component over five orders of magnitude
- → Characterised by leptonic or hadronic acceleration model?

Broadband SED - Leptonic model fit

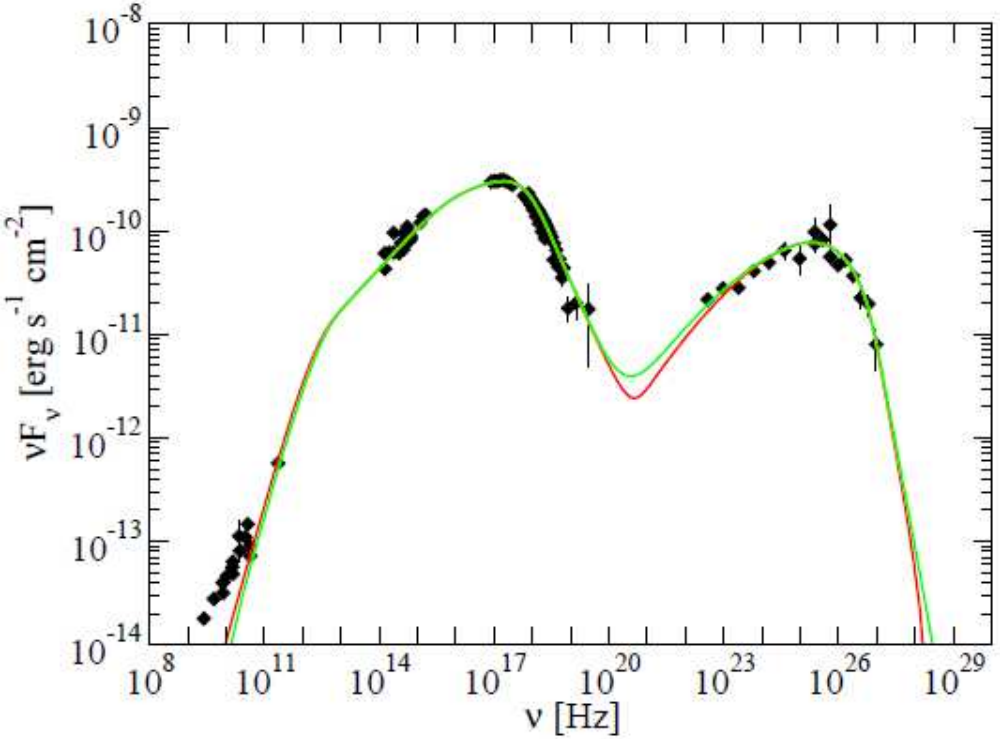


Figure: arXiv:/1106.1348

- SED is well described by a one-zone synchrotron self-compton model, with an emission region $\approx$ 0.15 pc and an electron population with two spectral breaks

Broadband SED - Hadronic model fit

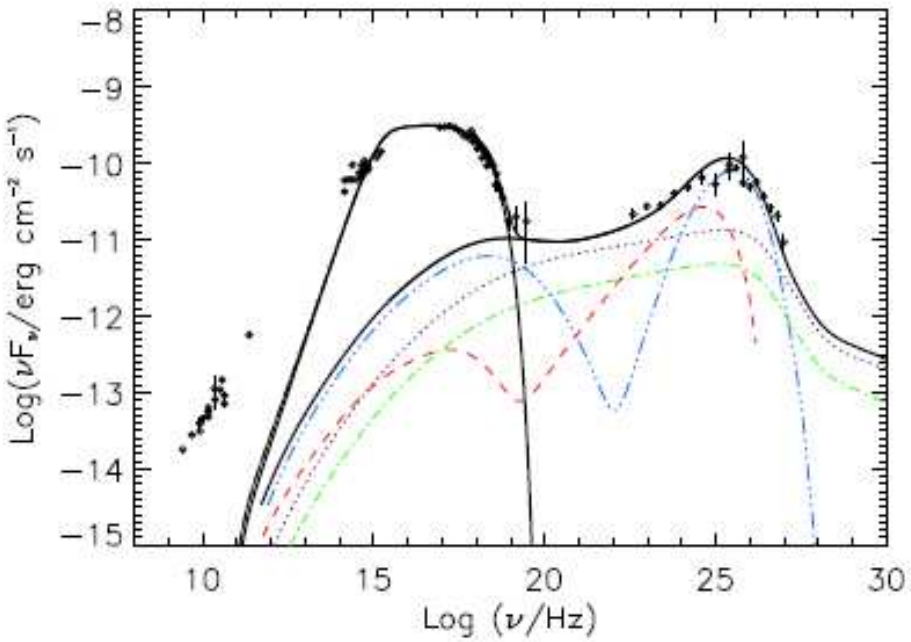
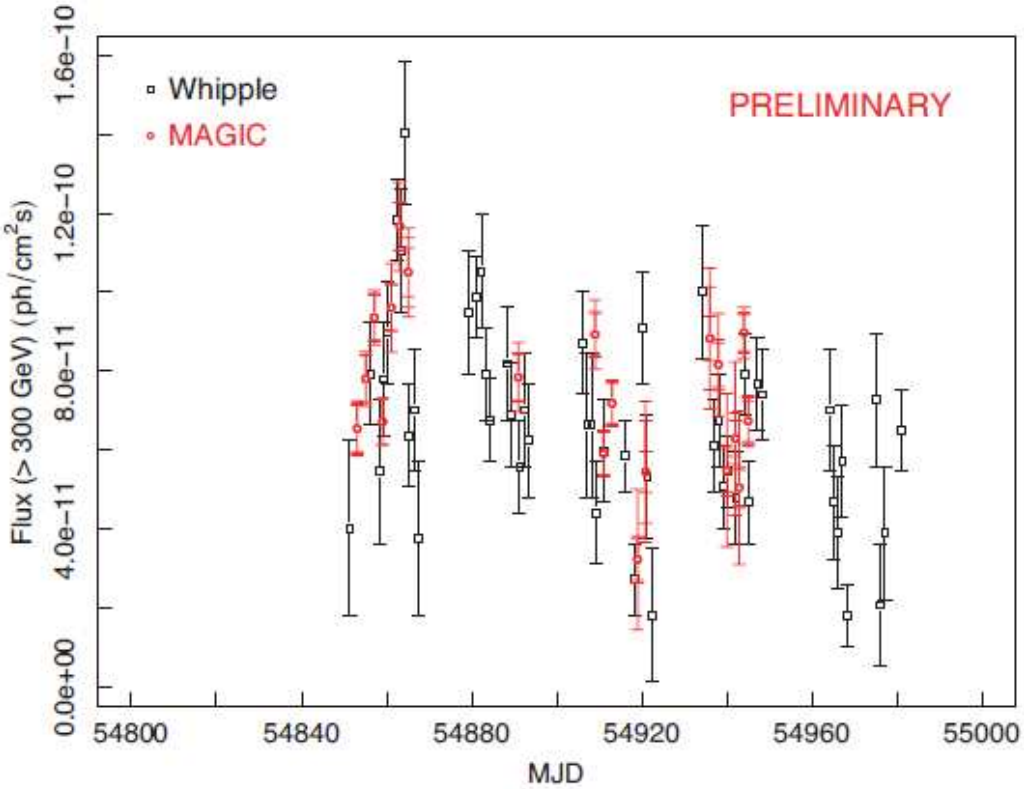


Figure: arXiv:/1106.1348

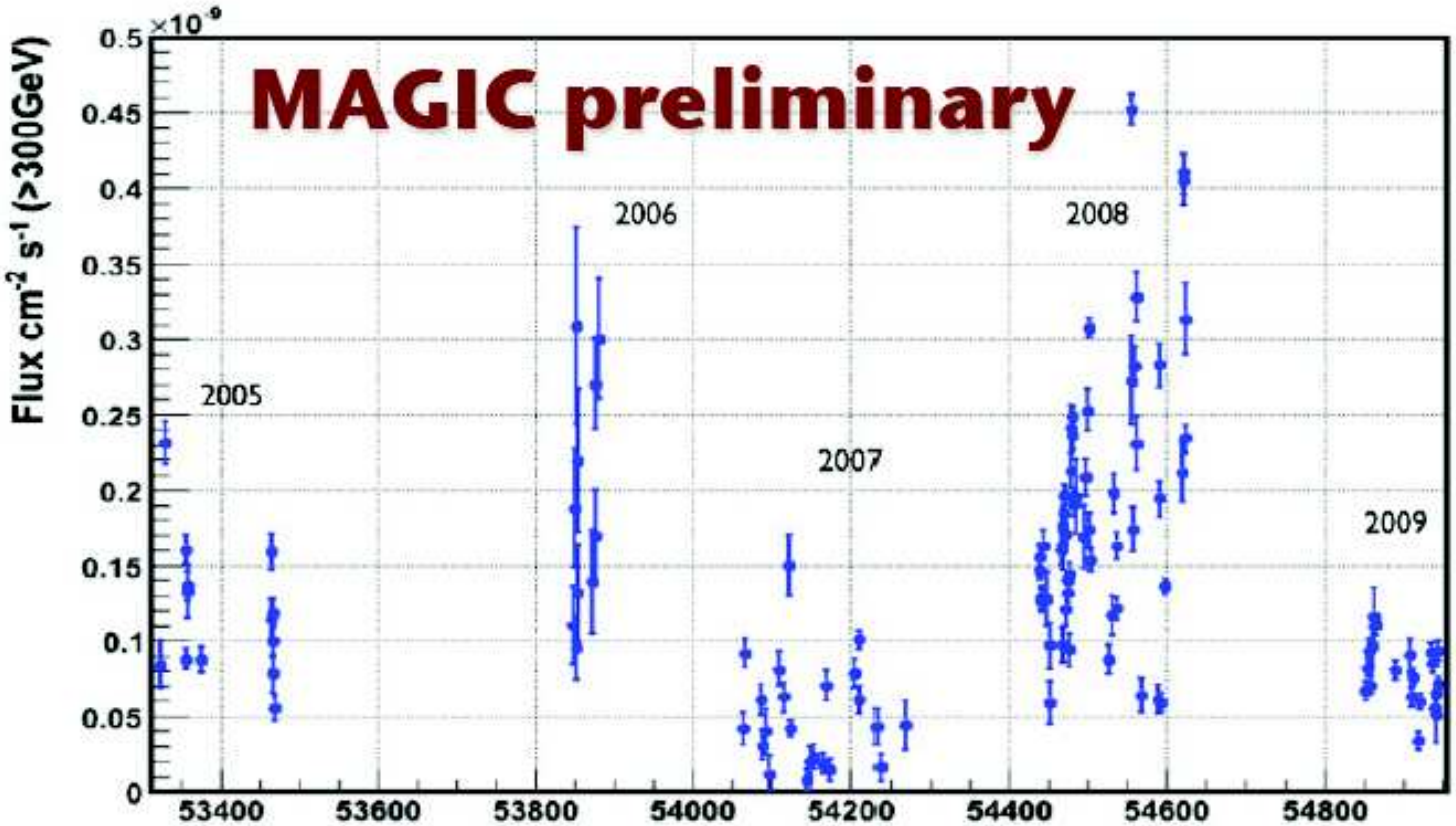
- ... but also hadronic model works
- If relativistic protons are present in the jet
- Predicts comparable jet emission power, but different environment for blazar emission: size only $\approx$ 0.0001 pc, magnetic field $\approx$ 1000x higher

VHE Lightcurve

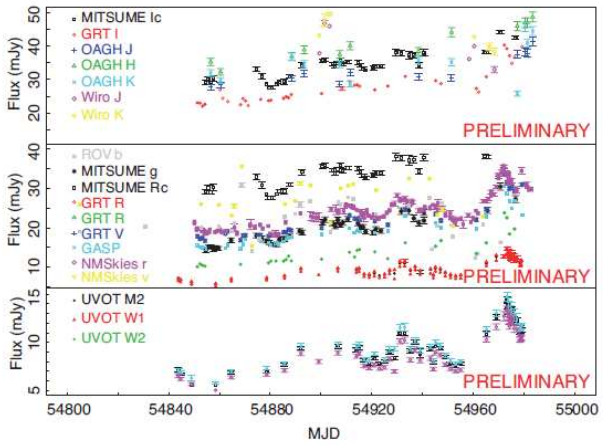


- Mrk 421 was in relatively low state during most of the campaign
- No significant flaring, some level of variability
- Correlation between energy bands?

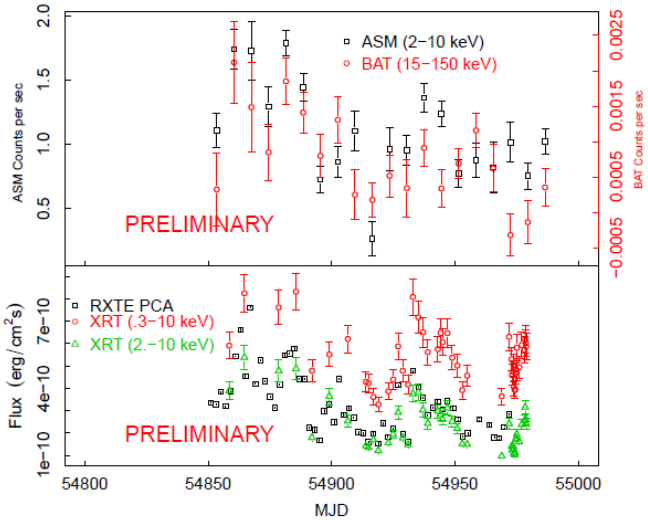
VHE Lightcurve - Compared to previous years



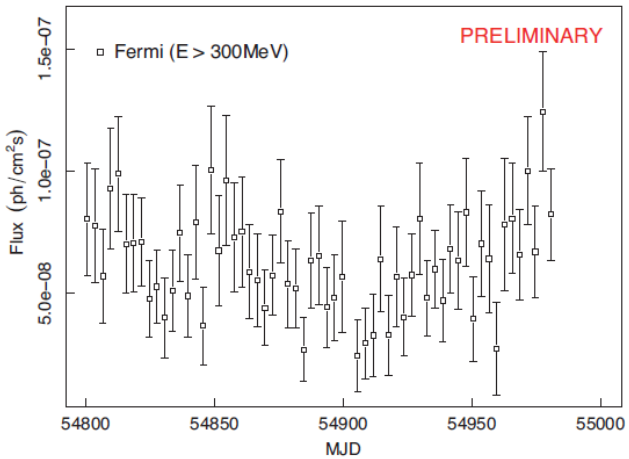
Multiband Lightcurve



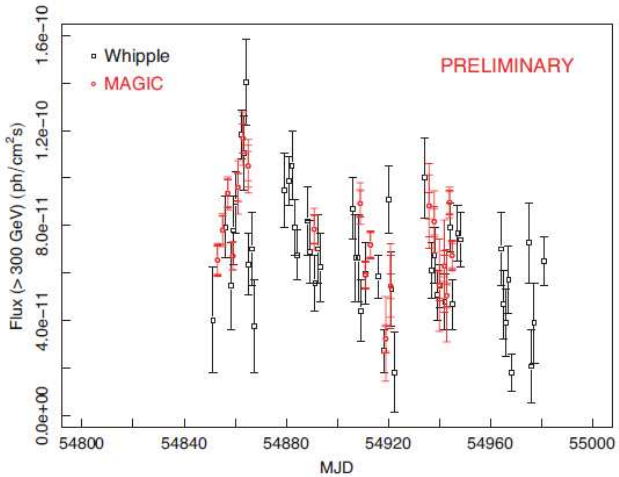
Optical data



X-ray data



Fermi data



VHE data

Figure: (Proceedings of the 32nd ICRC, Beijing 2011: Barres de Almeida et al. Multifrequency Campaigns of Mkn 421 and Mkn 501 in 2009)

Summary and Outlook

- MAGIC is performing very well
  - Largest IACT (17m mirror dishes) → lowest energy threshold (25–50 GeV)
  - Excellent overlap with FERMI data
  - Better performance in stereo mode (since 2009)
- Extensive multiwavelength studies for strong established AGNs
  - Mutlifrequency SED and Lightcurve allow deeper understanding
  - Nearby and strong Blazar Mrk 421 is a good target
  - Observed for 4.5 months in 2009 → Much interesting physics
- Ongoing...
  - Analysis of 2010 multiwavelength data