MAGIC observations of Markarian 421

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescope

DPG Frühjahrstagung 2012 Göttingen

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Motivation: Markarian 421

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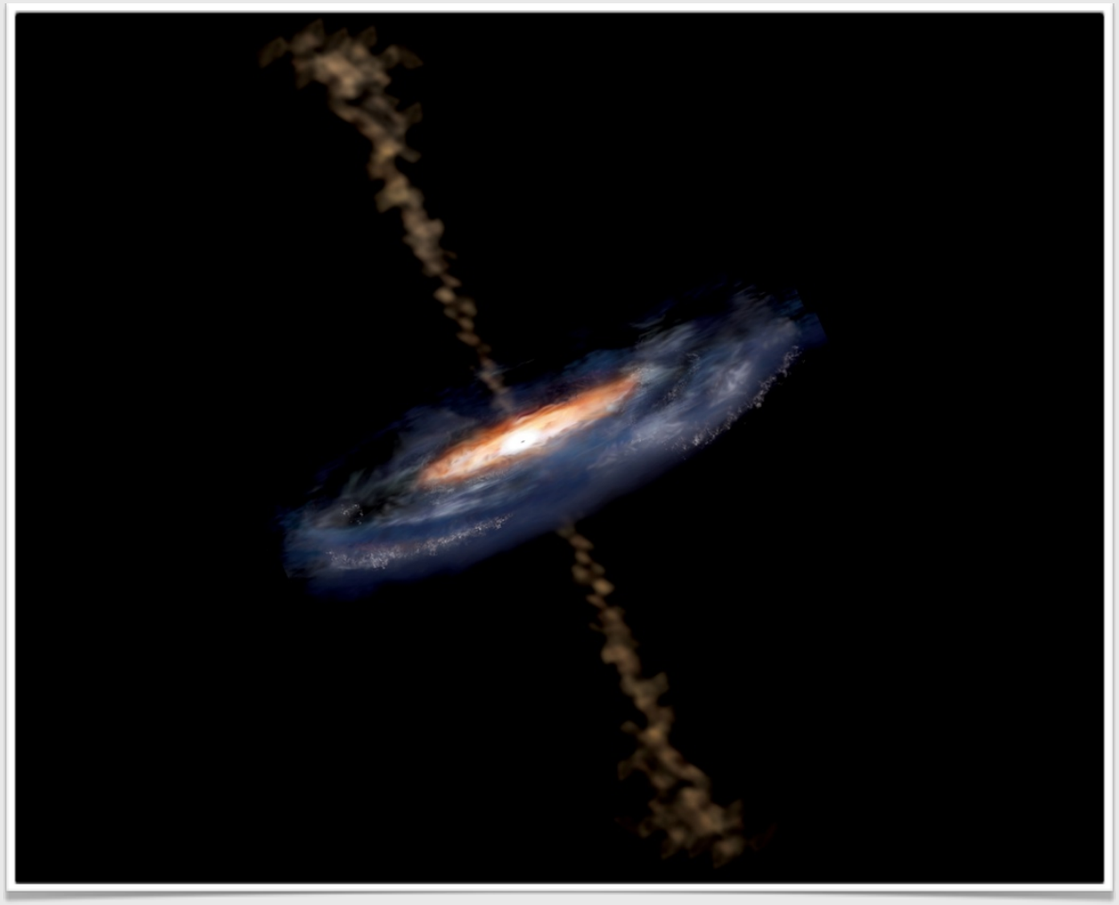
Active Galactic Nuclei (AGN)

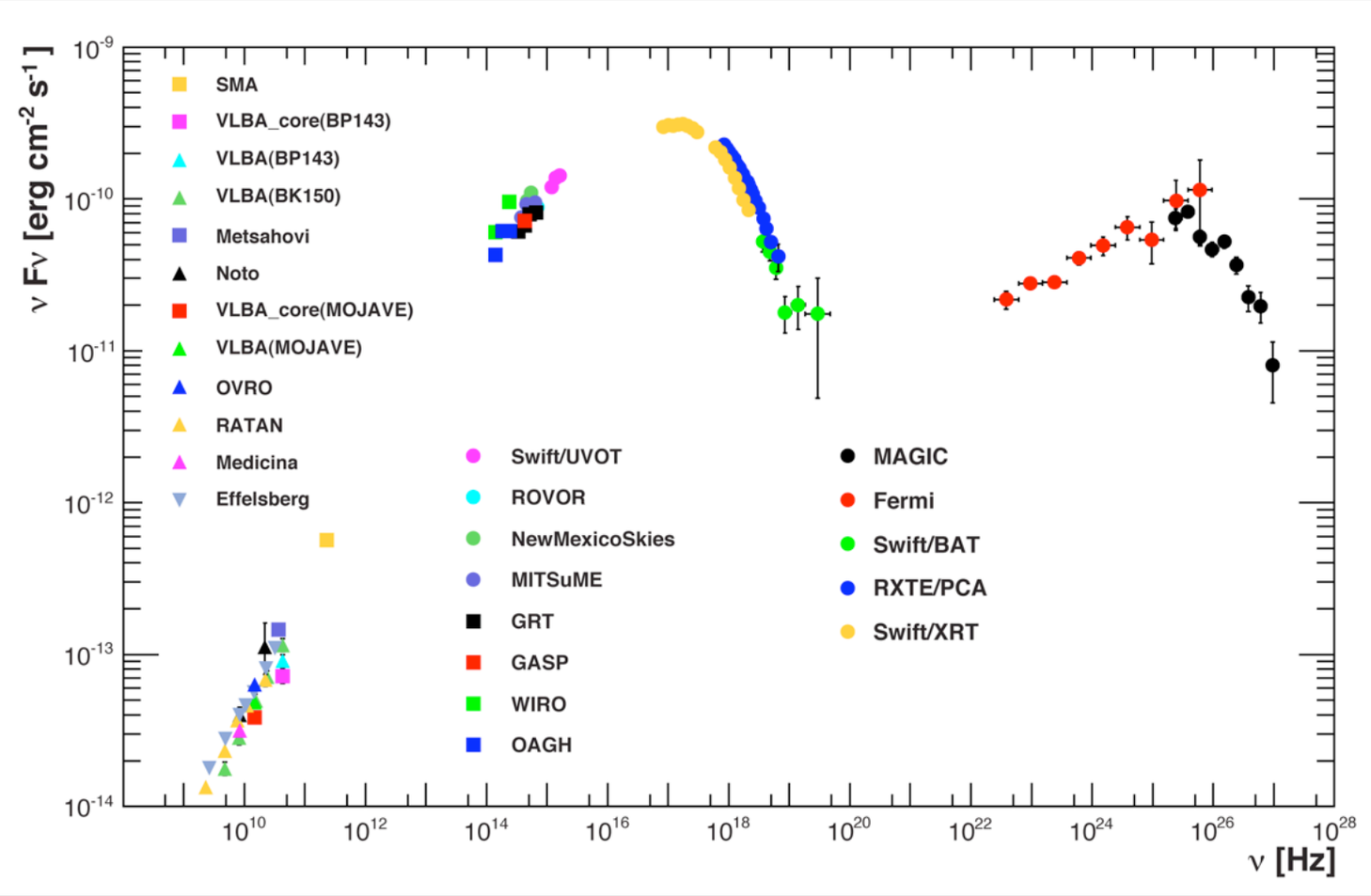


Illustration, credit: A. Simonnet

- One of the closest blazars to earth (400 million light years)
- Detected and observed in all wavelenghts (1992 VHE γ-ray...)
- Numerous observations since detection by various instruments

Motivation: Markarian 421

Spectral energy distribution (SED)



Abdo et al., ApJ **736** (2011) 131

- Most complete SED ever collected for Mrk 421
- Extensive MWL campaign in 2009 (Jan - Jun 2009)
- Typical two peak structure
- MAGIC: 80 GeV to 5 TeV

Motivation: Markarian 421

Additionally...

- Flux variations by more than one order of magnitude
  Fossati et al., ApJ **677** (2008) 906

- Occasional flux doubling times as short as 15 min
  Aharonian et al., A&A **393** (2002) 89

Motivation: Markarian 421

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How can we improve our knowledge?

- Other wavebands: high sensitivity on short timescales
- VHE γ-ray: averaging of particularly long periods
- Since 2009: MAGIC stereo, improved quality on short timescales → day to day evolution of spectral features!

The MAGIC telescopes

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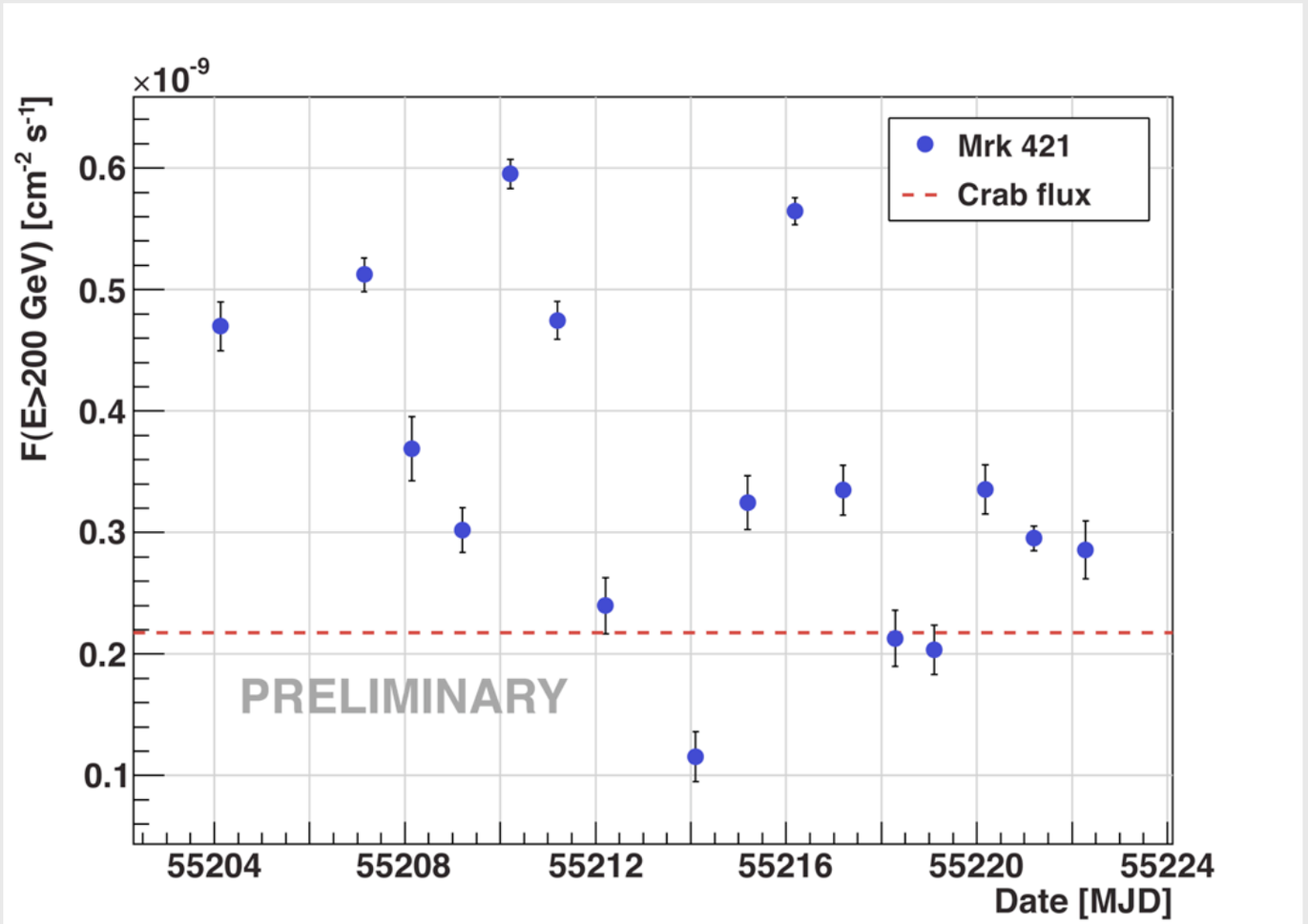
- System of two IACT (Imaging Atmospheric Cherenkov telescopes)
- Each telescope: 17m diameter mirror
- Threshold ≈ 50 GeV
- Sensitivity ≈ 0.8% crab (50 hours, > 300 GeV)
- Energy resolution ≈ 16% (medium energies)

MAGIC observations January 2010

Lightcurve Mrk 421 January 2010

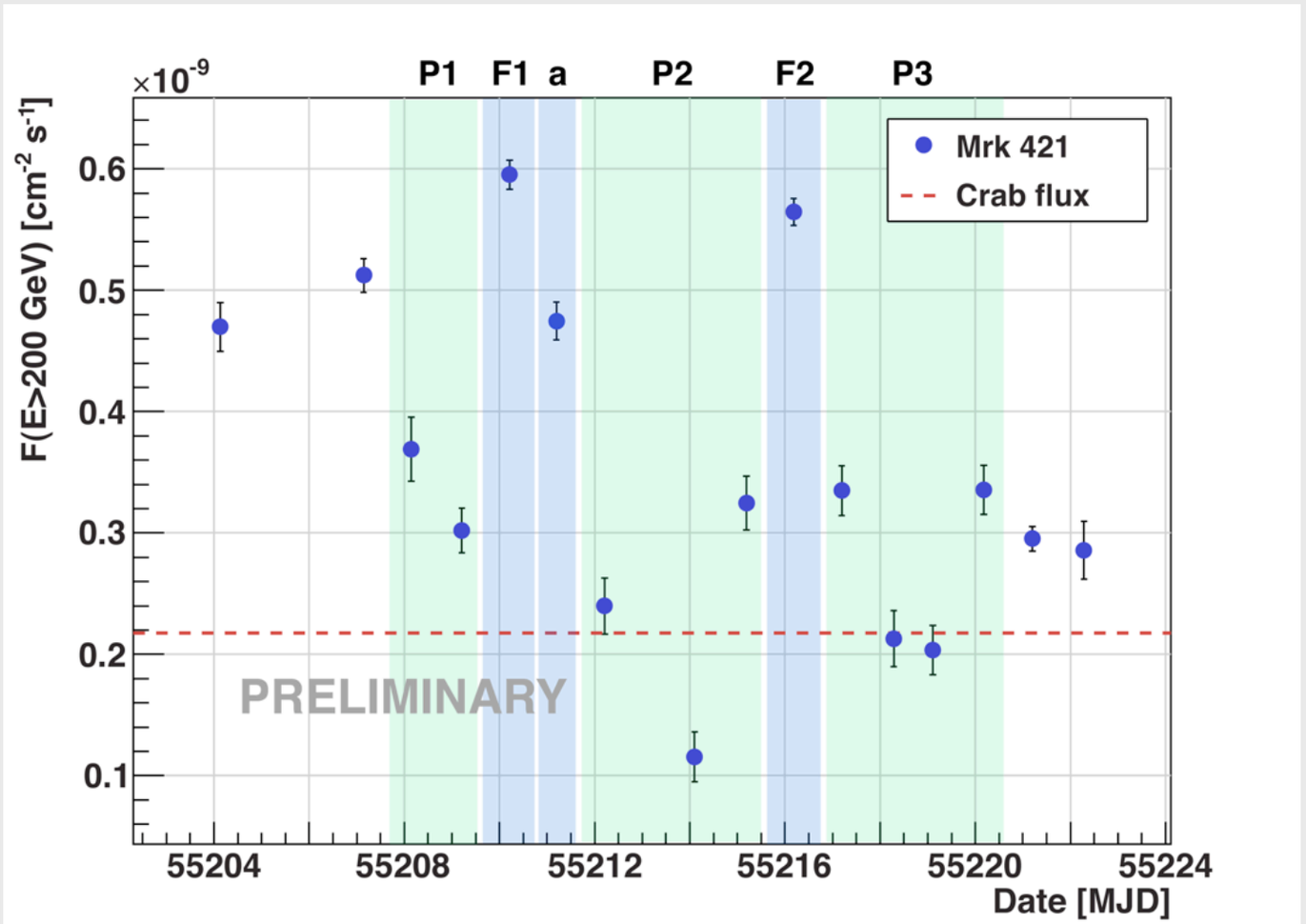


- 16 days analysed:
  08/01/2010 - 26/01/2010
- Two distinct flares:
  Jan 14th (≈ 2.7 c.u.)
  Jan 20th (≈ 2.6 c.u.)

Day-by-day binning
Each observation shows significant detection (> 5 σ)

MAGIC observations January 2010

Lightcurve Mrk 421 January 2010



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MAGIC observations January 2010

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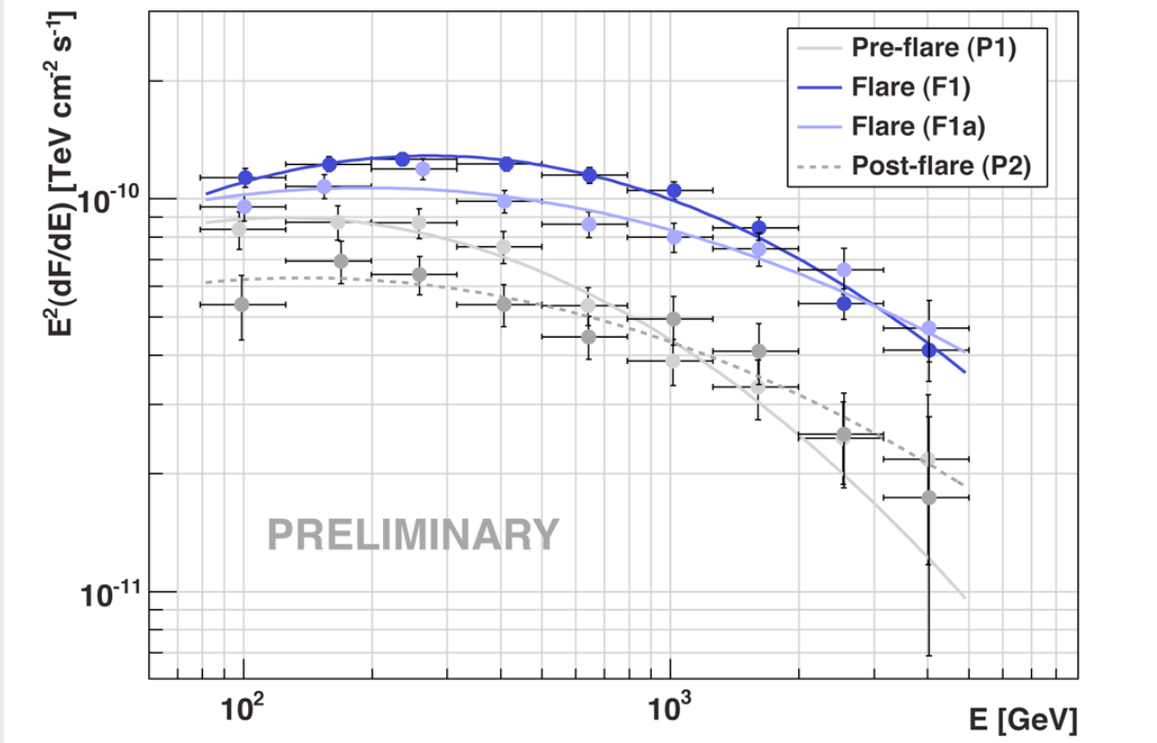
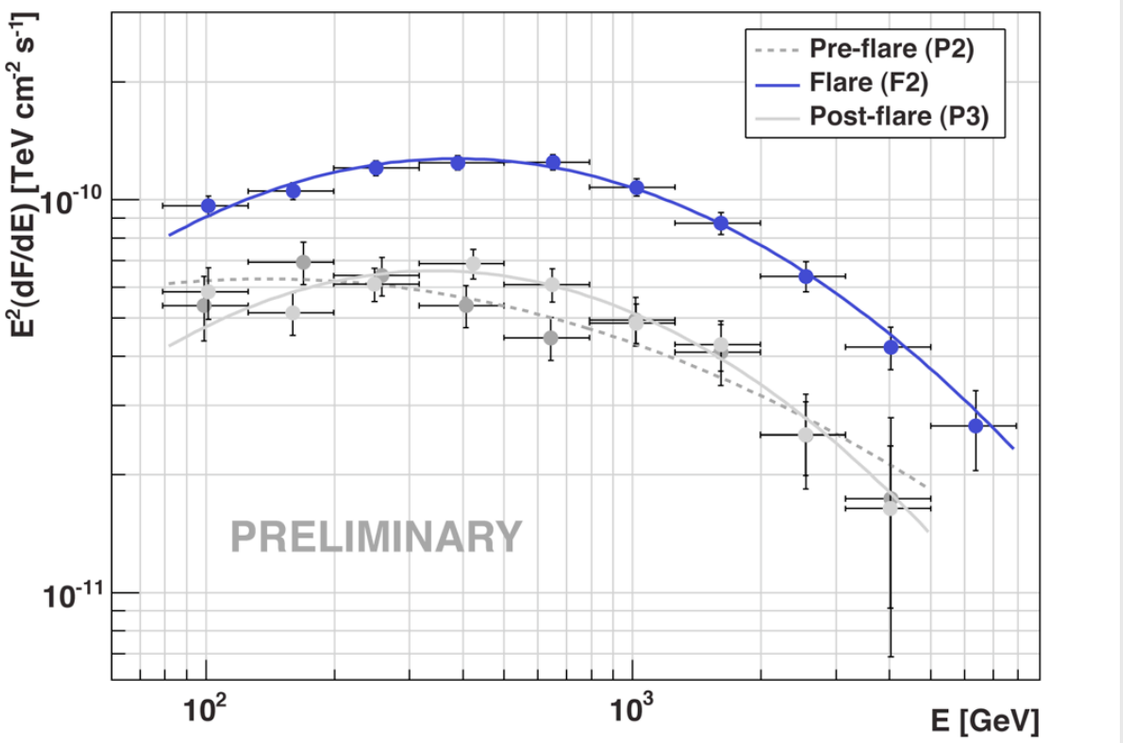
SED for flare F1 and adjacent periods



SEDs from 80 GeV to 5 TeV

SED for flare F2 and adjacent periods



F2 SED extends from 80 GeV to 8 TeV

MWL observations and modelling

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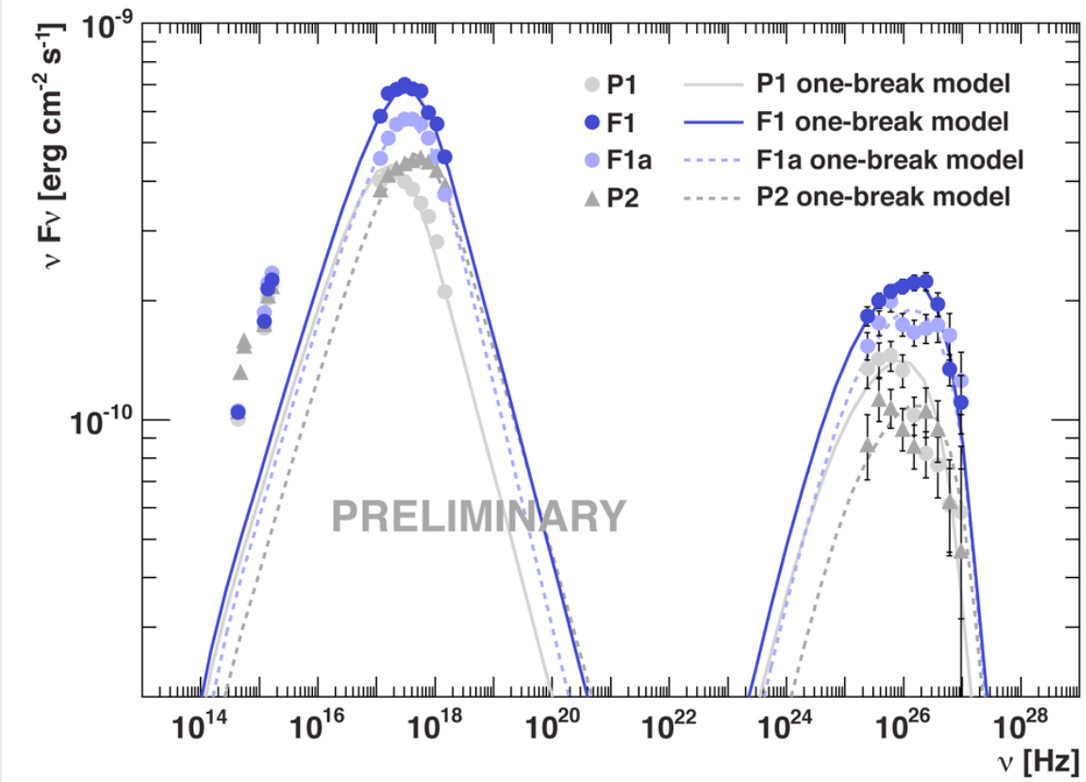
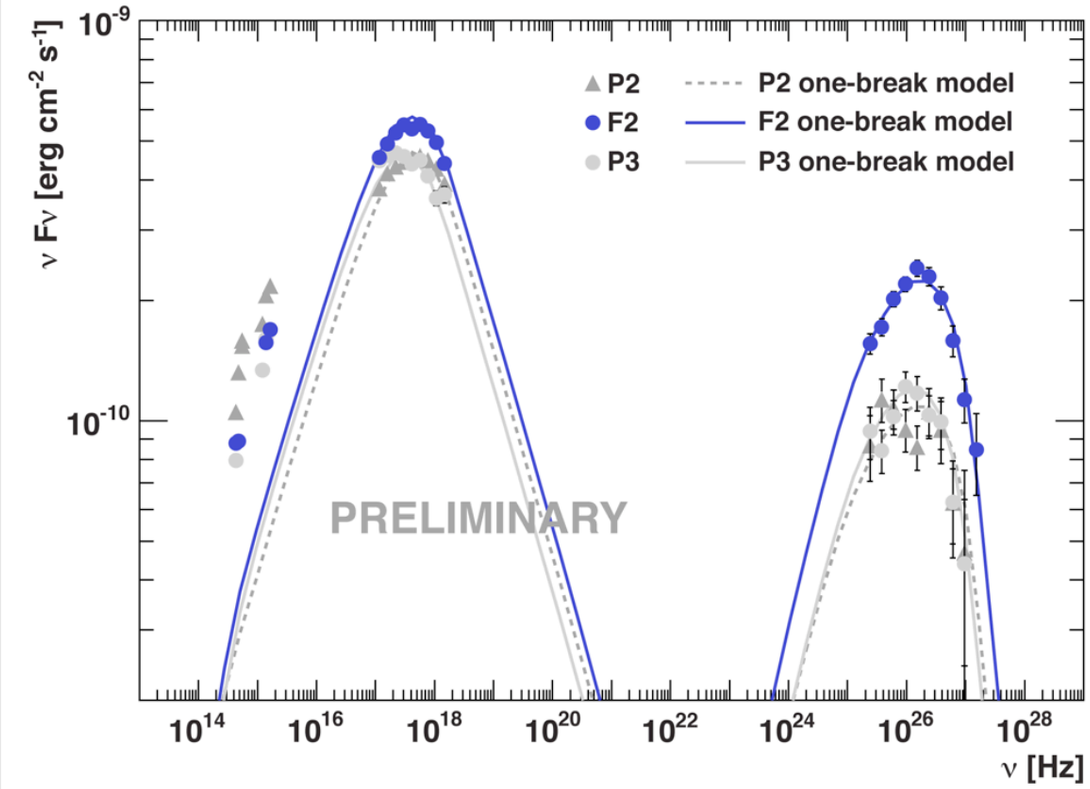
SED for flare F1 and adjacent periods

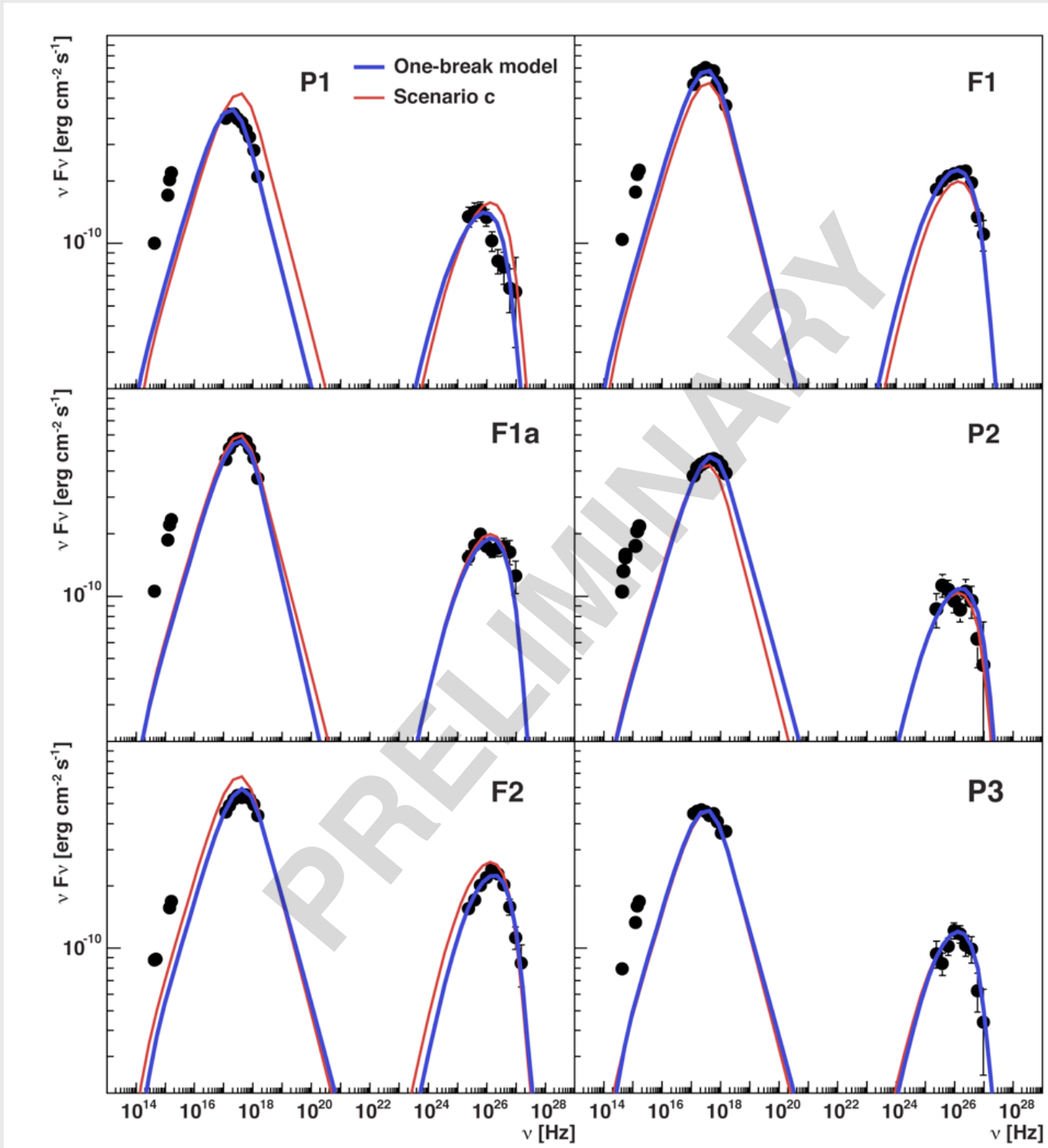


SED for flare F2 and adjacent periods



Optical	GASP, NMS, BRT
UV	Swift/UVOT
X-ray	Swift/XRT
[Radio]	[UMRAO, OVRO, Metsähovi]

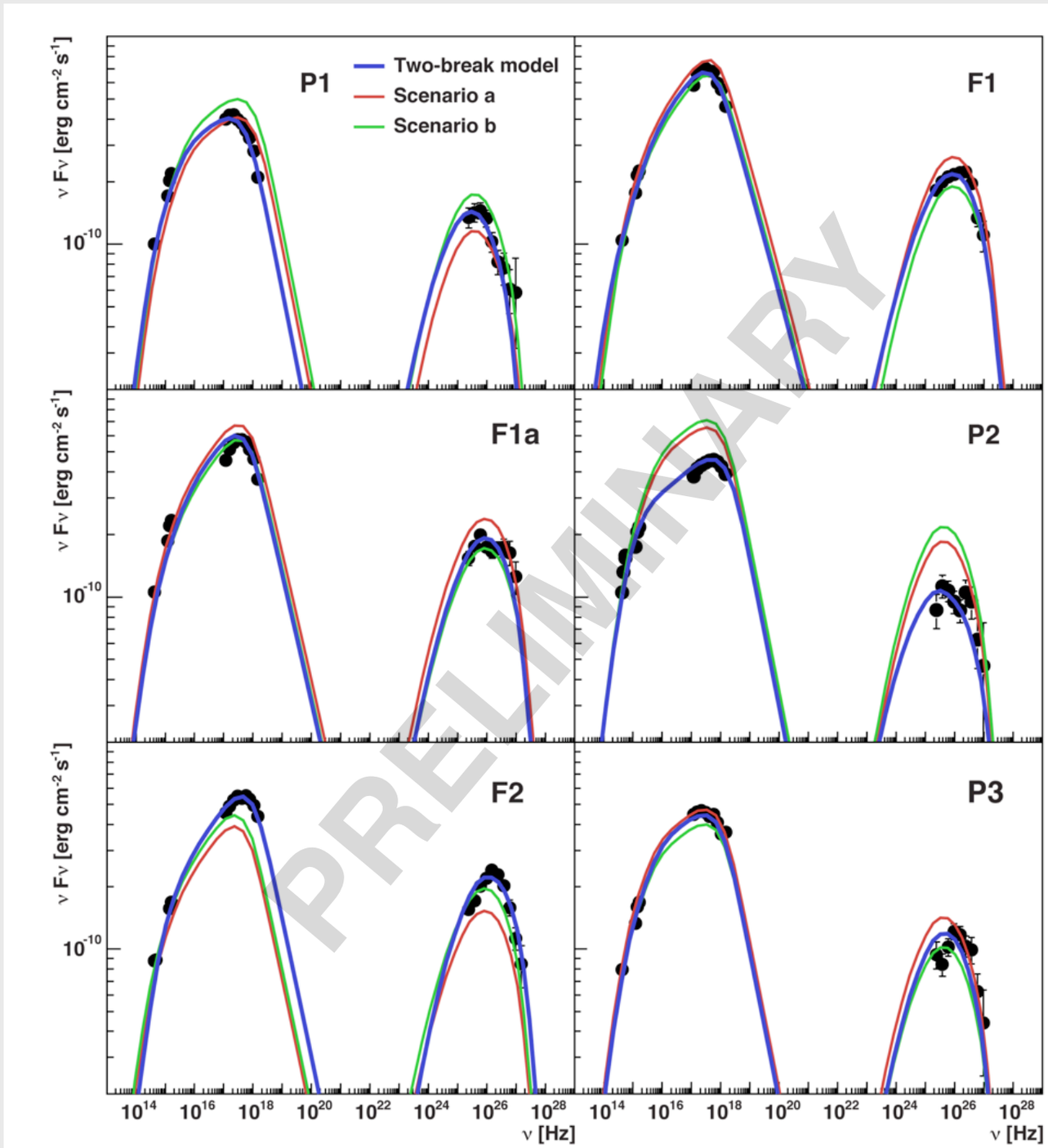
MWL observations and modelling



One-break SSC model

Emission region	9 x 10^{15} cm
Beaming	45
Magnetic field	32-42 mG
Electron number density	**650-1030 cm^{-3}**
Electron Lorentz factors:	
Minimum	3-6 x 10^{3}
Break	1.6-2.8 x 10^{5}
Maximum	1 x 10^{8}
Spectral indices:	
Low energy	2.0
High energy	4.0-4.2

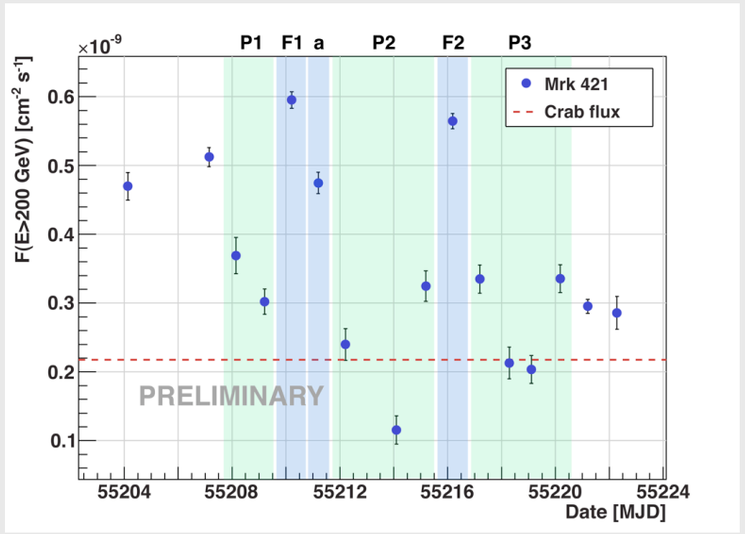
MWL observations and modelling

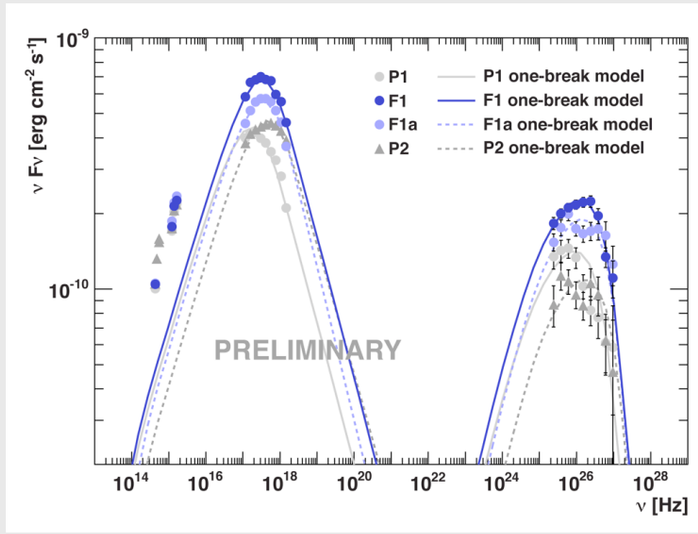


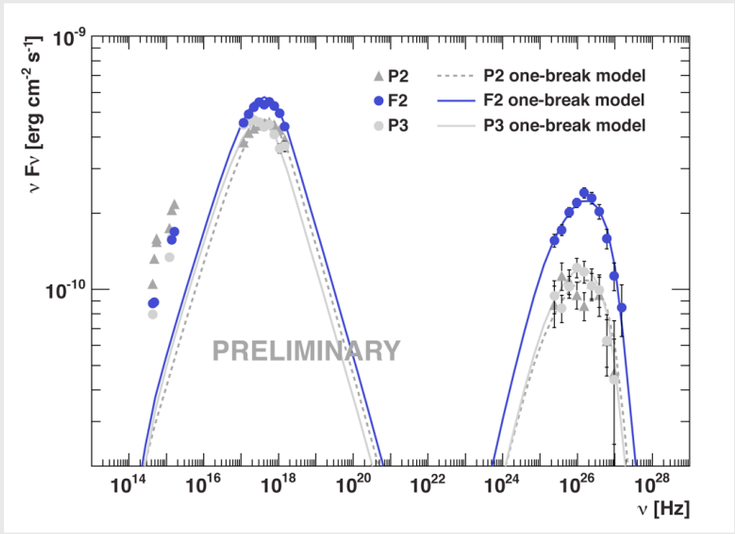
Two-break SSC model
(including optical)

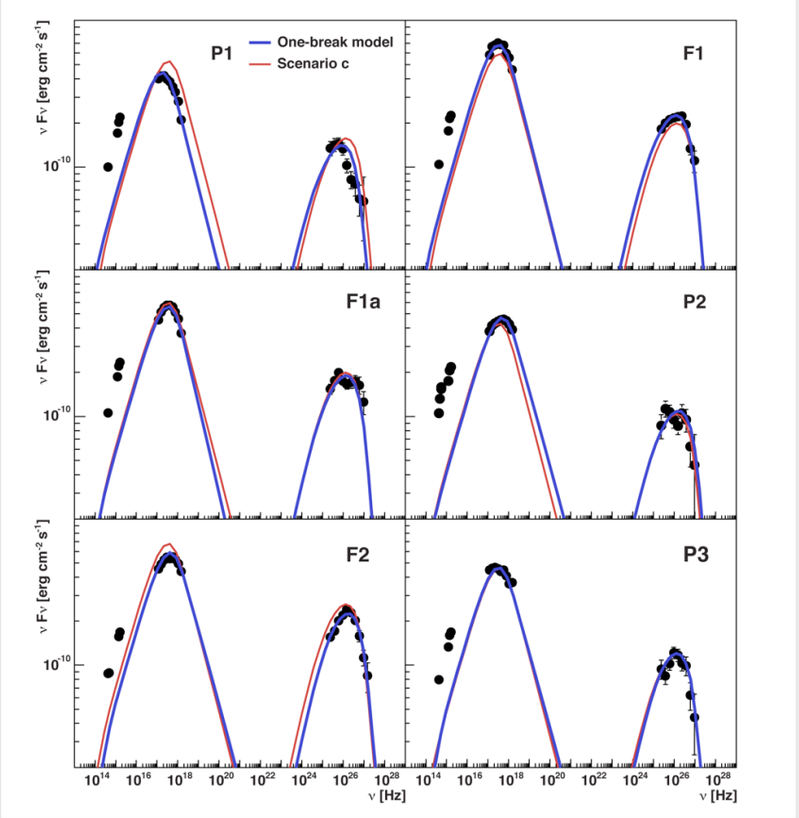
Emission region	2.5 x 10^{16} cm
Beaming	**32-50**
Magnetic field	**13-40 mG**
Electron number density	90-130 cm^{-3}
Electron Lorentz factors:	
Minimum	5-12 x 10^{3}
Break 1	2-4 x 10^{4}
Break 2	3-5.5 x 10^{5}
Maximum	1 x 10^{8}
Spectral indices:	
Low energy	1.9
Medium energy	**2.55-2.75**
High energy	**4.0-4.4**

Conclusion









- First spectral evolution measurement during flares in VHE γ-ray regime
- In one-break one-zone SSC model flares are mainly driven by changes in electron number density

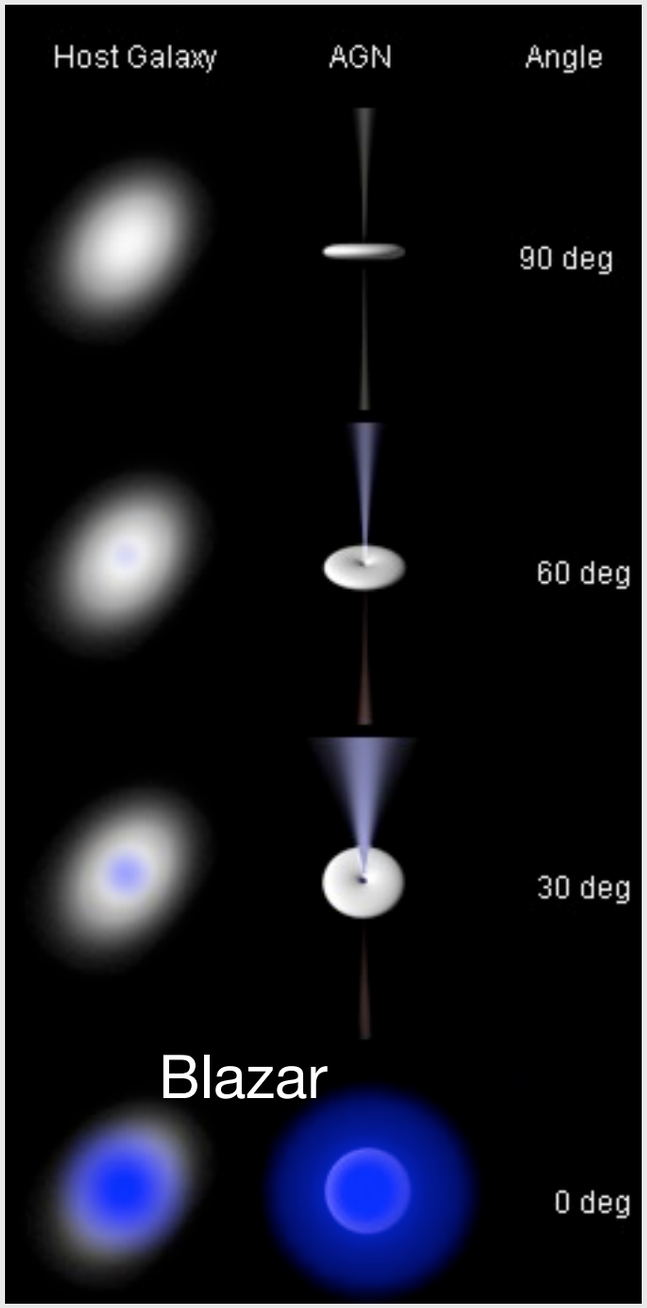
Thank you for your attention

wwwmagic.mppmu.mpg.de

Backup slides

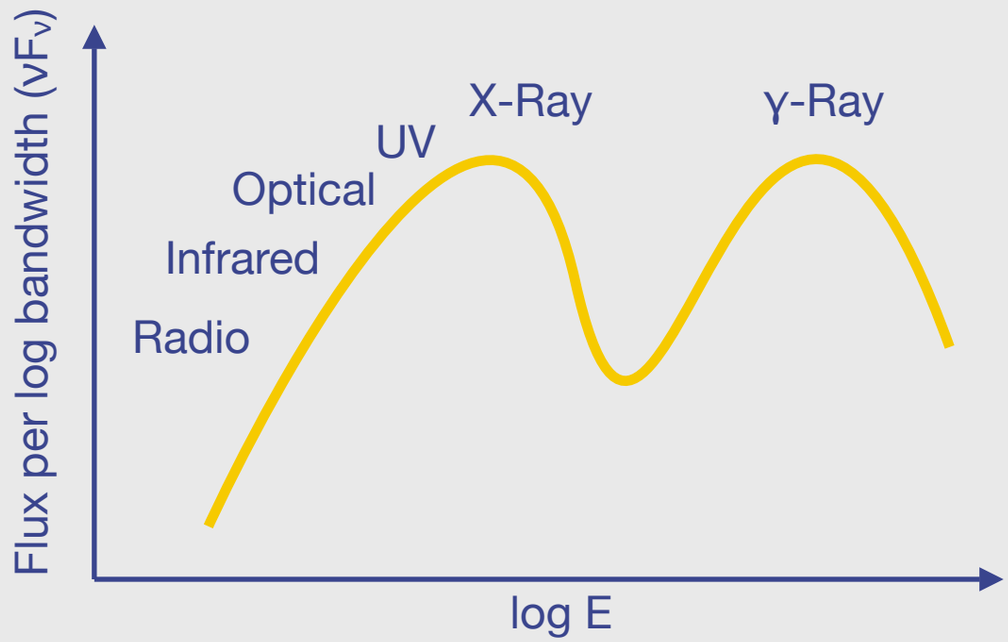
Backup slides

Active Galactic Nuclei (AGN)



Credit: Ron Kollgaard

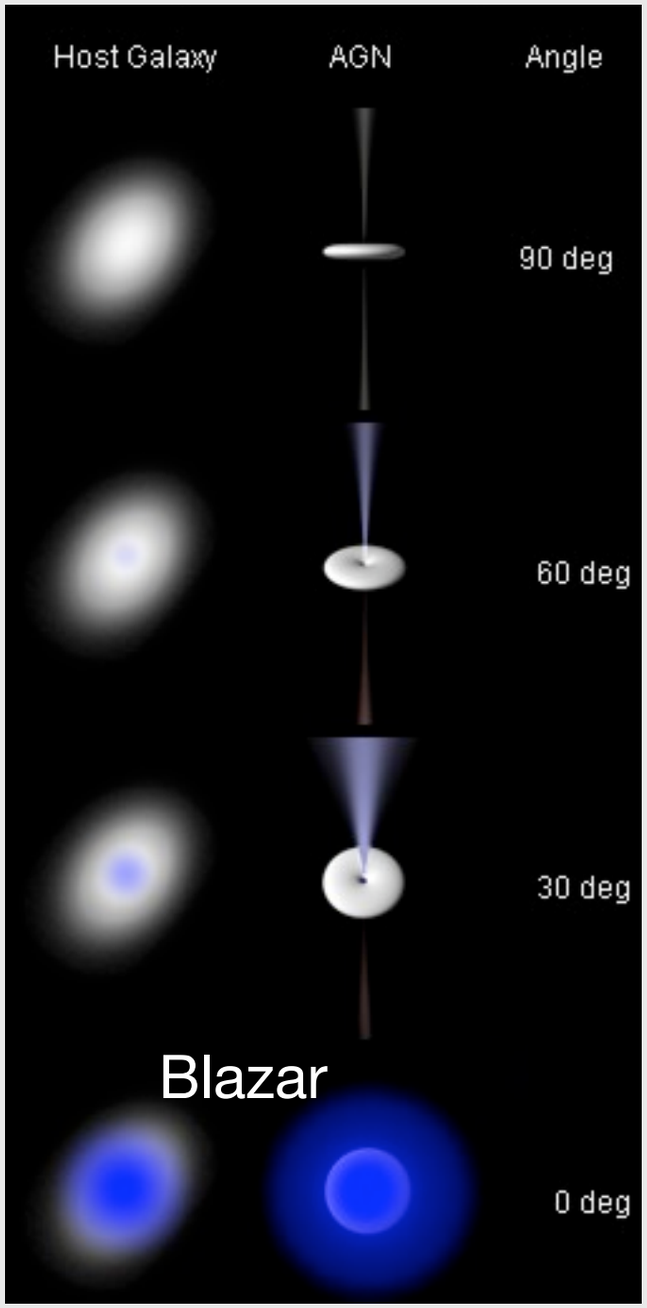
Continous Spectral Energy Distribution (SED)



2 typical peaks in SED of blazars:

Origin is assumed to be from synchrotron radiation and inverse Compton up-scattering of synchrotron photons (SSC model).

Active Galactic Nuclei (AGN)



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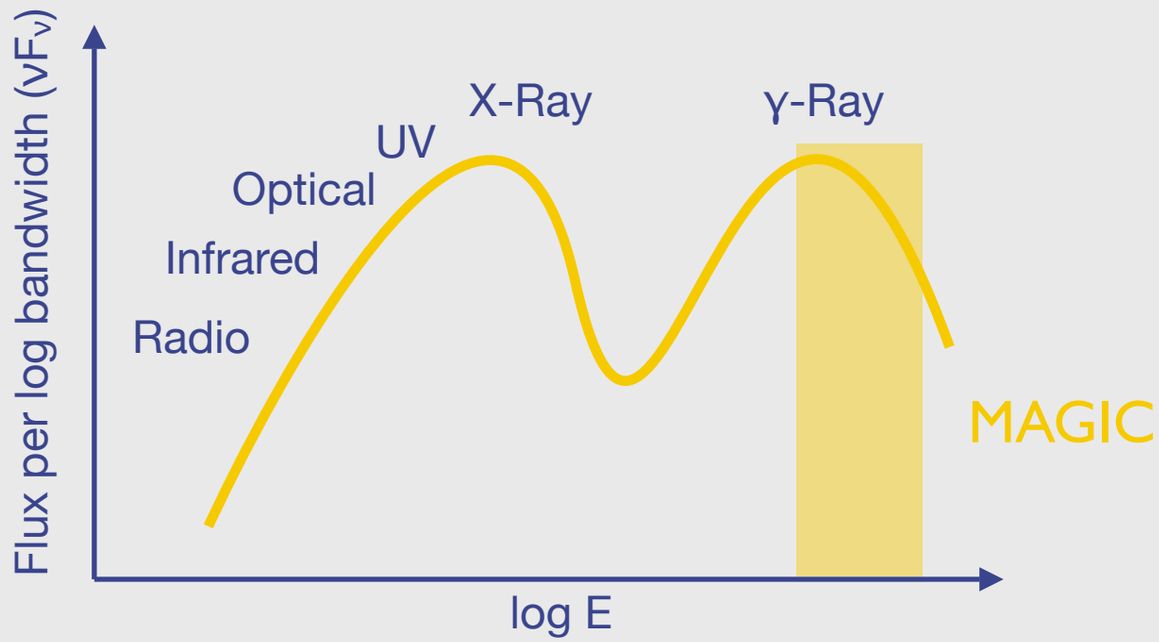

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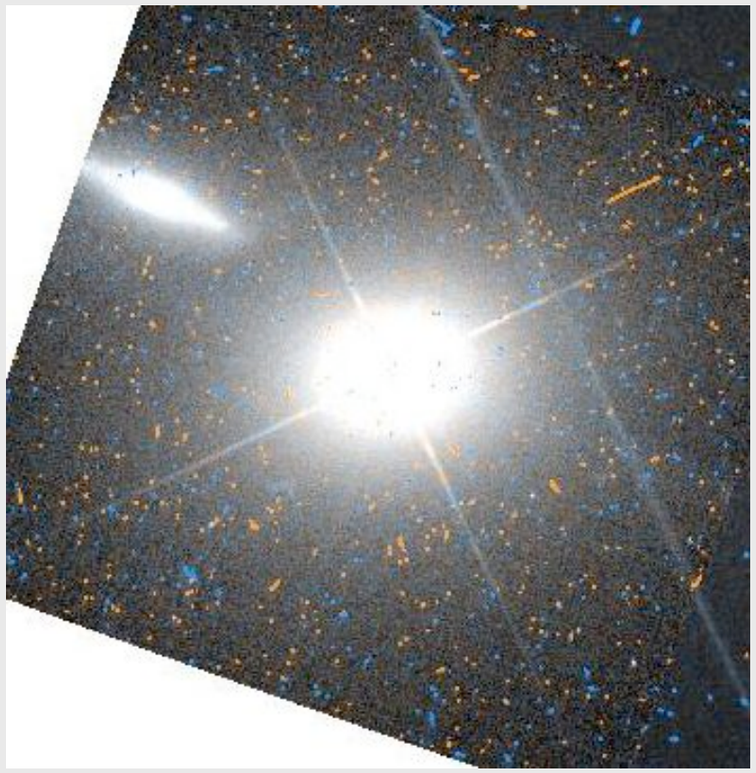
Markarian (Mrk) 421



Credit: Hubble Telescope

- One of the closest blazars to earth, making it one of the brightest AGN in night sky
- 400 million light years from earth (redshift 0.03, 120 Mpc)
- Detected and observed in all wavelenghts (1992 VHE γ-ray...)
- Numerous observations since detection by various instruments

The MAGIC II camera

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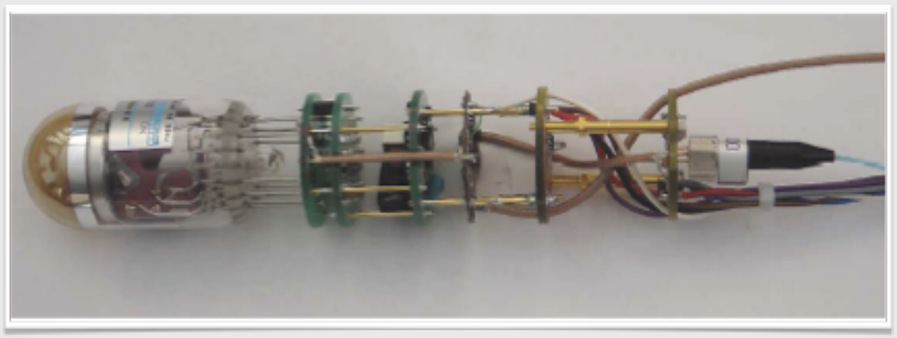
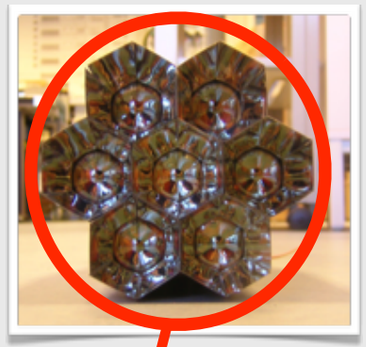
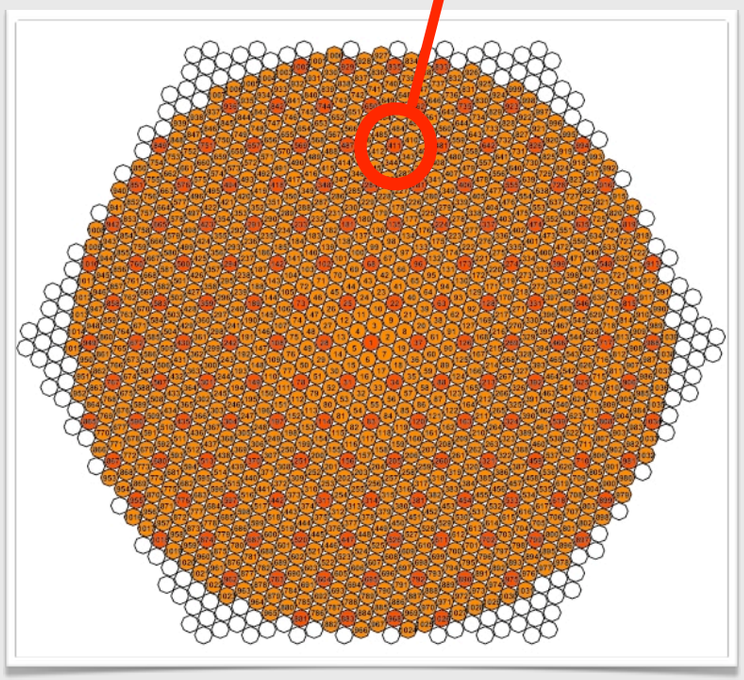
Hemispherical High QE PMT



7 PMT grouped in a cluster





1039 PMT in total

Imaging Air Cherenkov Technique

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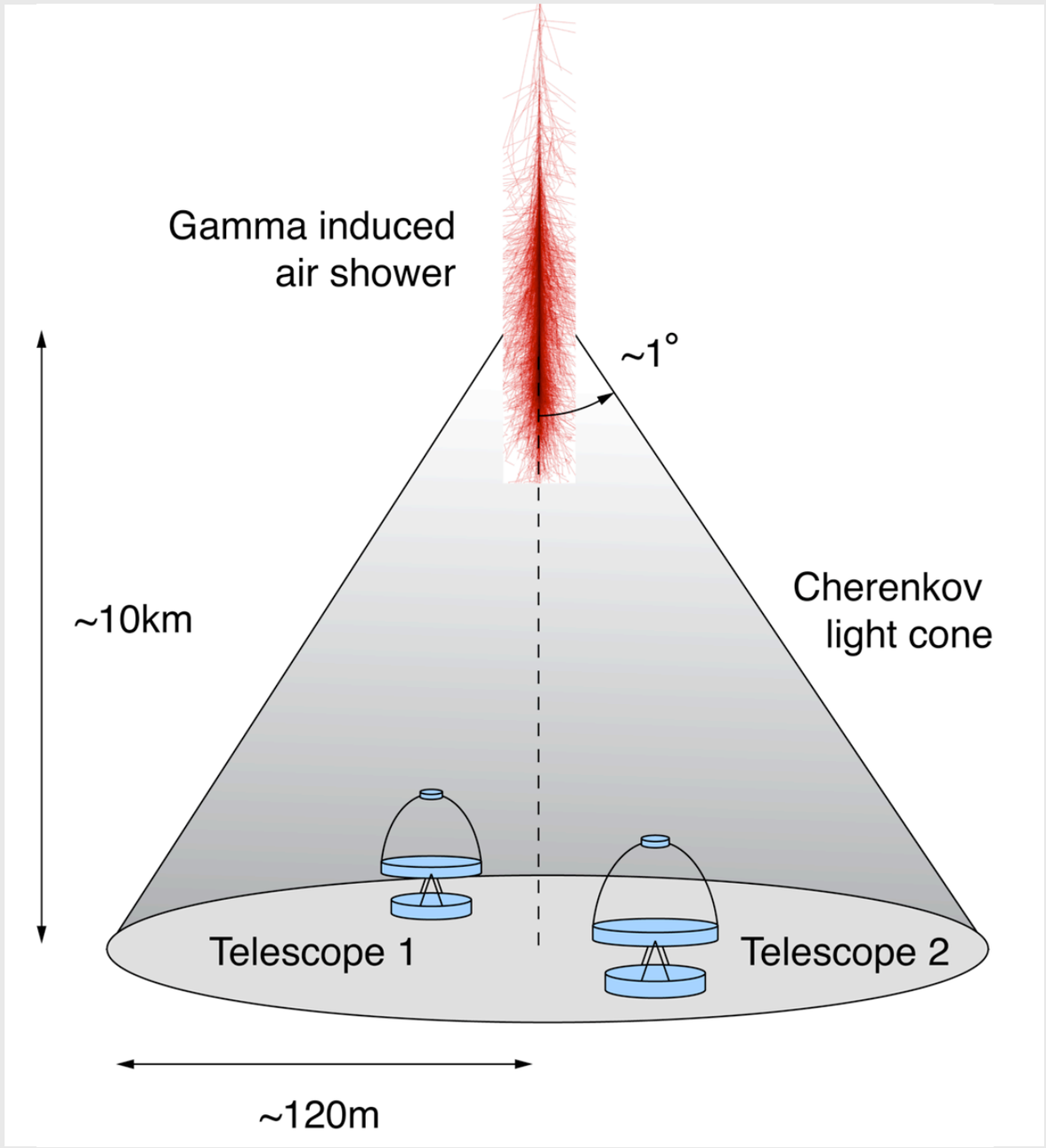
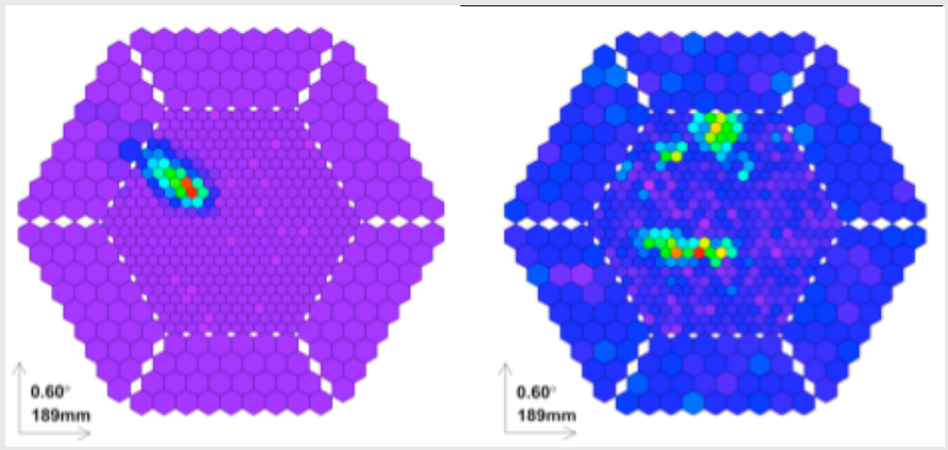


γ event

Hadron event



Hadrons (background) dominate over γ (signal) by a factor of several 100. They are rejected in the analysis.

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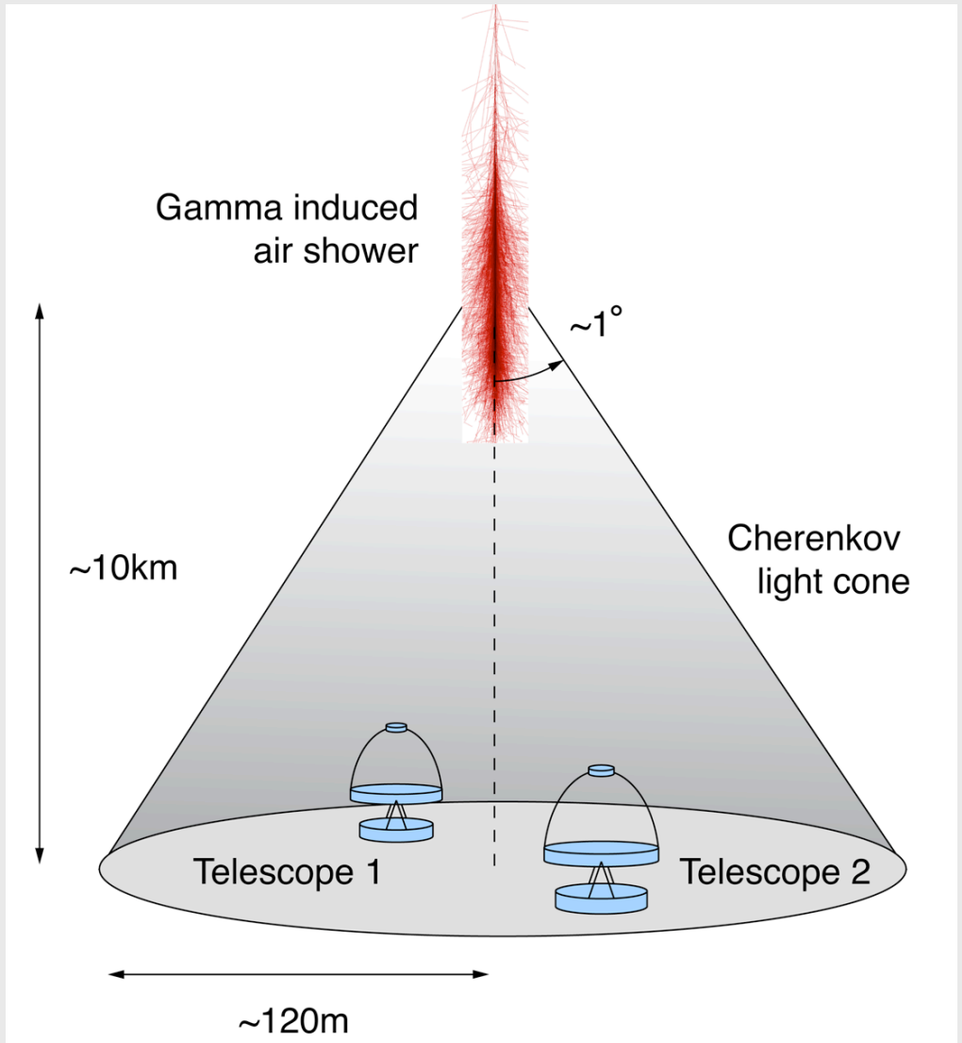

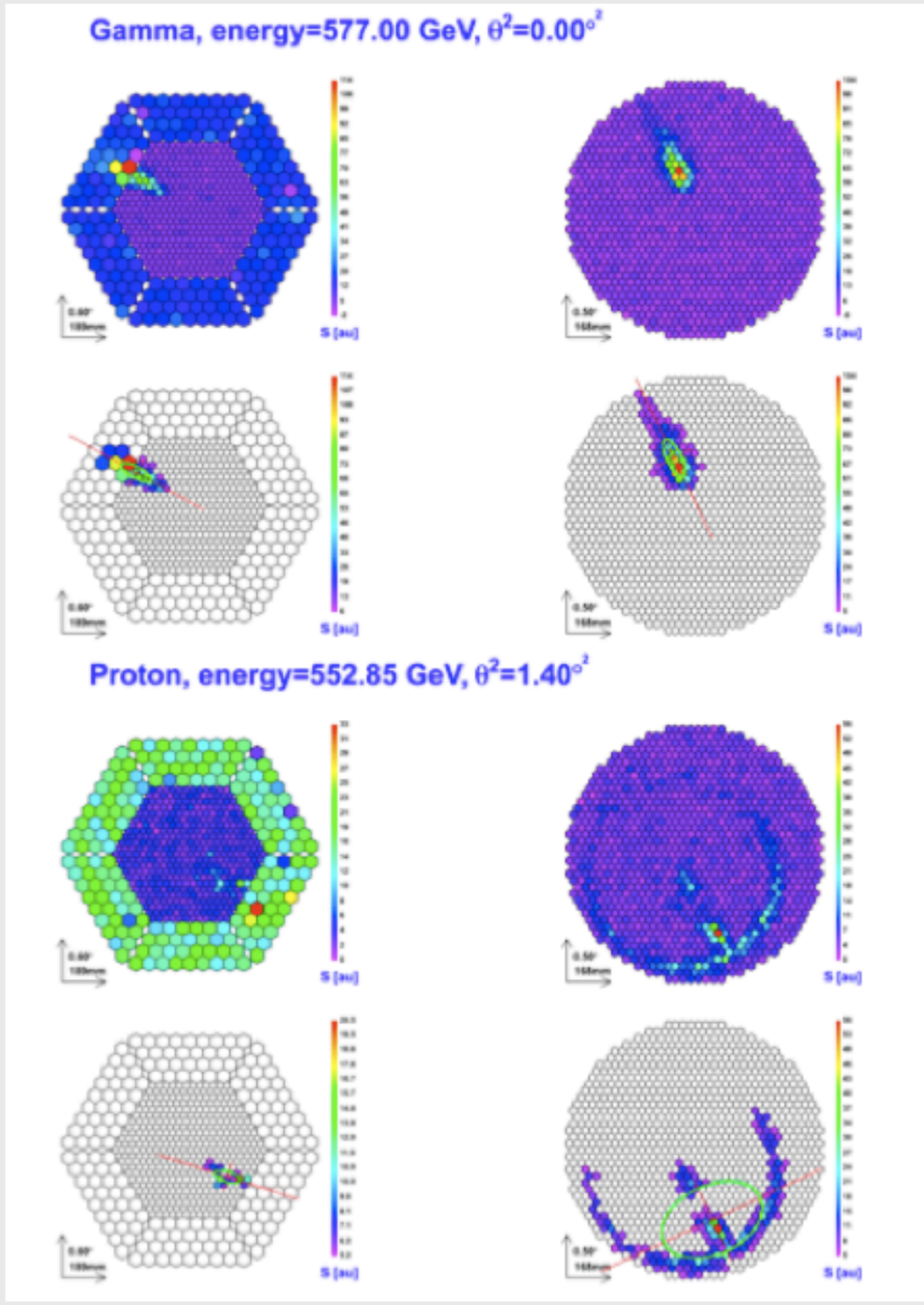

- 3D reconstruction of shower parameters
- Better source position determination
- Improved background reduction

MAGIC observations January 2010

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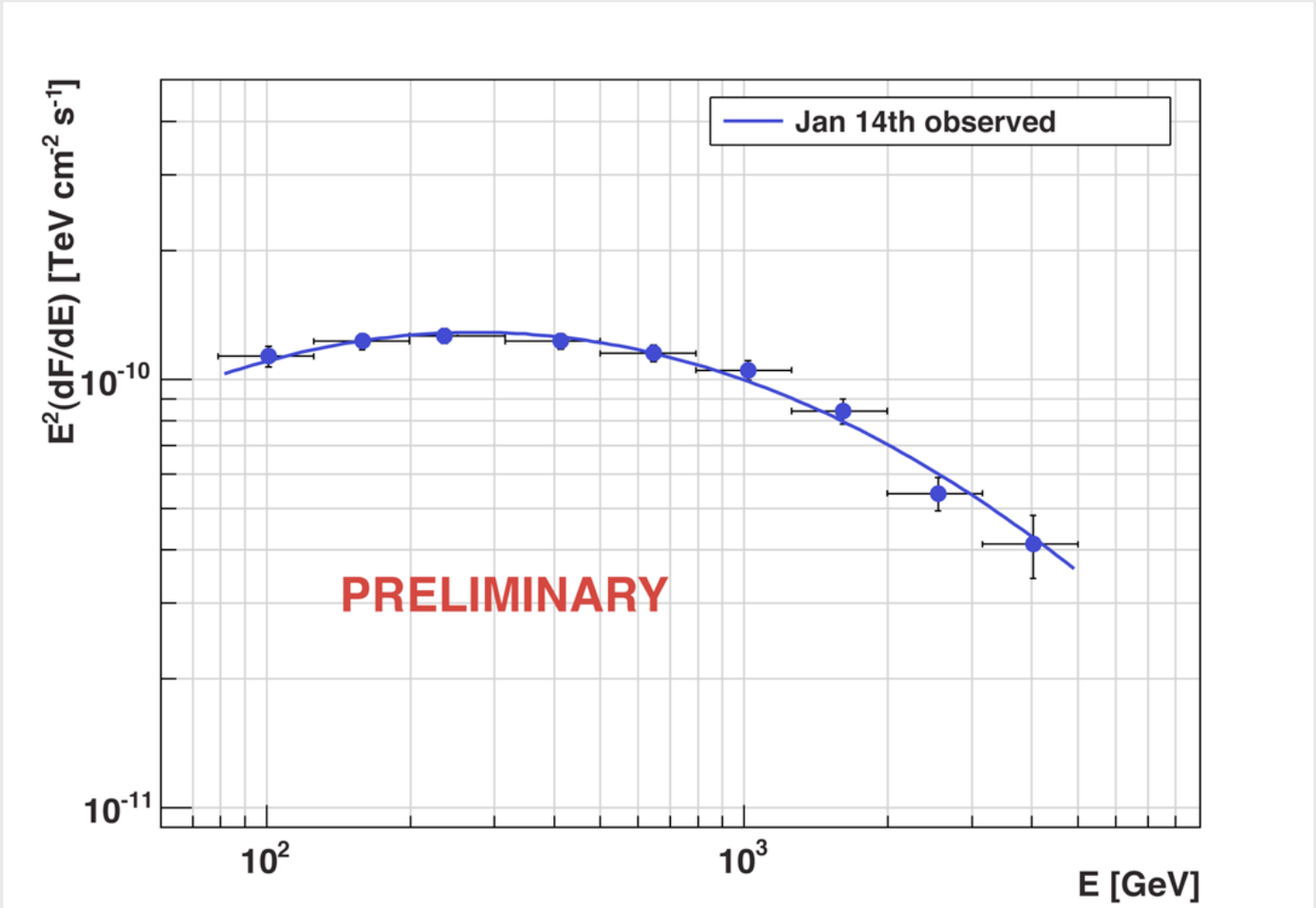
SED Mrk 421 January 14th 2010



- Effective observation time ≈ 2.3 h
- Significance: 55 σ
- SED: 80 GeV - 5 TeV
- Curved power law fit
- Turnover resolved

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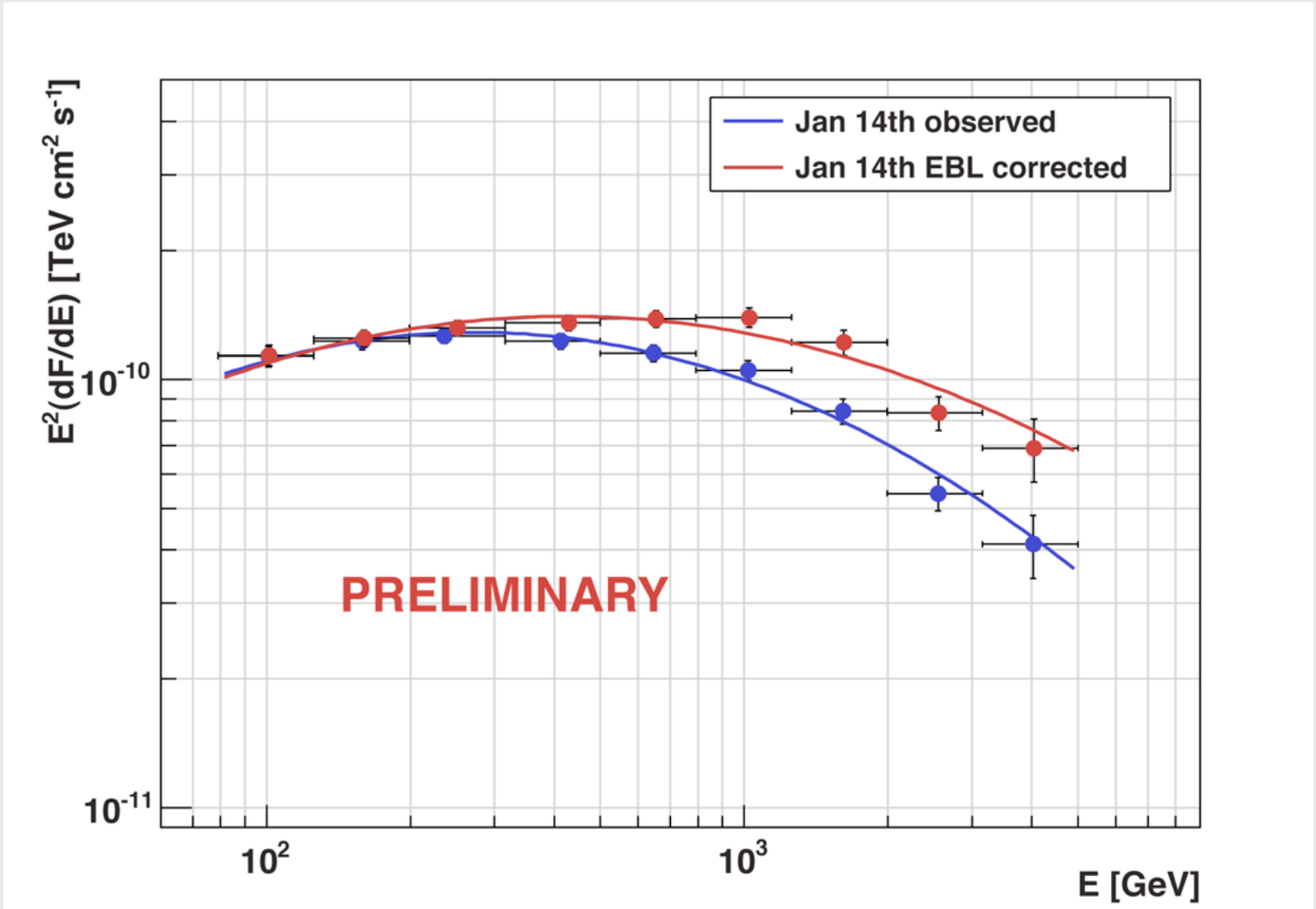
SED Mrk 421 January 14th 2010



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EBL correction:

- Franceschini model:
  Franceschini, A., Rodighiero, G. & Vaccari, M., A&A **487** 83 (2008)

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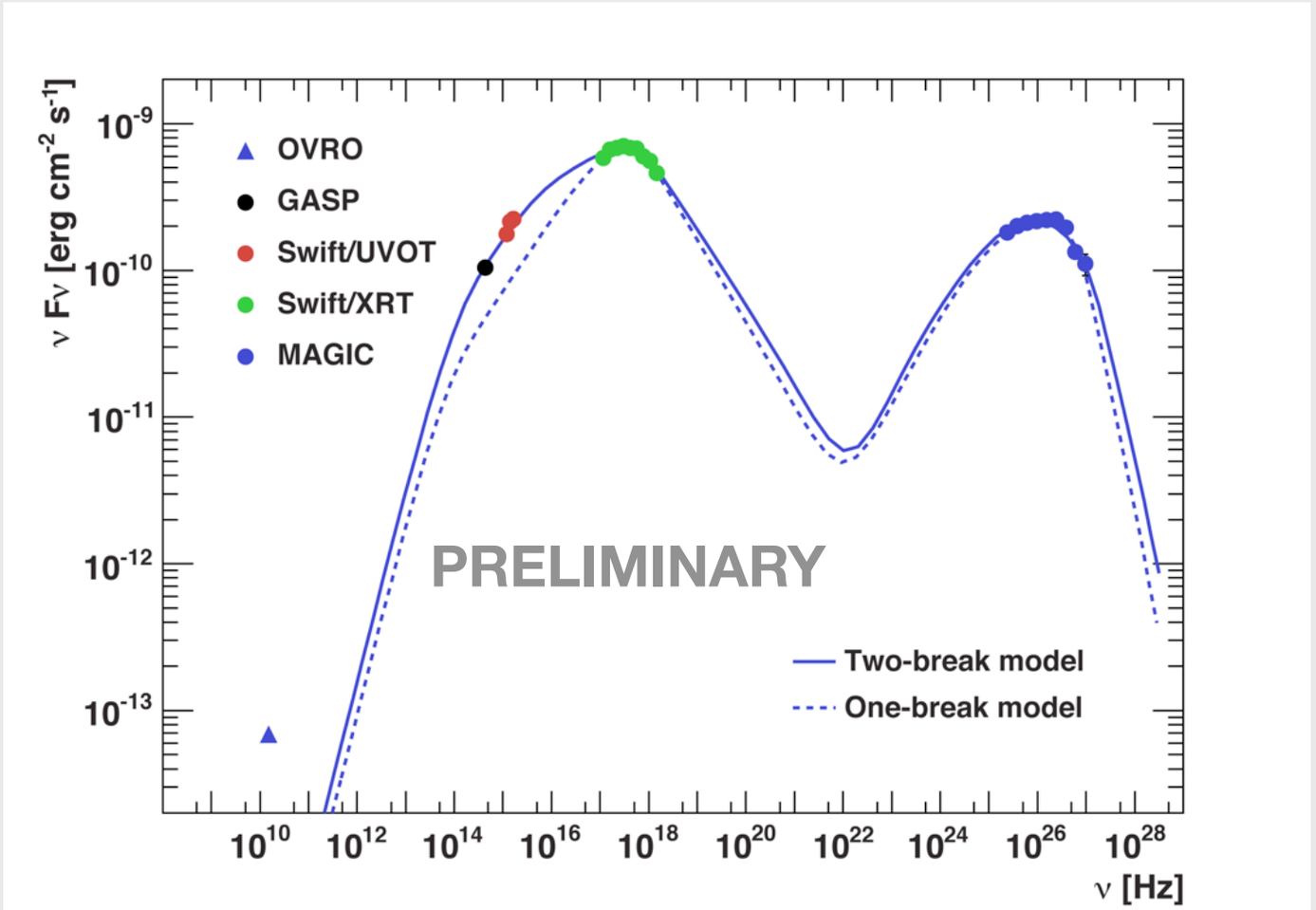
SED Mrk 421 January 14th 2010



OVRO (radio, 1.5 GHz)

GASP (optical, *R* band, 461 THz)

Swift/UVOT (UV, 1.05-1.93 PHz)

Swift/XRT (X-ray, 0.3-9.6 keV)

MAGIC (γ-ray, 80 GeV - 5 TeV)