The Spectrum of Markarian 421 Above 100 GeV with STACEE

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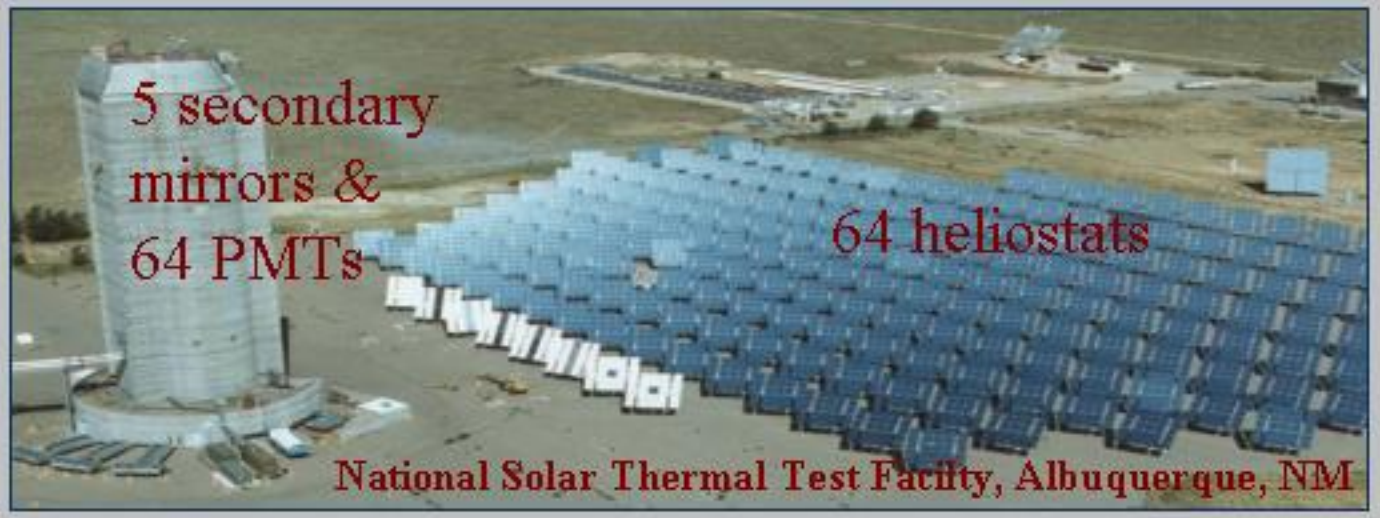
STACEE

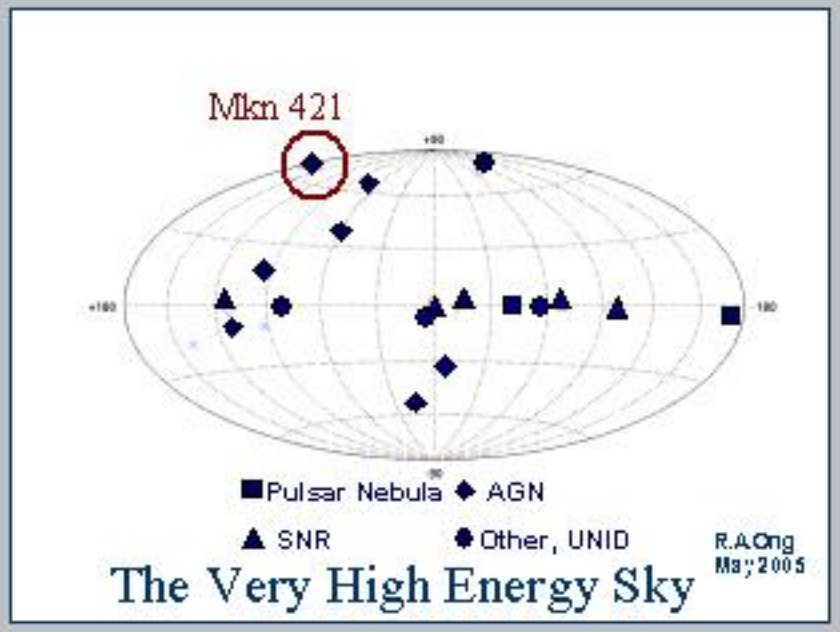
Solar Tower Atmospheric Cherenkov Effect Experiment

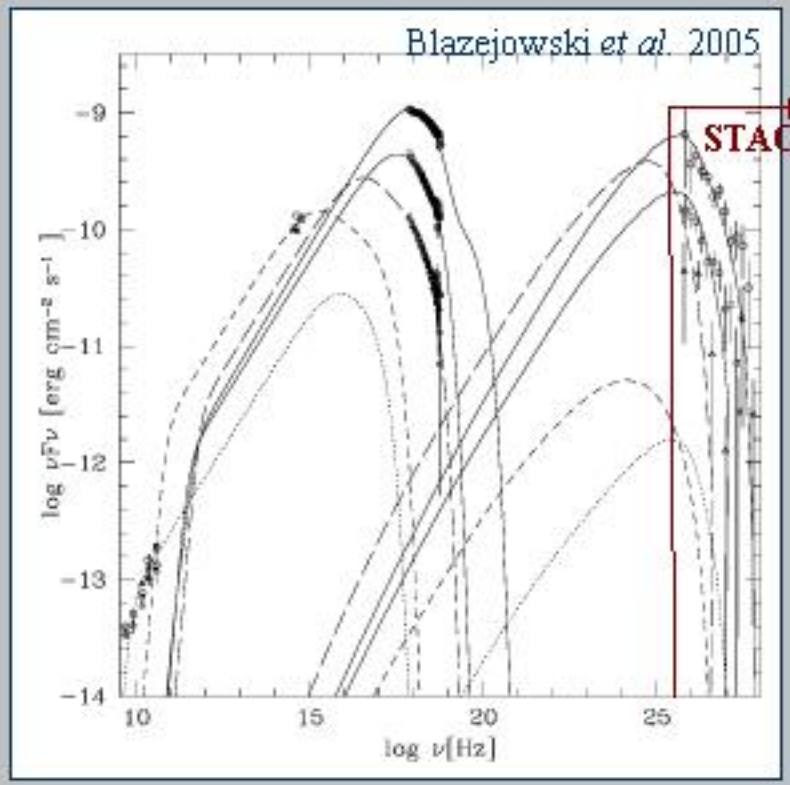


- Cherenkov light intensity on ground → energy of gamma ray
- Cherenkov pulse arrival times at heliostats → direction of source
- Large mirror area ($64 \times 37 m^2$) ⇒ low energy threshold (~100 GeV)
- Limited off-line cosmic ray rejection ⇒ limited sensitivity
- Observing Strategy: equal-time background observations for every source observation

Markarian 421

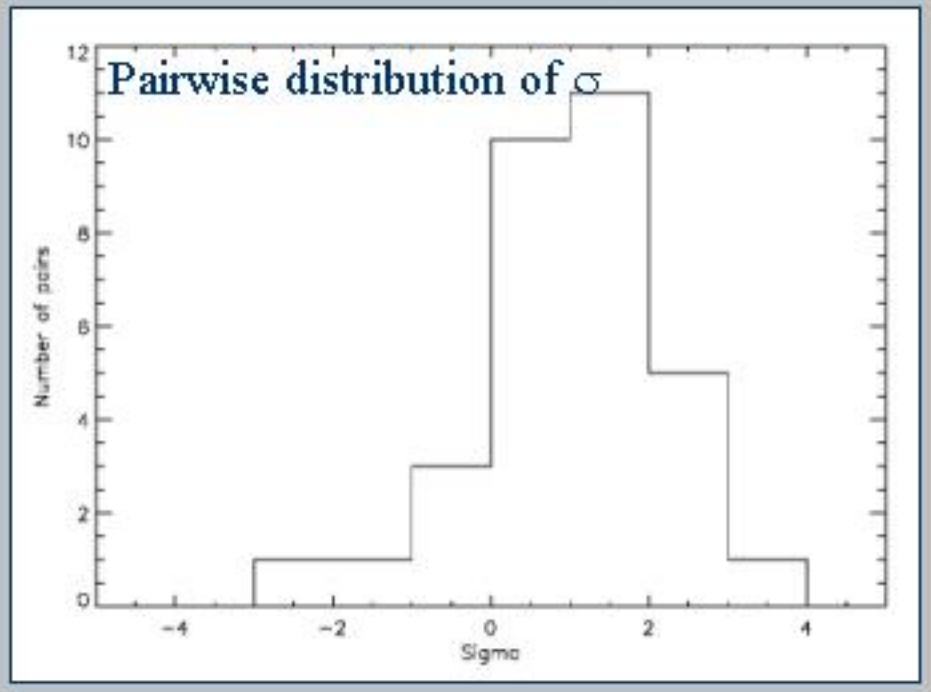
- Nearby: z = 0.03
- First TeV extragalactic source detected (1992)
- Well-studied at all wavelengths except 100-300 GeV
- Most models assume inverse-Compton scattering
- High-energy peak expected around 100 GeV
- Only on previous measurement at ~100 GeV

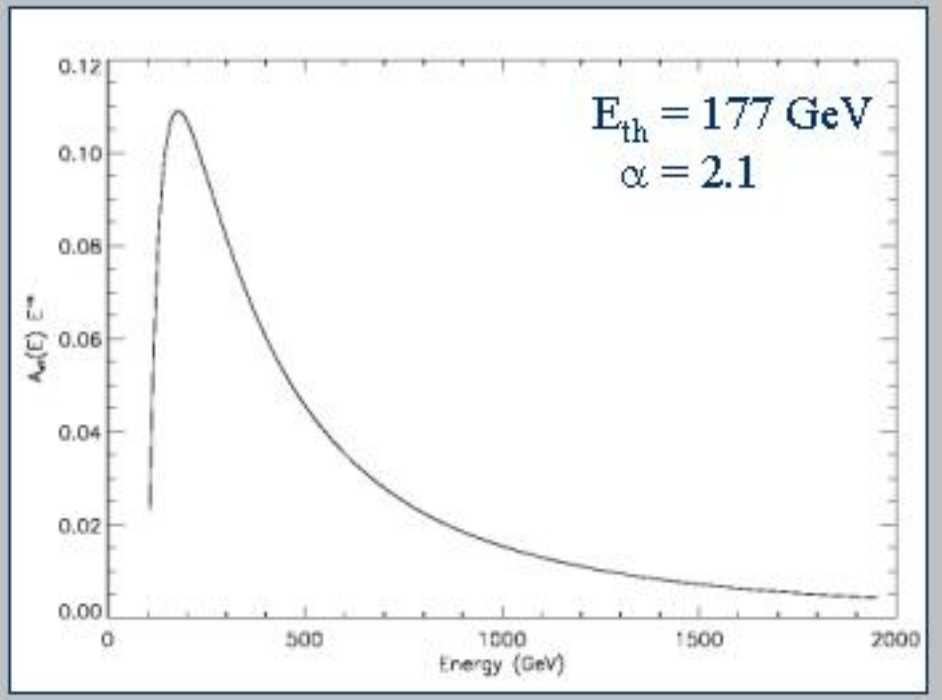




Detection!

- Observed by STACEE January – May 2004
- 9.1 hours on-source + equal time in background observations
- Gamma-ray "excess" = N_{on} - $N_{background}$
- 5.8σ detection
- 5.52 ± 0.95 gamma rays per minute
- Energy threshold ~175 GeV for $\alpha = 2.1$





Energy Reconstruction Method

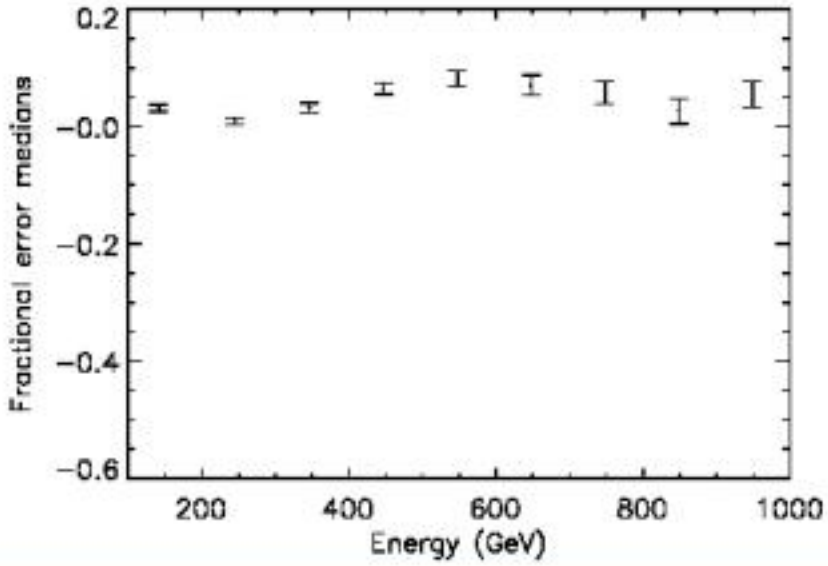
New method to find energies of gamma rays from STACEE data:

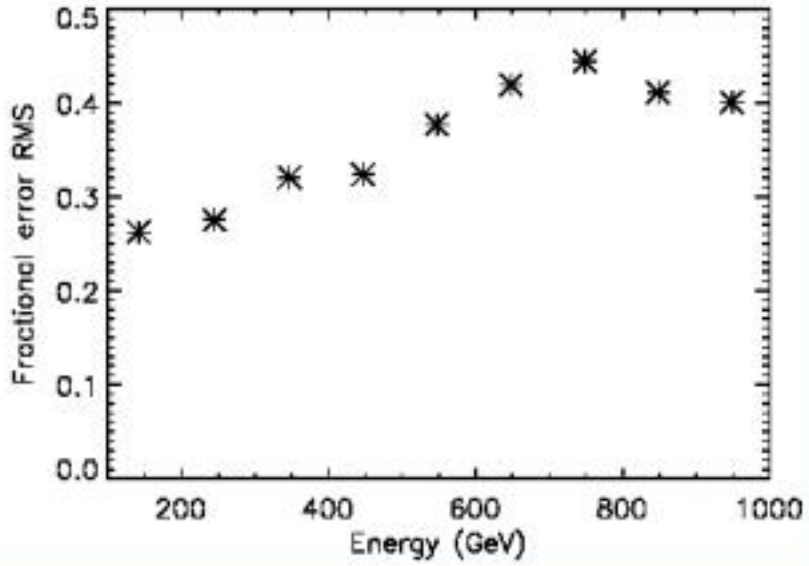
1. Reconstruct Cherenkov light distribution on the ground from PMT charges
2. Reconstruct energy from spatial distribution of light

Results:

fractional errors < 10%

energy resolution ~25-35%

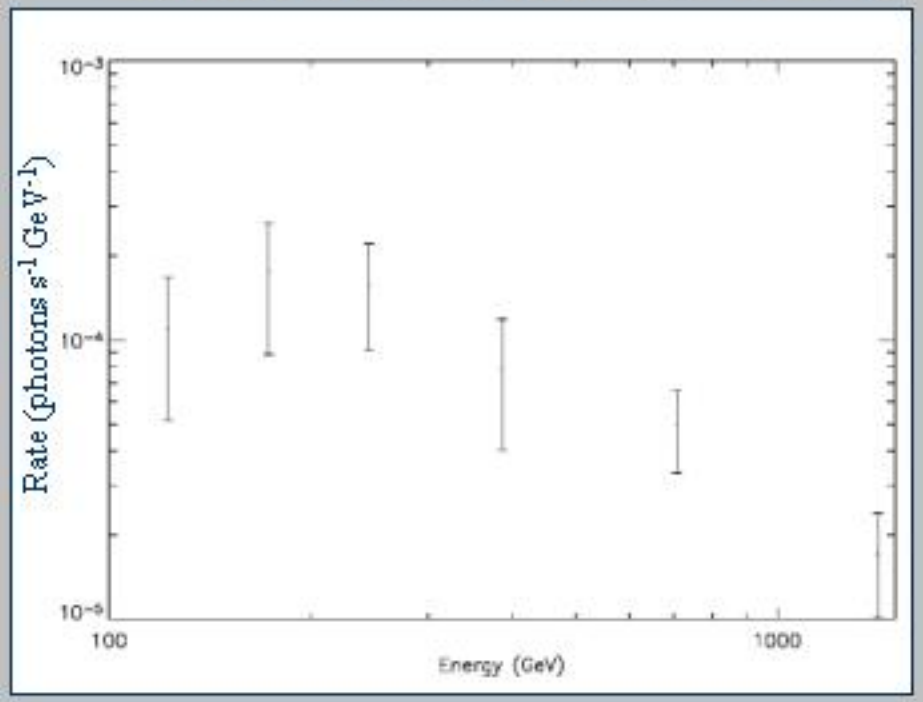




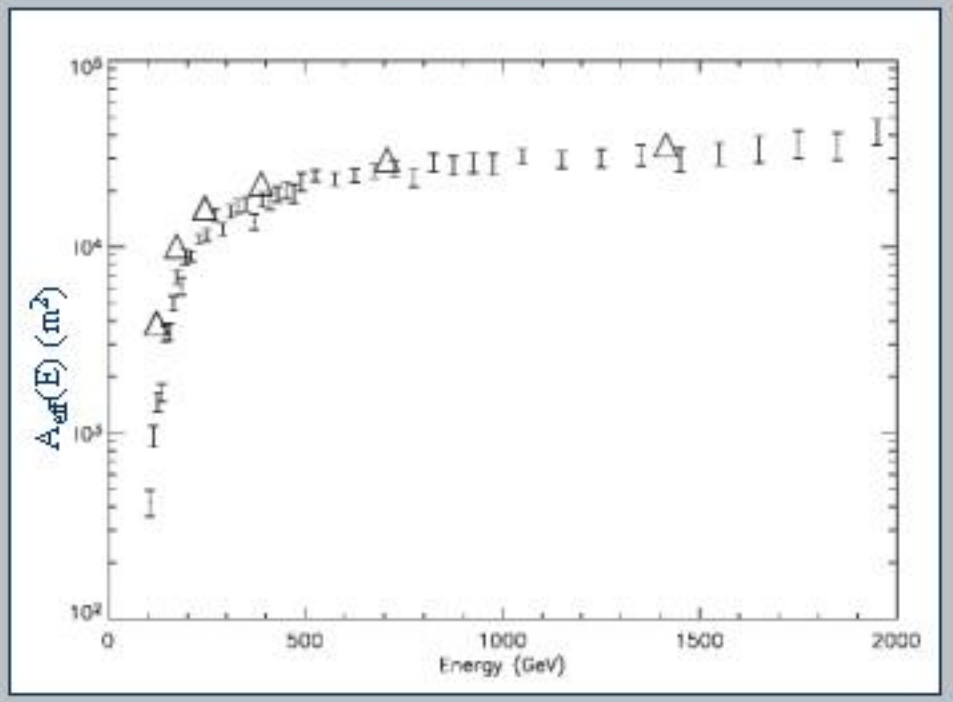
Spectral Analysis of Mkn 421

- Six energy bins between 100 GeV and 1.6 TeV
- Find gamma-ray excess in each bin
- Convert to differential flux with effective area curve

Gamma-ray rate (photons s^{-1} GeV^{-1})



Effective area (m^2)



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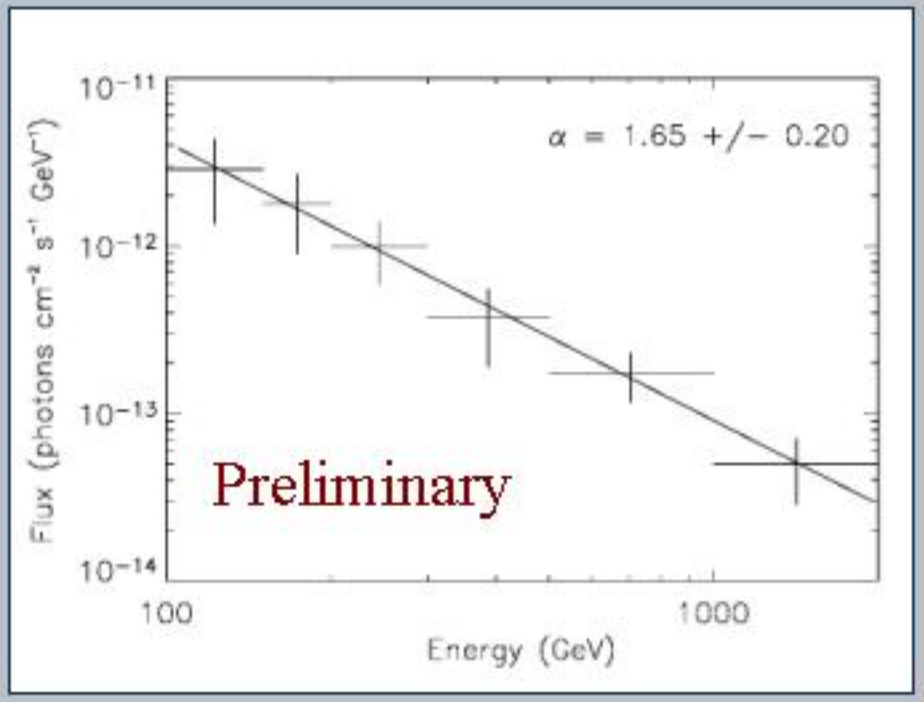
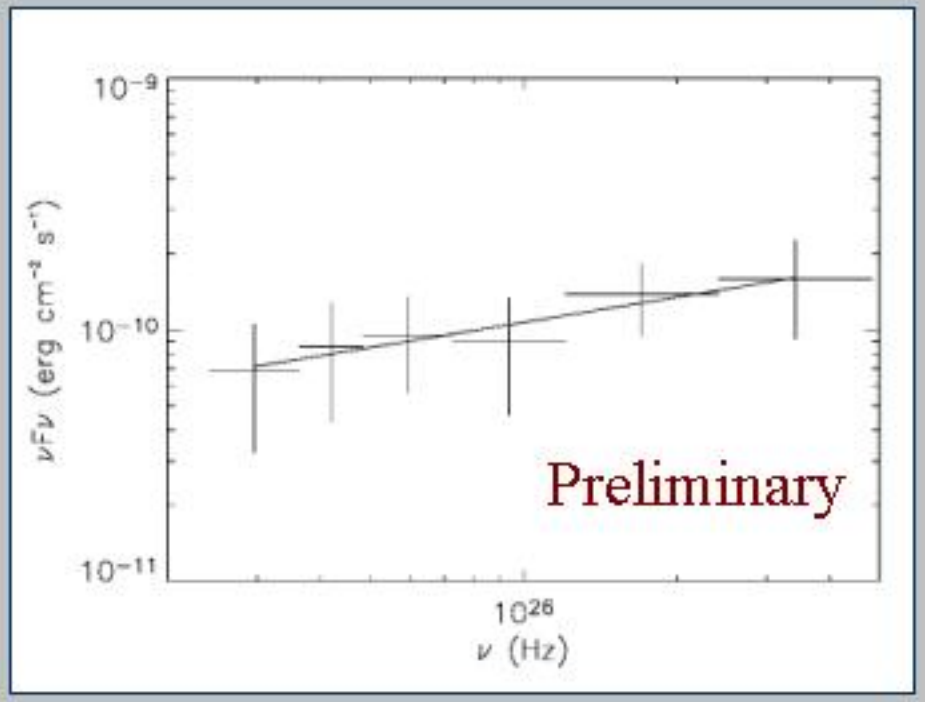
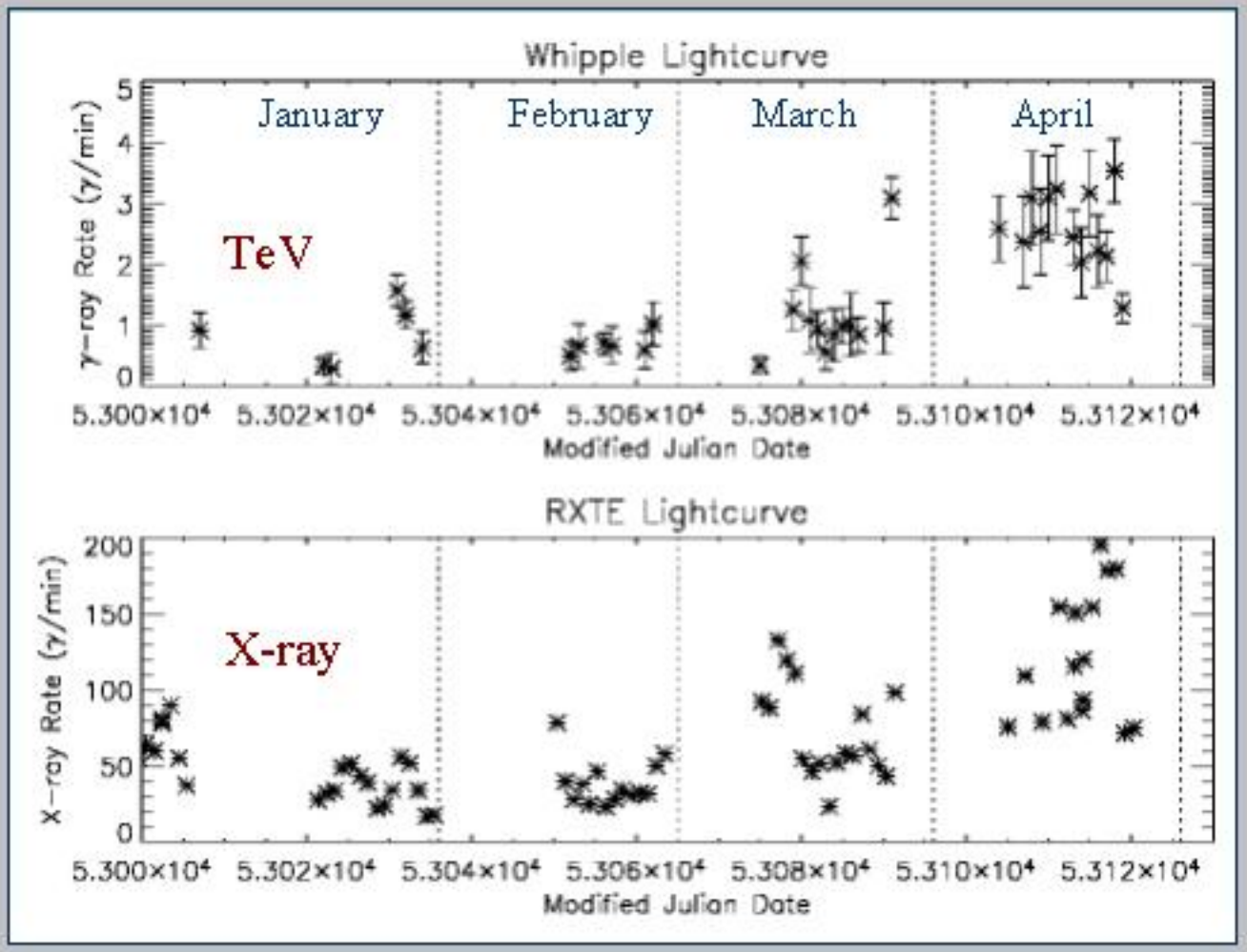




STACEE's first spectrum!

$\alpha = 1.65 \pm 0.20_{stat}$

2004 Multiwavelength Campaign



PCA data courtesy of W. Cui, Blazejowski *et al.* 2005

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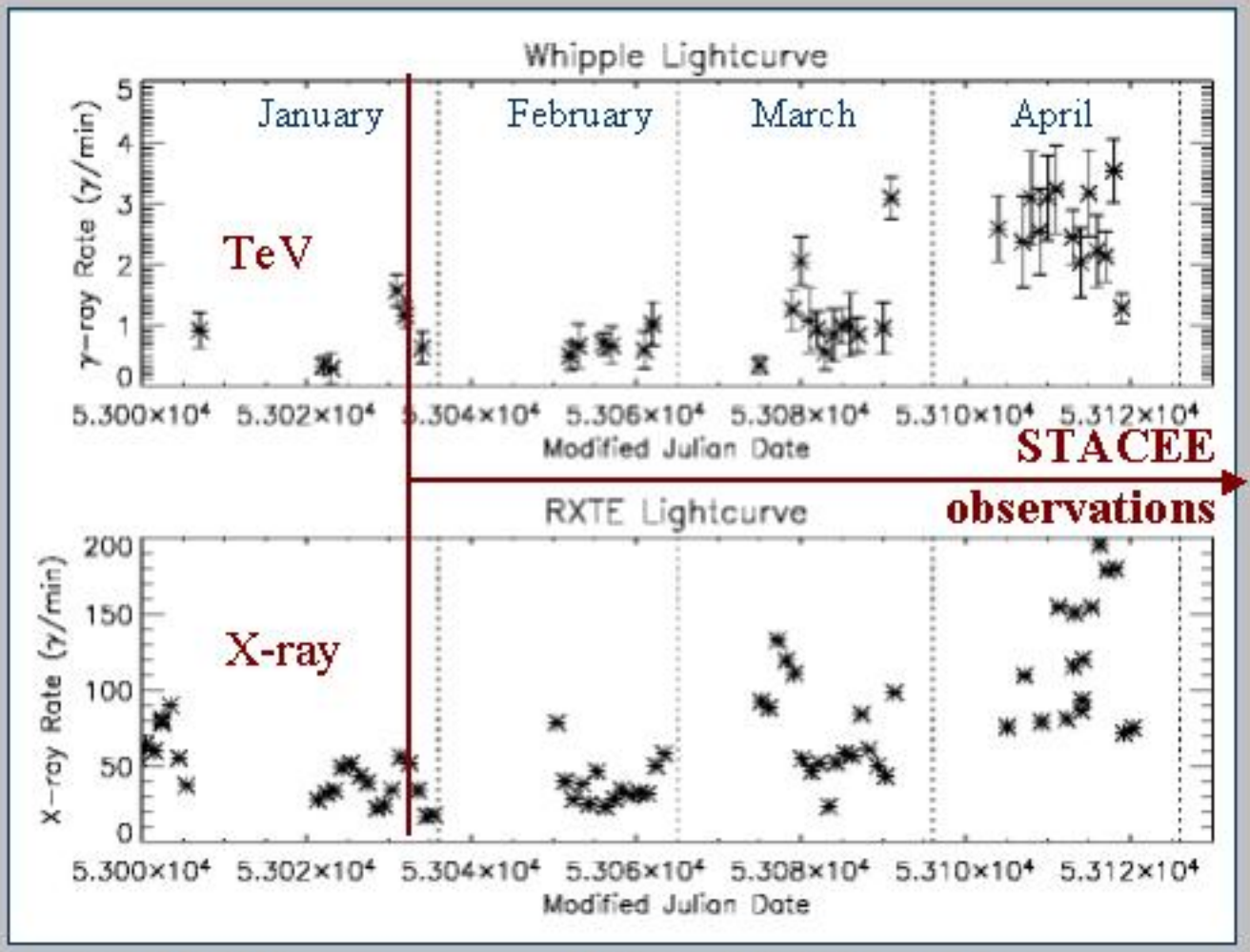
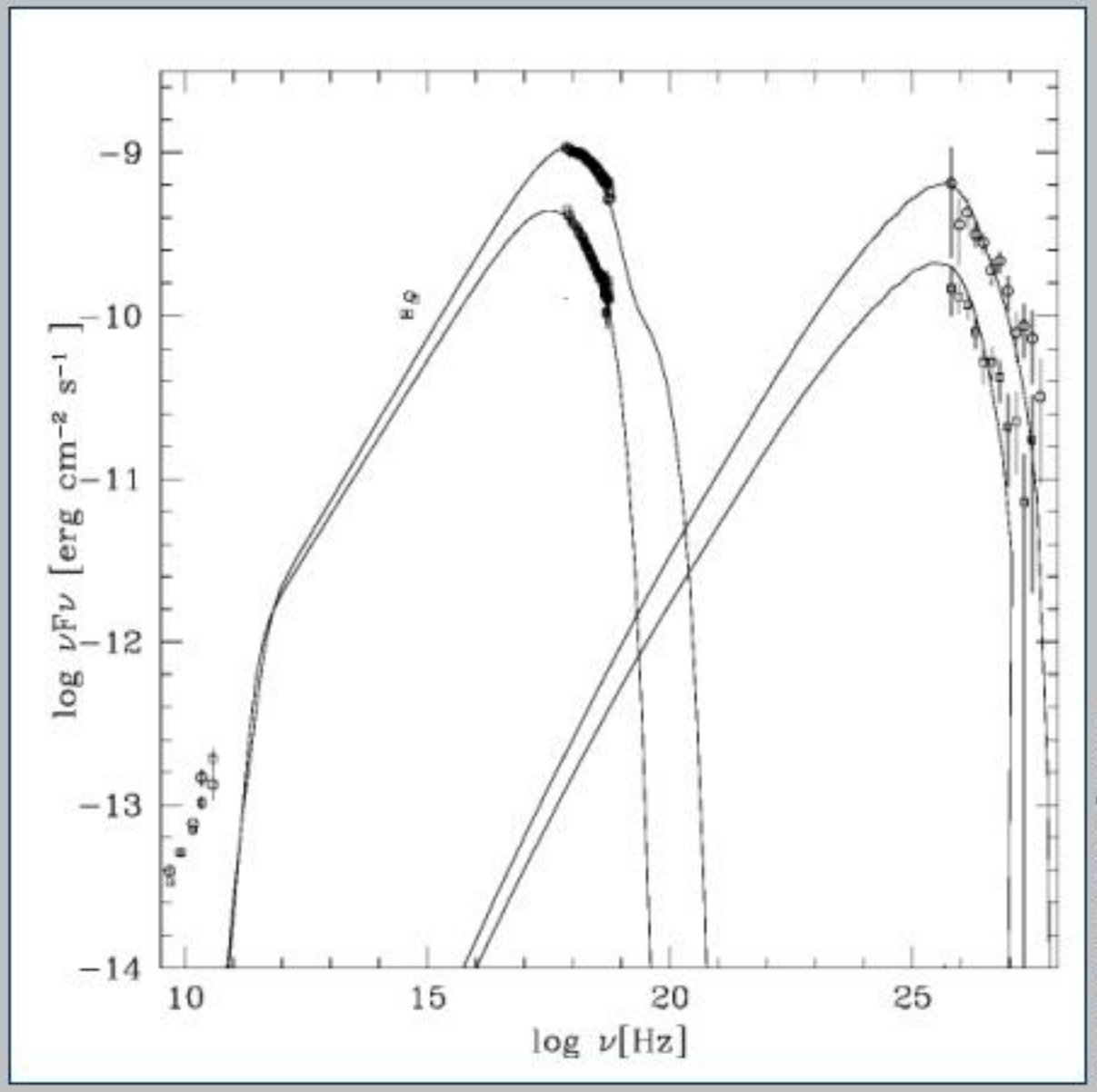


PCA data courtesy of W. Cui, Blazejowski *et al.* 2005

- STACEE coverage: 40% of MW nights
- ~90% of STACEE data taken during MW nights
- STACEE combines low and high flux states

Multiwavelength Results



Blazejowski *et al.* 2005

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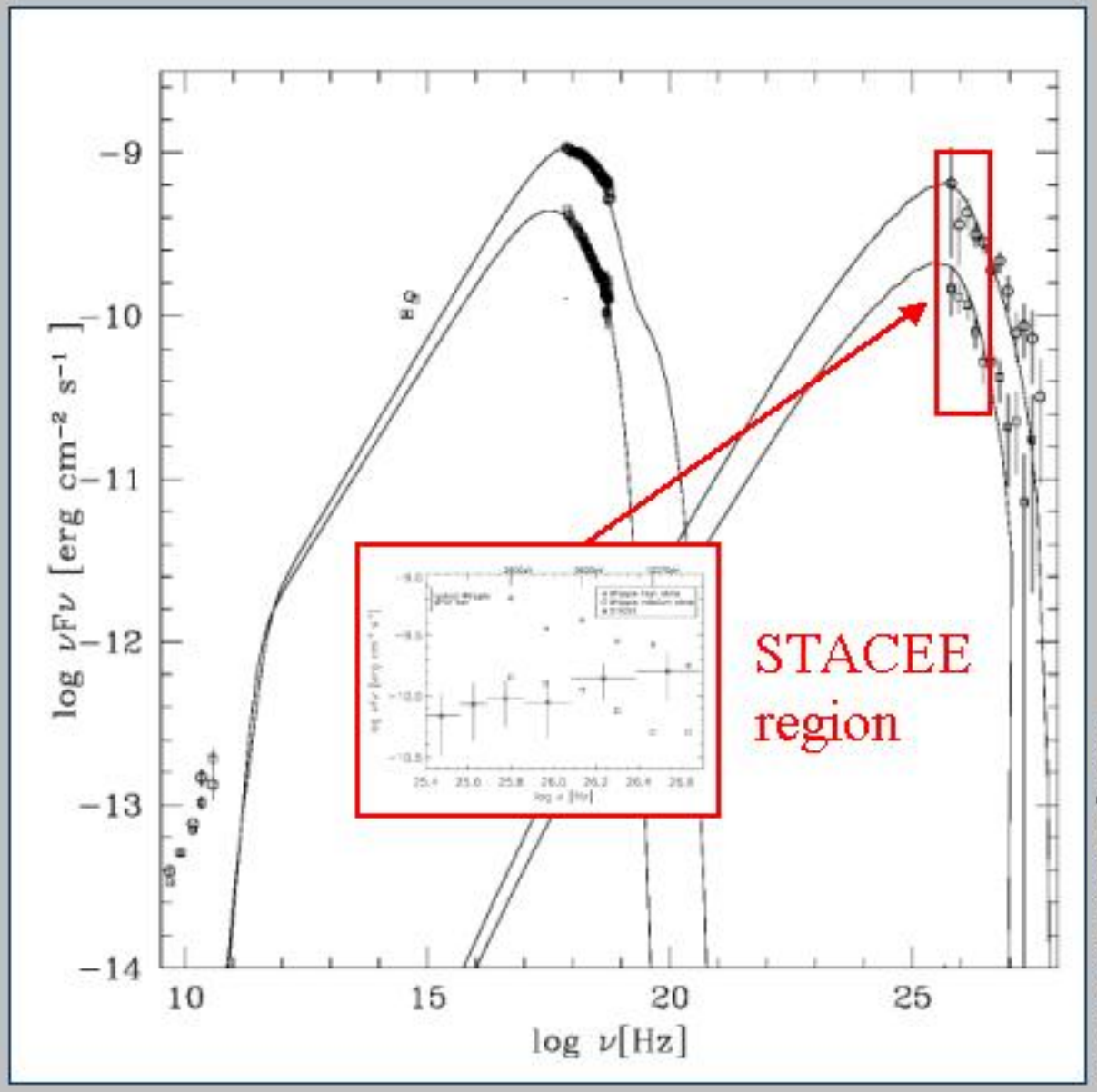
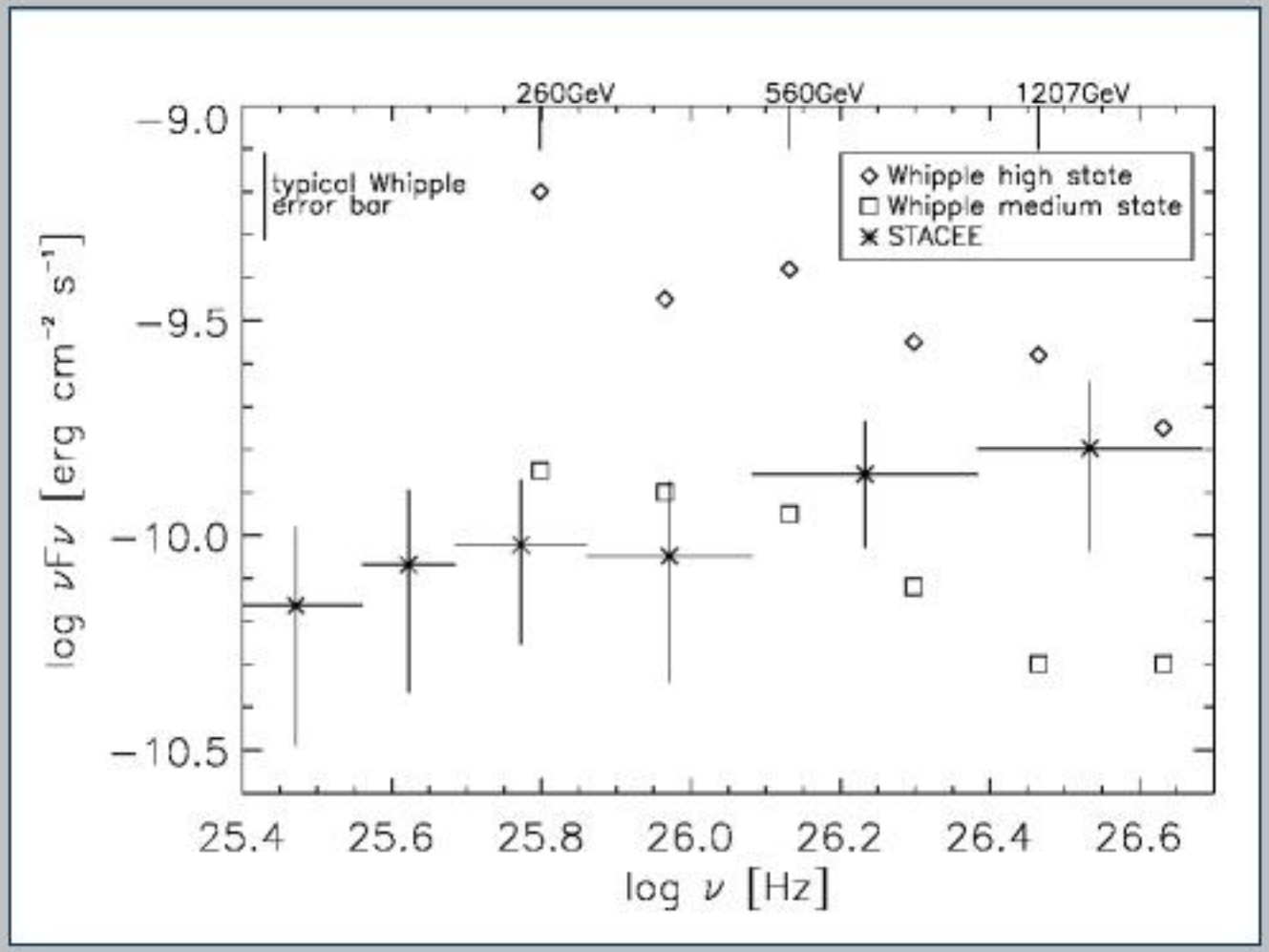


Blazejowski *et al.* 2005

STACEE + Whipple Results



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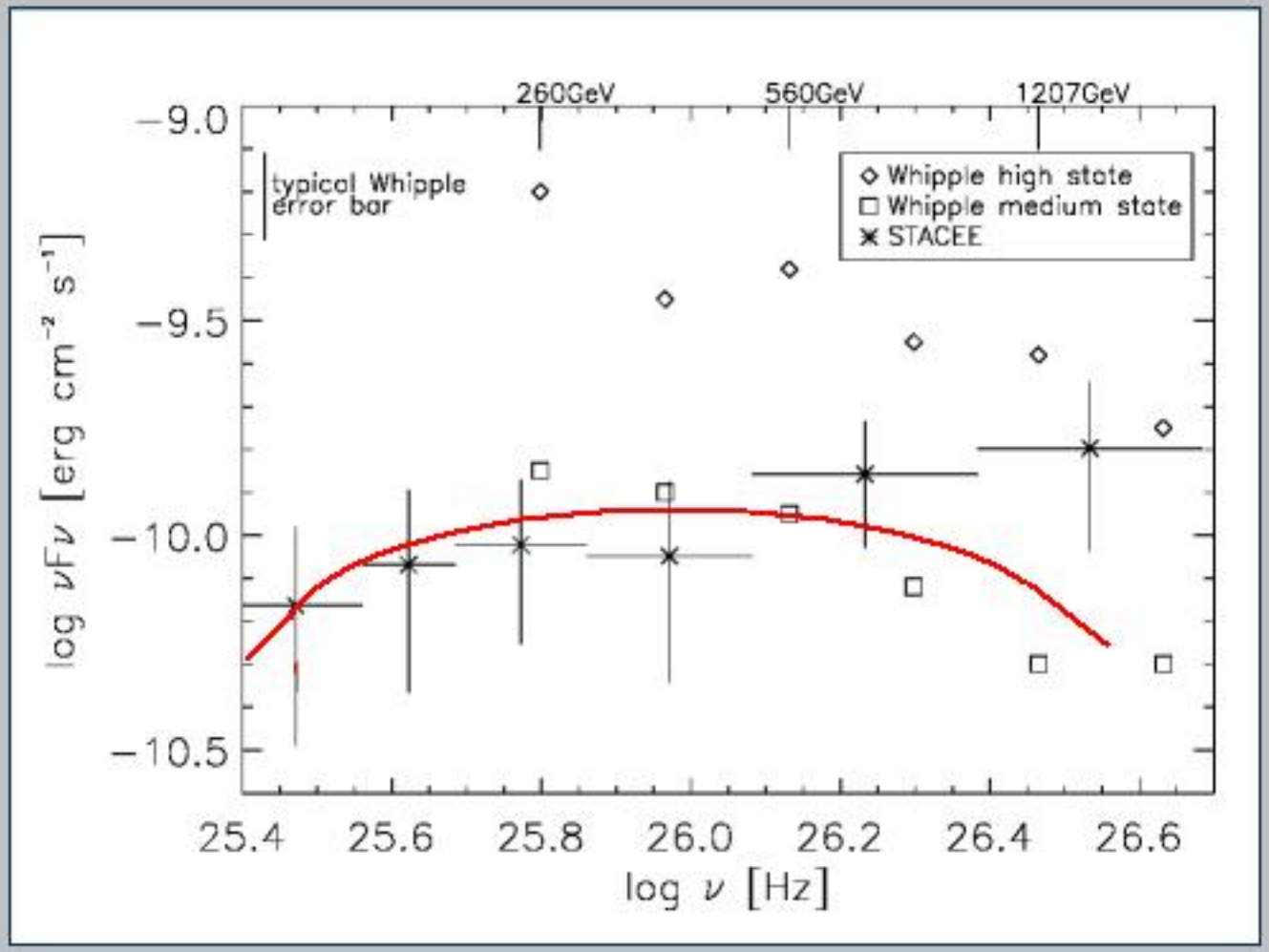


Science Interpretation

- STACEE's first energy bin is ~140 GeV below Whipple's.
- STACEE result:

→ is consistent with a flat or rising SED.

→ suggests that the high-energy peak is above ~300 GeV.

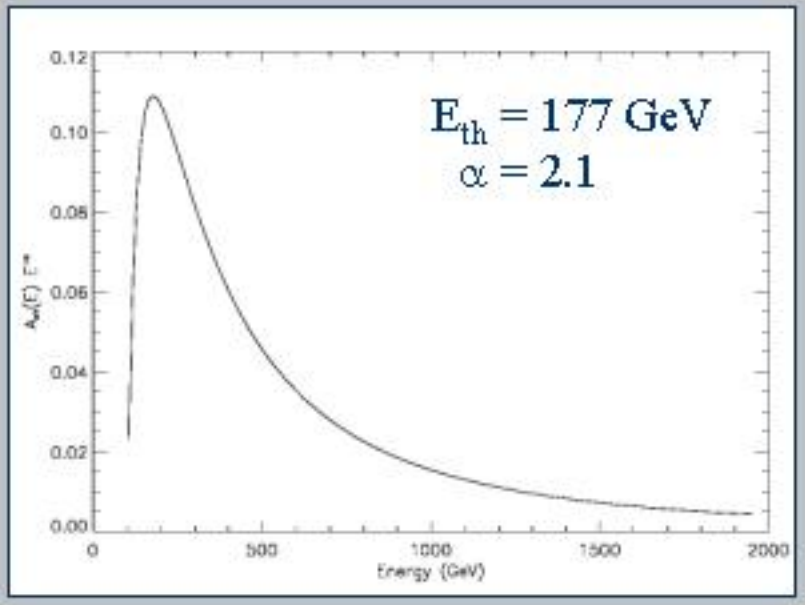
→ is inconsistent with most past IC modeling.

- Combined STACEE/Whipple data suggest that the peak is around 300-500 GeV.
- SED peak reflects peak of electron energy distribution.

Conclusions

- STACEE is a "1st-generation" instrument sensitive to ~100 GeV gamma rays
- 5.8σ detection of Markarian 421
- Energy and core reconstruction methods are successful
- Preliminary spectrum between 100 GeV and 1.6 TeV
- First spectral results from STACEE!
- Only the second spectrum of Mkn 421 at 100-300 GeV
- High-energy peak is above ~300 GeV

Integral Flux



α	E_{th} (GeV)	Φ_{int}*	σ_{Φ} (systematic)
1.7	207	4.08 ± 0.73	+0.86,-0.62
2.1	177	5.06 ± 0.91	+1.50,-1.00
2.5	159	6.27 ± 1.15	+2.48,-1.55

* 10^{-6} photons m^{-2} s^{-1}