H.E.S.S. Observations of Extragalactic Jet Sources

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H.E.S.S.

High Energy Stereoscopic System

Khomas Highlands, near Windhoek

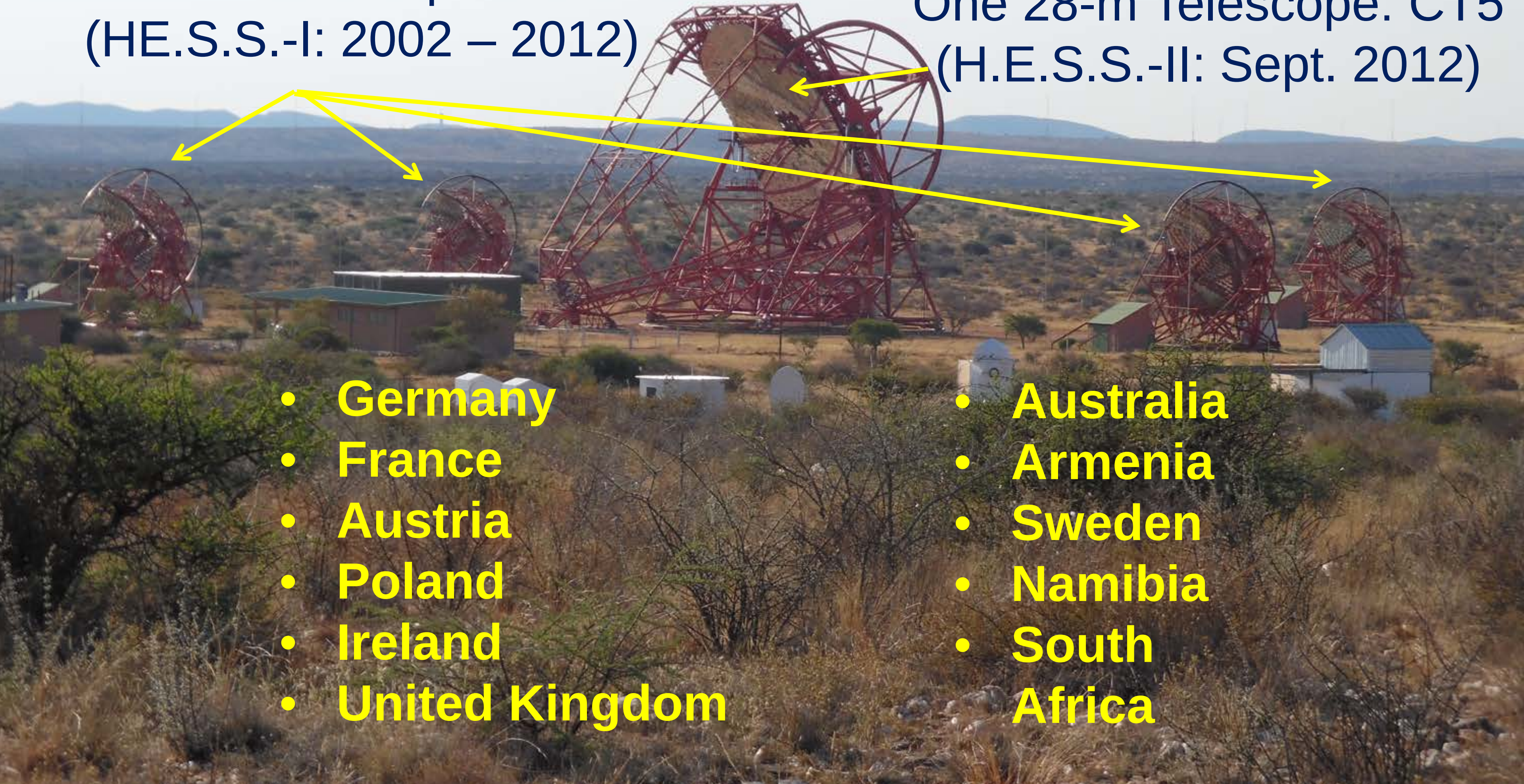
About 100 km along C26

H.E.S.S.-II

International Collaboration of ~ 260 Scientists from 11 Countries

Four 12-m Telescopes: CT1 – 4
(HE.S.S.-I: 2002 – 2012)

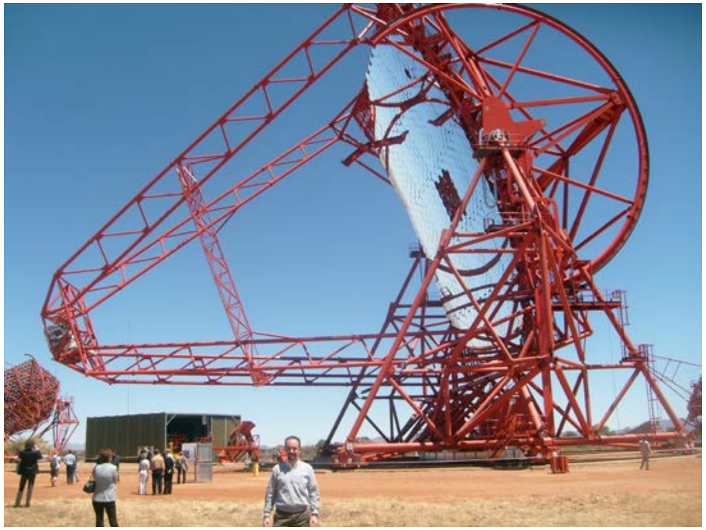
One 28-m Telescope: CT5
(H.E.S.S.-II: Sept. 2012)



- **Germany**
- **France**
- **Austria**
- **Poland**
- **Ireland**
- **United Kingdom**
- **Australia**
- **Armenia**
- **Sweden**
- **Namibia**
- **South Africa**

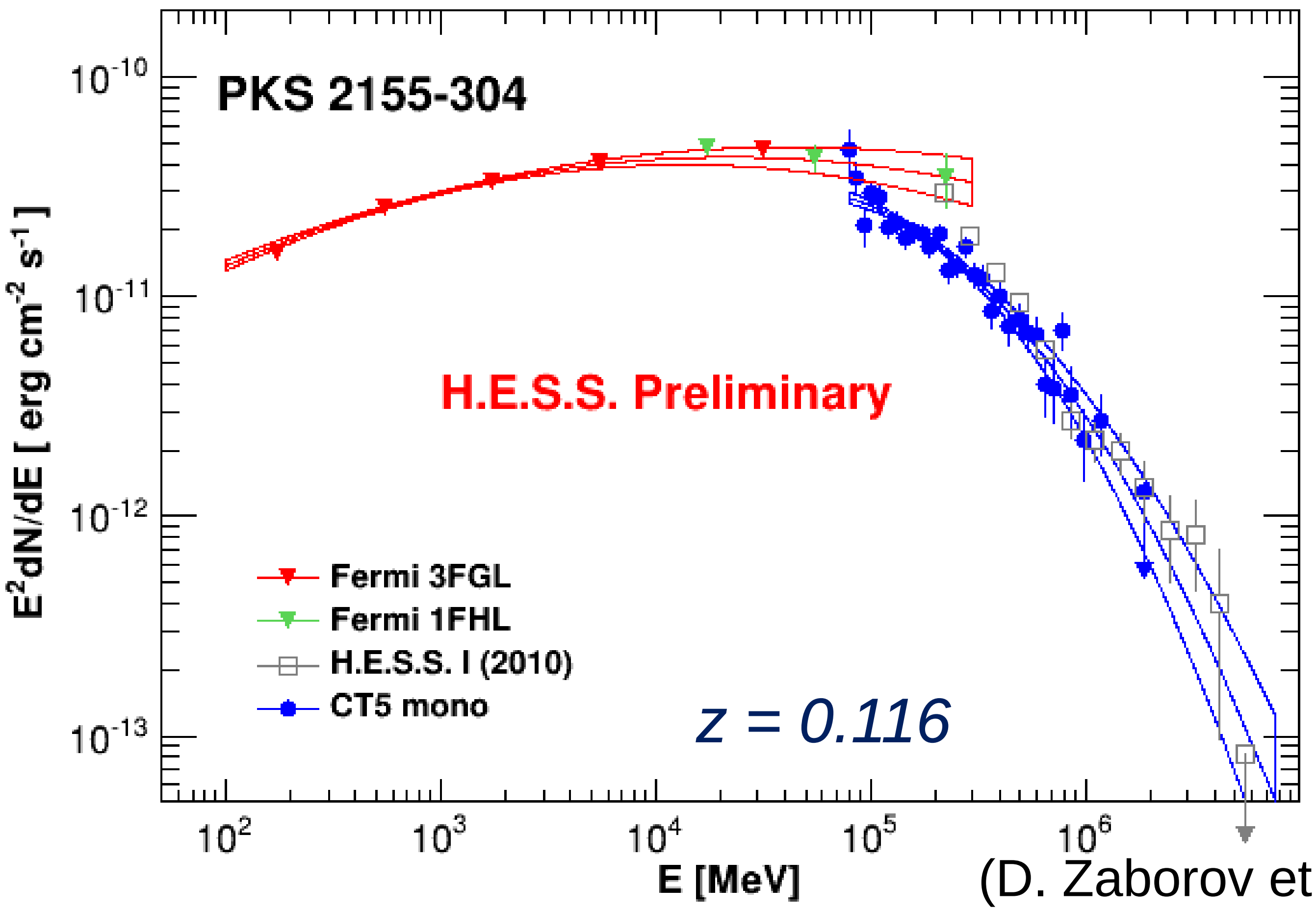
H.E.S.S. II Observations/Analyses

- CT5 Mono: Only CT5 data
  → Lowest energy threshold
  (< 100 GeV)



- HESS-II Hybrid: Complete array (CT1 – 5): Best background rejection, but slightly higher energy threshold than CT5 mono.

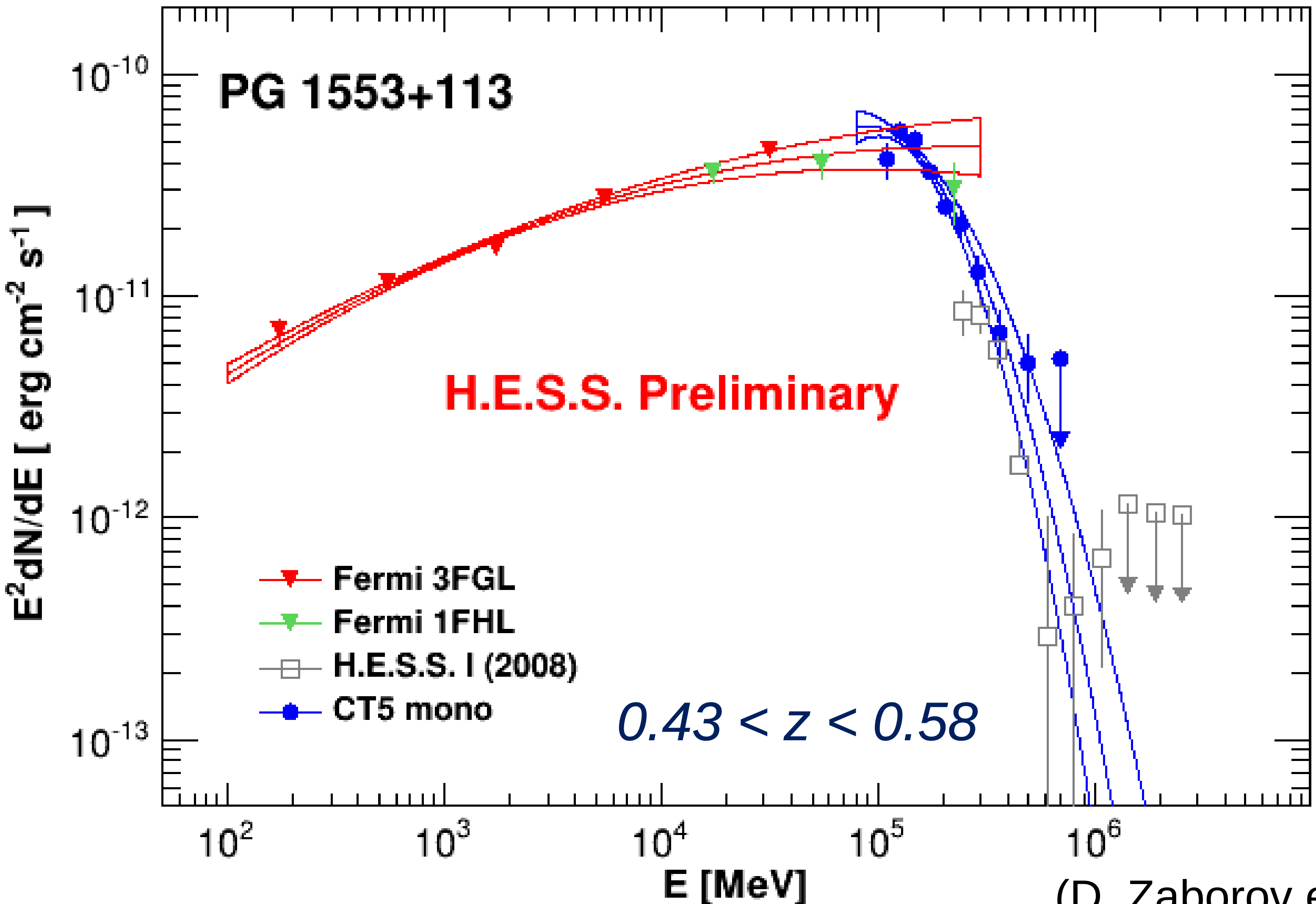
CT5 Mono Observations of Blazars



(D. Zaborov et al. 2015)

- Significant overlap with Fermi-LAT
- Excellent agreement with H.E.S.S.-I (CT1 – 4)

CT5 Mono Observations of Blazars



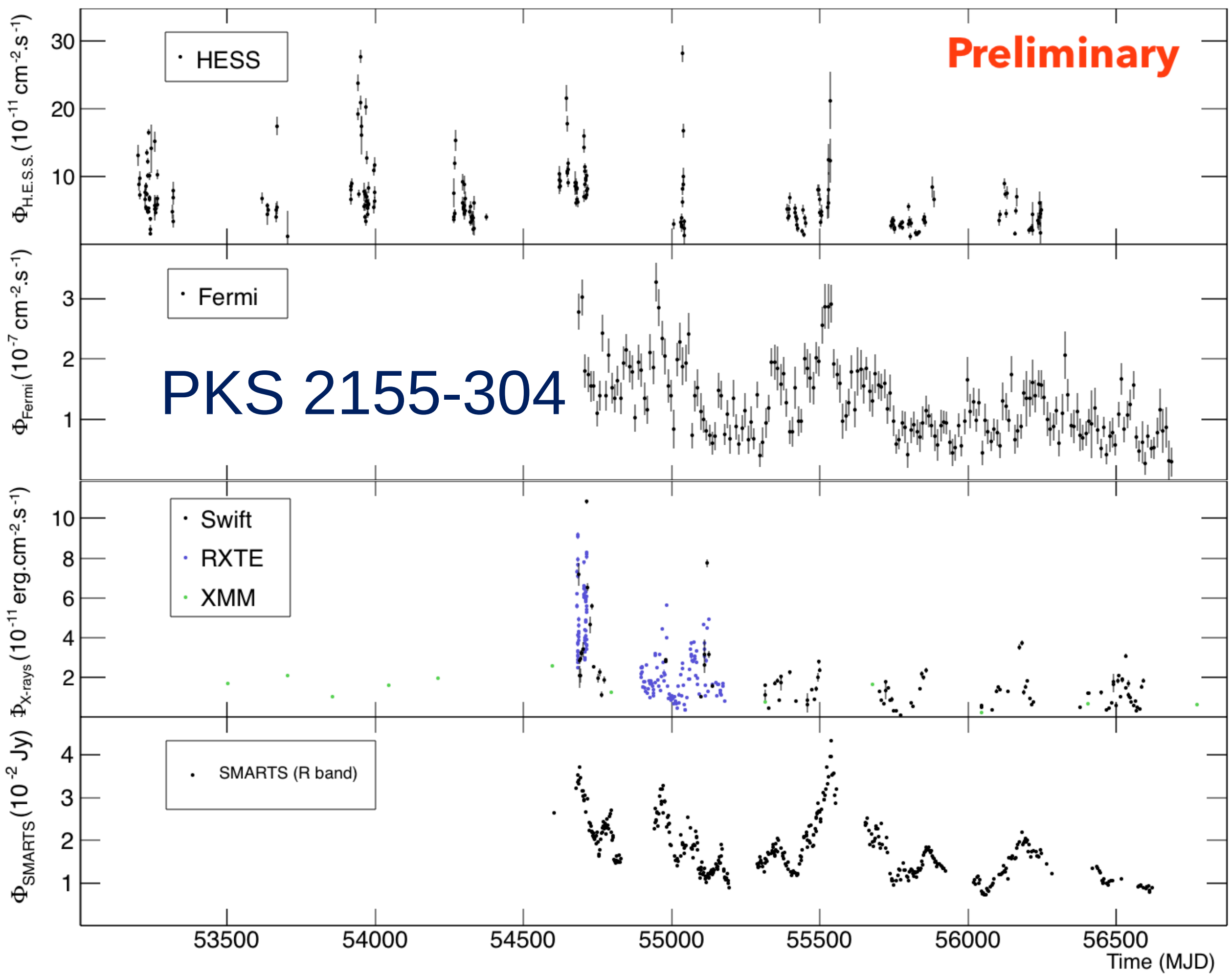
(D. Zaborov et al. 2015)

H.E.S.S. II Extragalactic Observing Program

- ToO observations and long-term monitoring of known VHE AGN
  - Particle acceleration / particle content / site of γ-ray emission region(s)
  - Physics beyond the standard model (LIV)
- Discovery of new potential VHE sources (including radio galaxies, radio-quiet AGN and non-active galaxies)
  - Population studies
  - EBL studies
  - Origin of cosmic rays
- Gravitationally lensed blazars
- GRB follow-up (prompt and early afterglow)
- Muli-messenger astronomy (incl. IceCube neutrino counterparts)
- Search for dark matter annihilation signatures

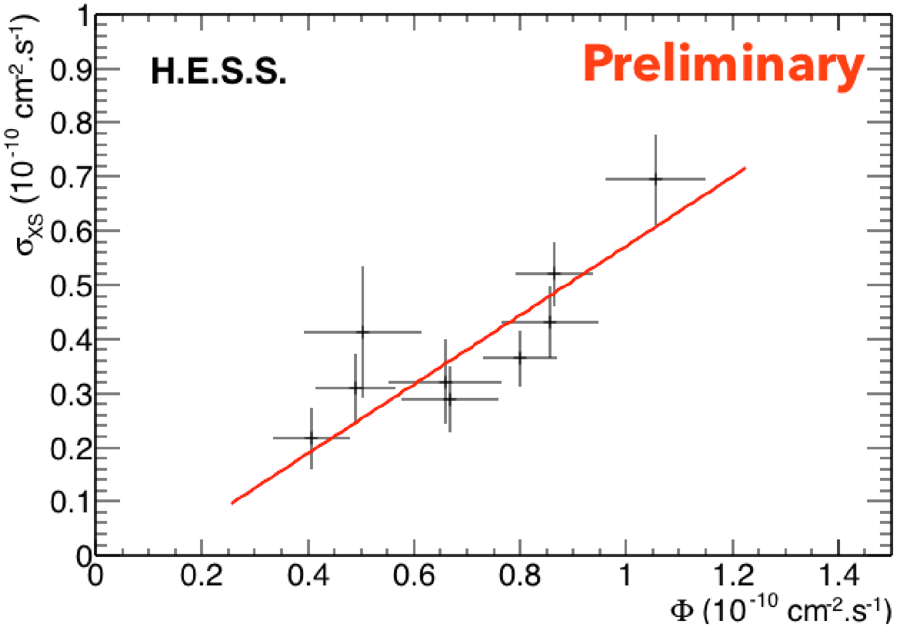
Long-Term Monitoring of Known VHE Blazars

~ 13 year time line since H.E.S.S.-I first light!



(J. Chevalier et al. 2015)

Long-Term Monitoring of Known VHE Blazars



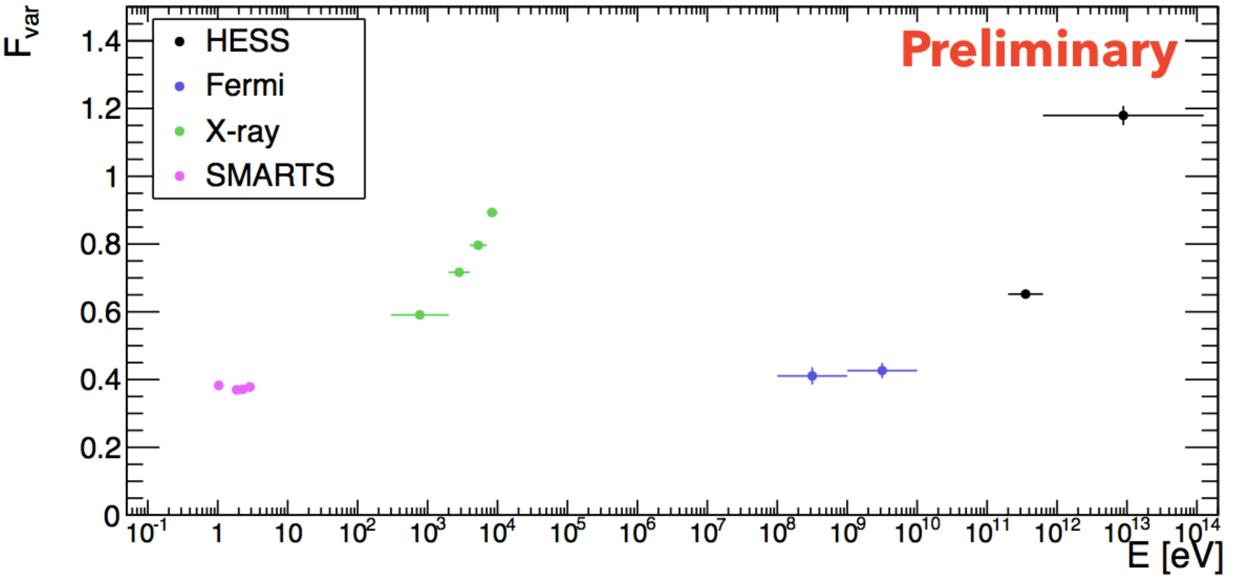
PKS 2155-304

Fractional variability amplitude F_{var} increasing throughout SED components

Excess rms variability

σ_{XS} ~ flux Φ

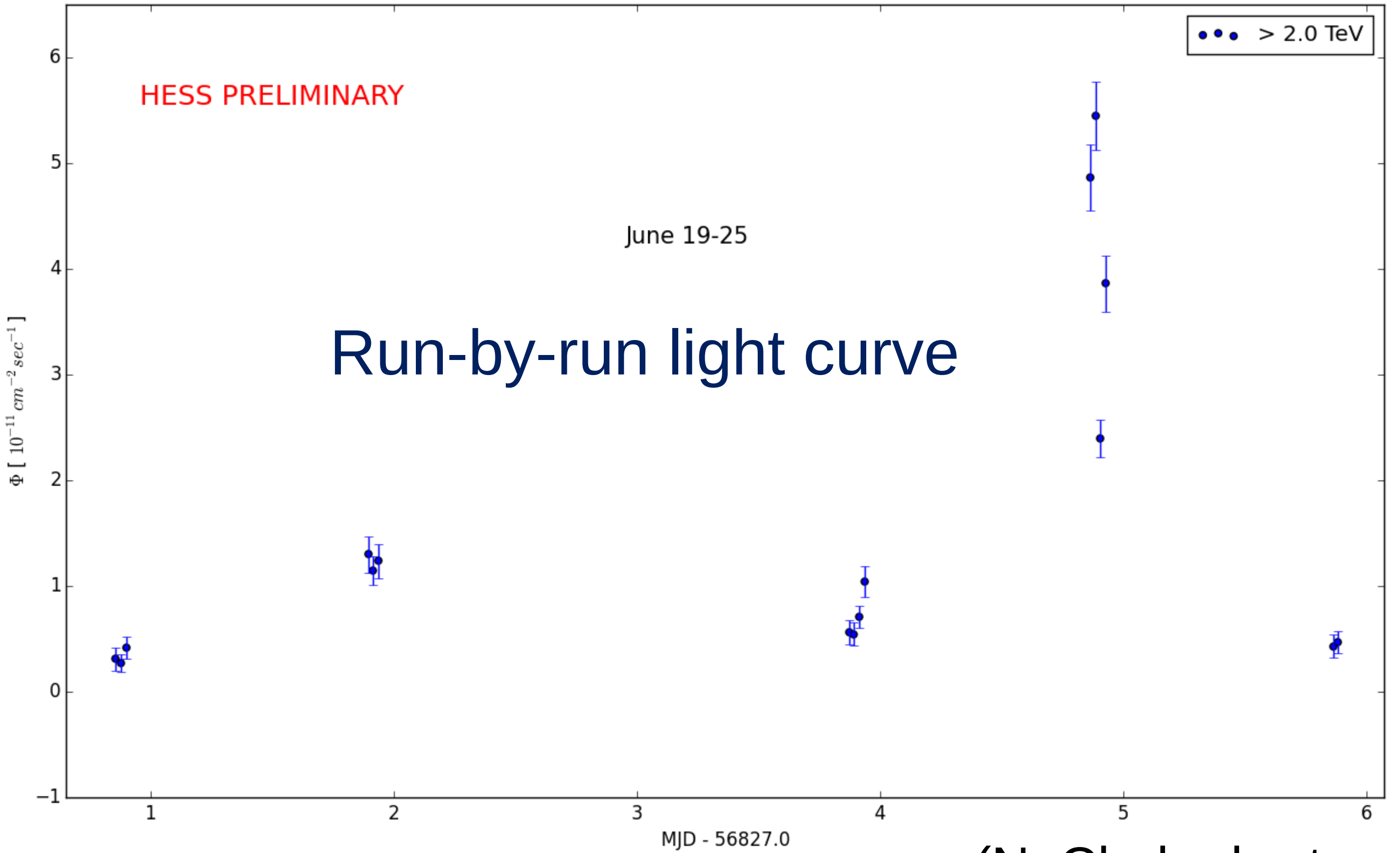
→ Multiplicative process



(J. Chevalier et al. 2015)

Rapid Variability of Mrk 501 at Multi-TeV energies

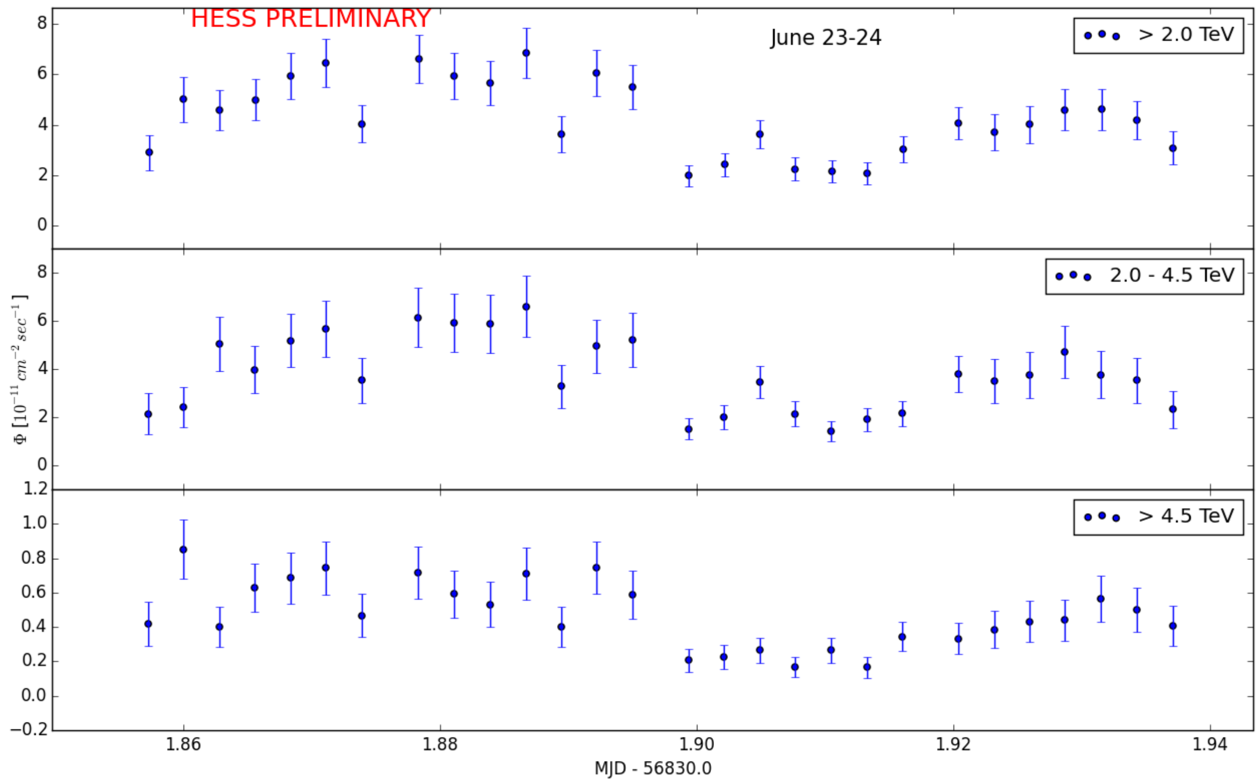
Major flaring state in June 2014



(N. Chakraborty et al. 2015)

Rapid Variability of Mrk 501 at Multi-TeV energies

4-minute bins



(N. Chakraborty et al. 2015)

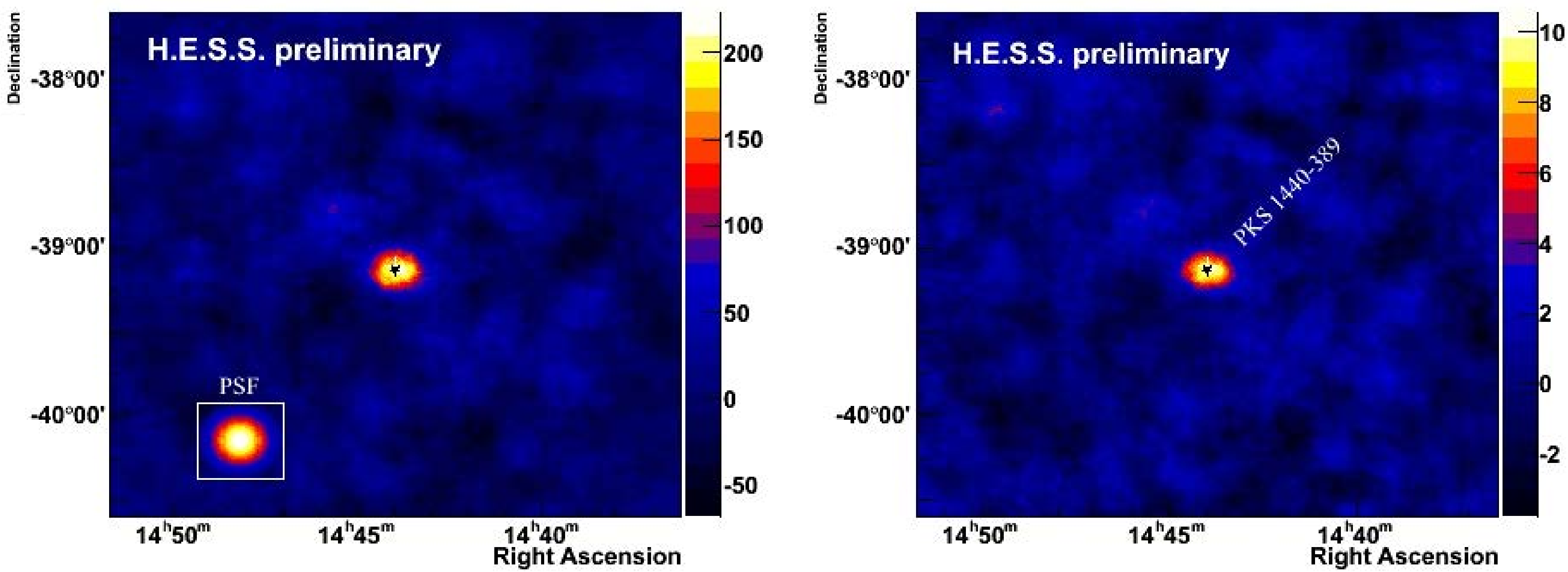
τ_{min} (> 2 TeV) < 10 min!

Rules out CR-induced VHE γ-ray emission dominating at highest energies.

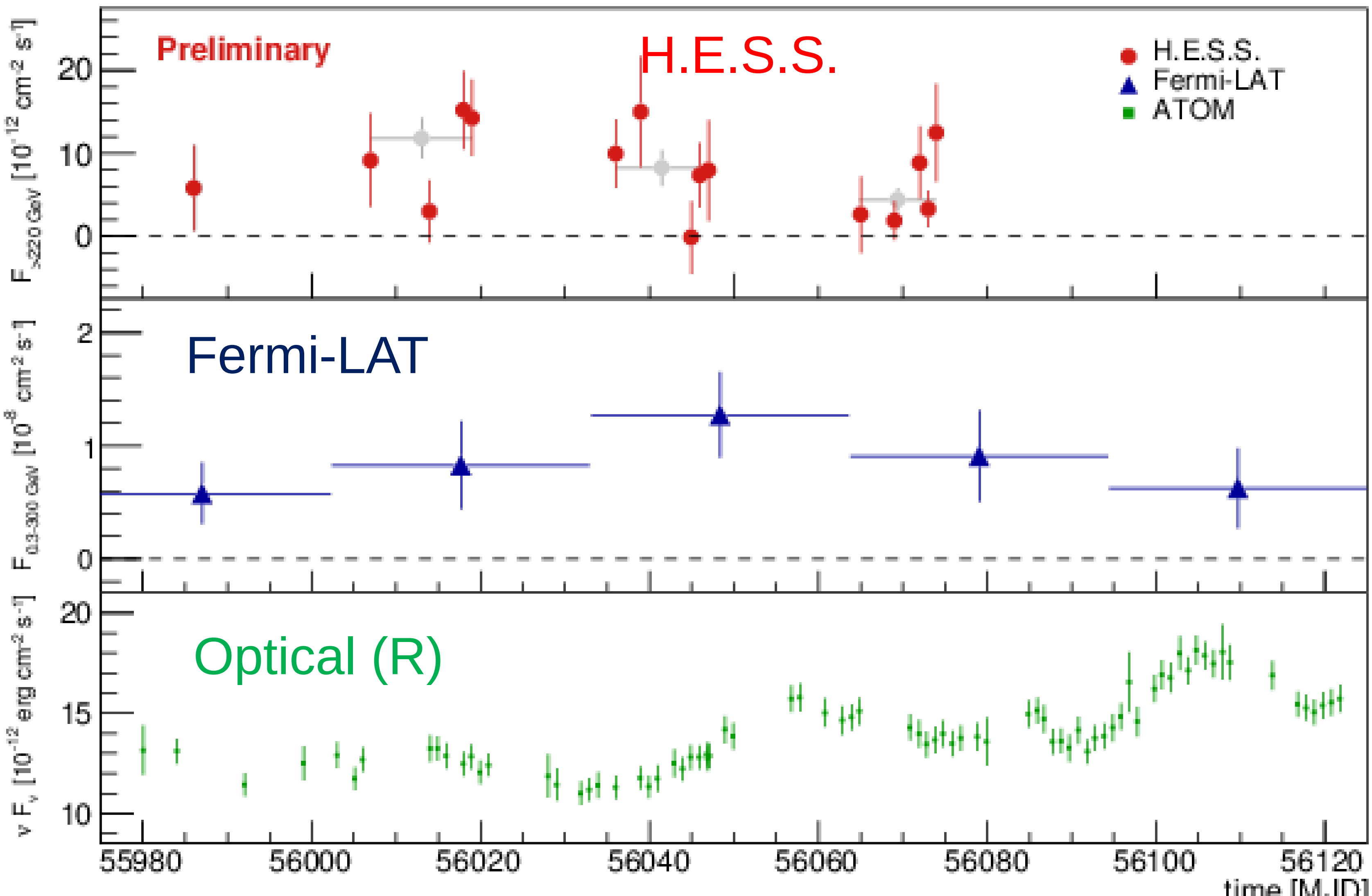
New Discoveries: PKS 1440-389

- HBL at uncertain redshift:
  - *z = 0.065* (preliminary 6dF Galaxy Survey);
  - *0.14 < z < 2.2* (Shaw et al. 2013)
- H.E.S.S. observations motivated by hard *Fermi*-LAT spectrum: $\Gamma_{2FGL} = 1.77 \pm 0.06$
- Total live time of ~ 12 hr during Feb. 29 - May 27, 2012
- 183 excess events → 9.1 σ

(H. Prokoph et al. 2015)

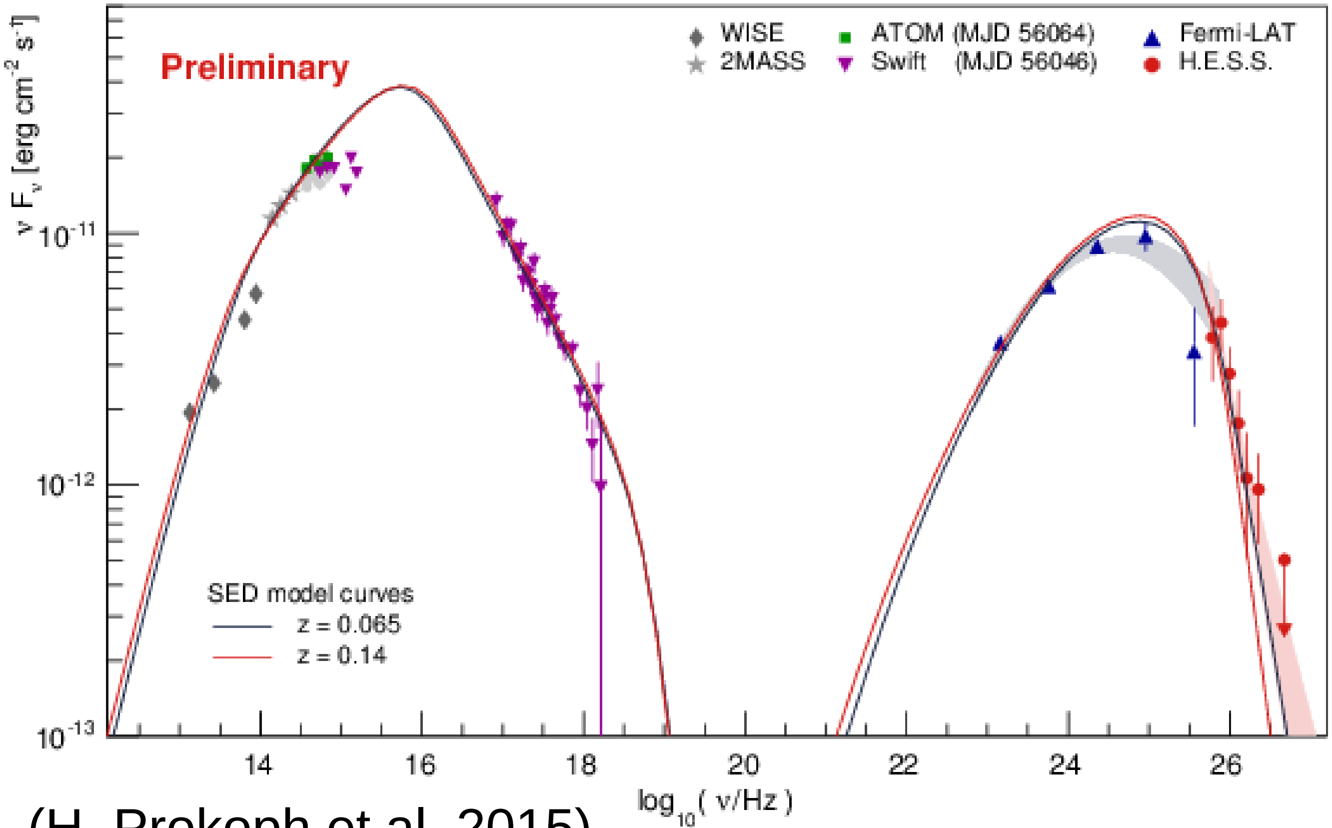


PKS 1440-389



(H. Prokoph et al. 2015)

PKS 1440-389



(H. Prokoph et al. 2015)

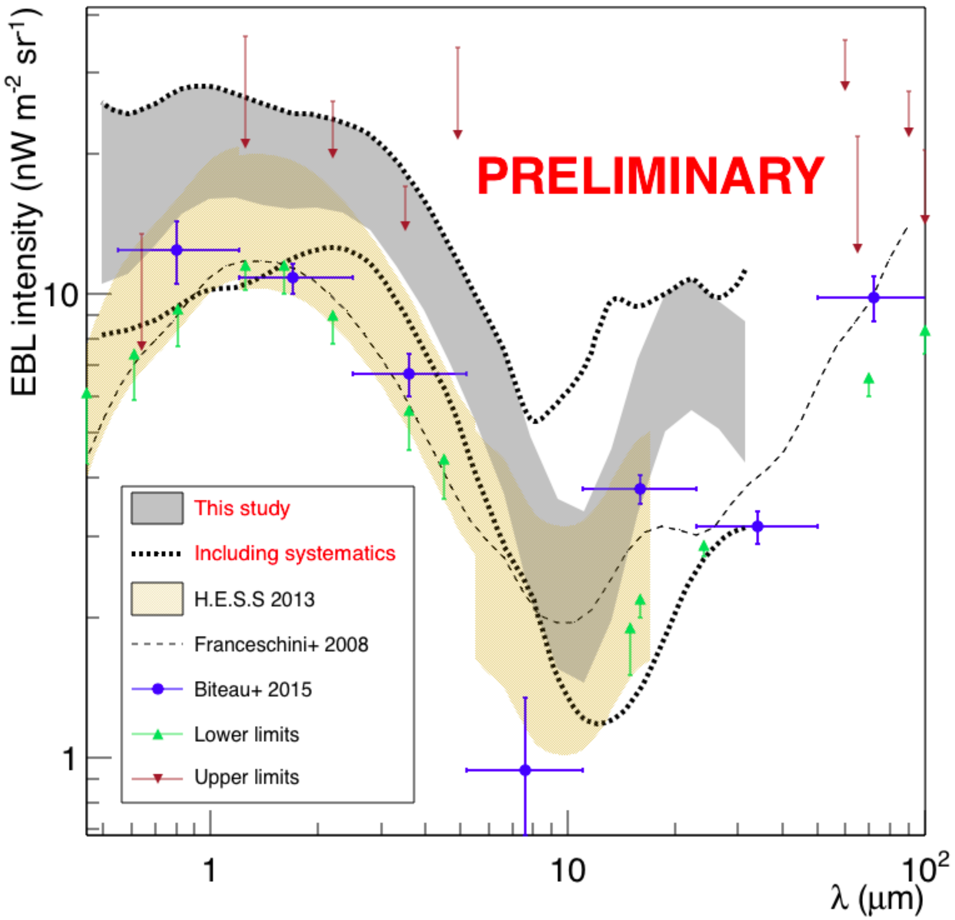
Steep H.E.S.S. spectrum ($\Gamma = 3.61 \pm 0.34$)

Single-zone SSC model provides good SED fit with slightly sub-equipartition B-field ($L_B/L_e \sim 0.1$)

H.E.S.S. spectrum difficult to reconcile with $z > 0.14$ due to EBL absorption

EBL Studies

- Determine both shape and intensity of the local EBL
- Based on 14 high-quality VHE spectra of blazars at $z < 0.2$
- Spline through grid points in EBL $\lambda - \lambda u_\lambda$ plane
- Intrinsic spectra = PL or log-parabola



(M. Lorentz et al. 2015)

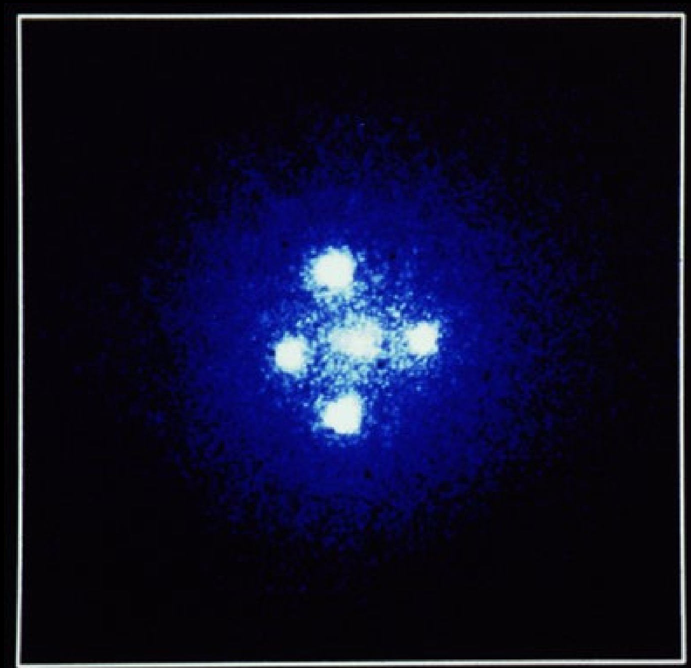
Gravitationally Lensed Gamma-Ray Blazars

→ Magnification of one of the images

→ Time Delay between two images

Possible way of "imaging" gamma-ray emission regions in blazars!

Gravitional-Lensing echoes observed in two blazars at GeV energies (Fermi)

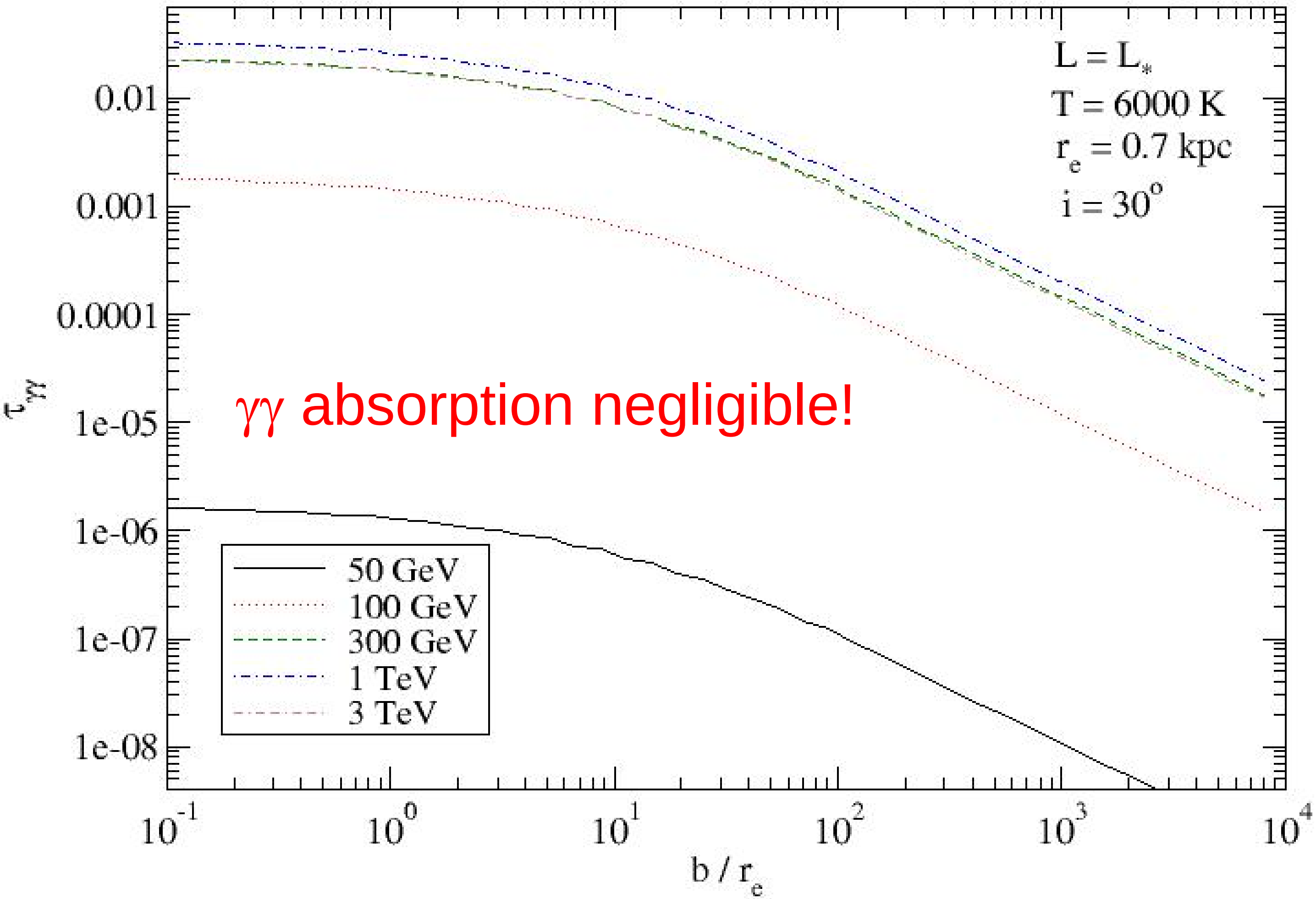


Gravitational Lens G2237+0305

MAGIC detection of B0218+357 (z = 0.94)

$\gamma\gamma$-Absorption in Gravitational Lenses?

- Intervening Lensing Galaxies (Macrolensing):

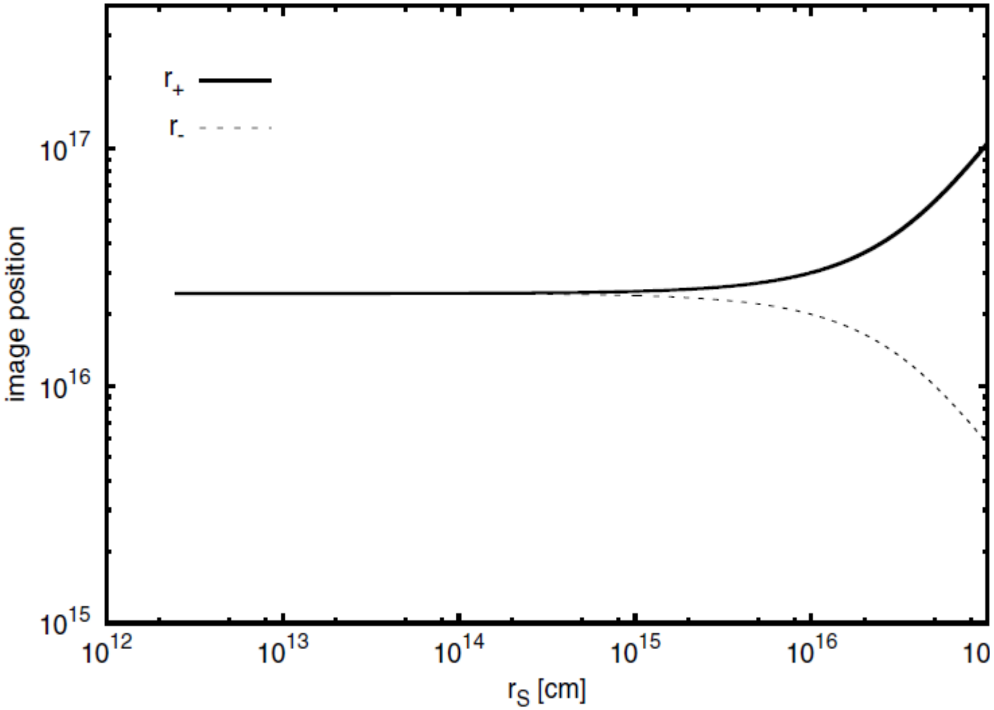


(Not H.E.S.S. Collaboration Work)

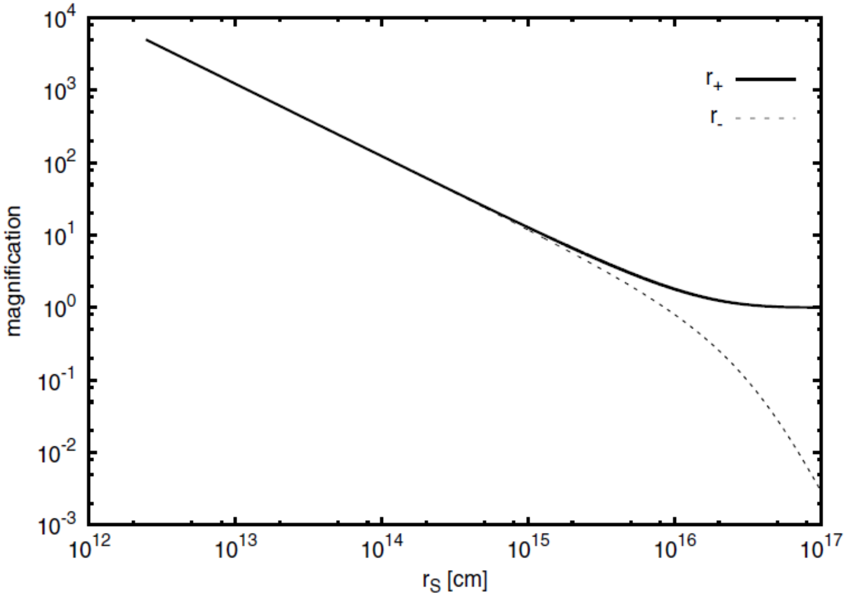
(Barnacka et al. 2014)

γγ-Absorption in Gravitational Lenses?

- Stars in Intervening Galaxies (Microlensing):



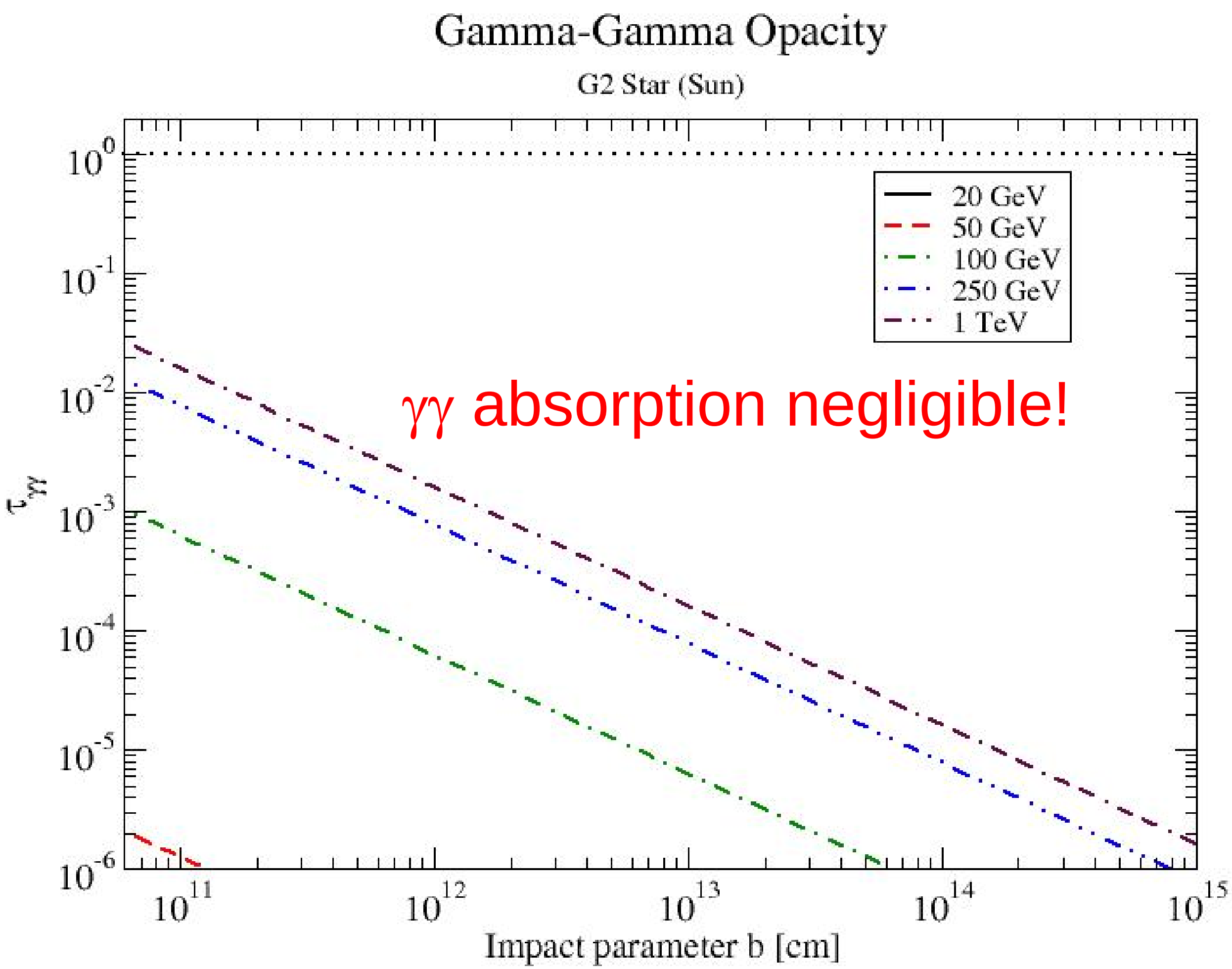
(Barnacka et al. 2014)



Position of visible image always > $2 \cdot 10^{16}$ cm *(M/M_0) from the lensing star!

γγ-Absorption in Gravitational Lenses?

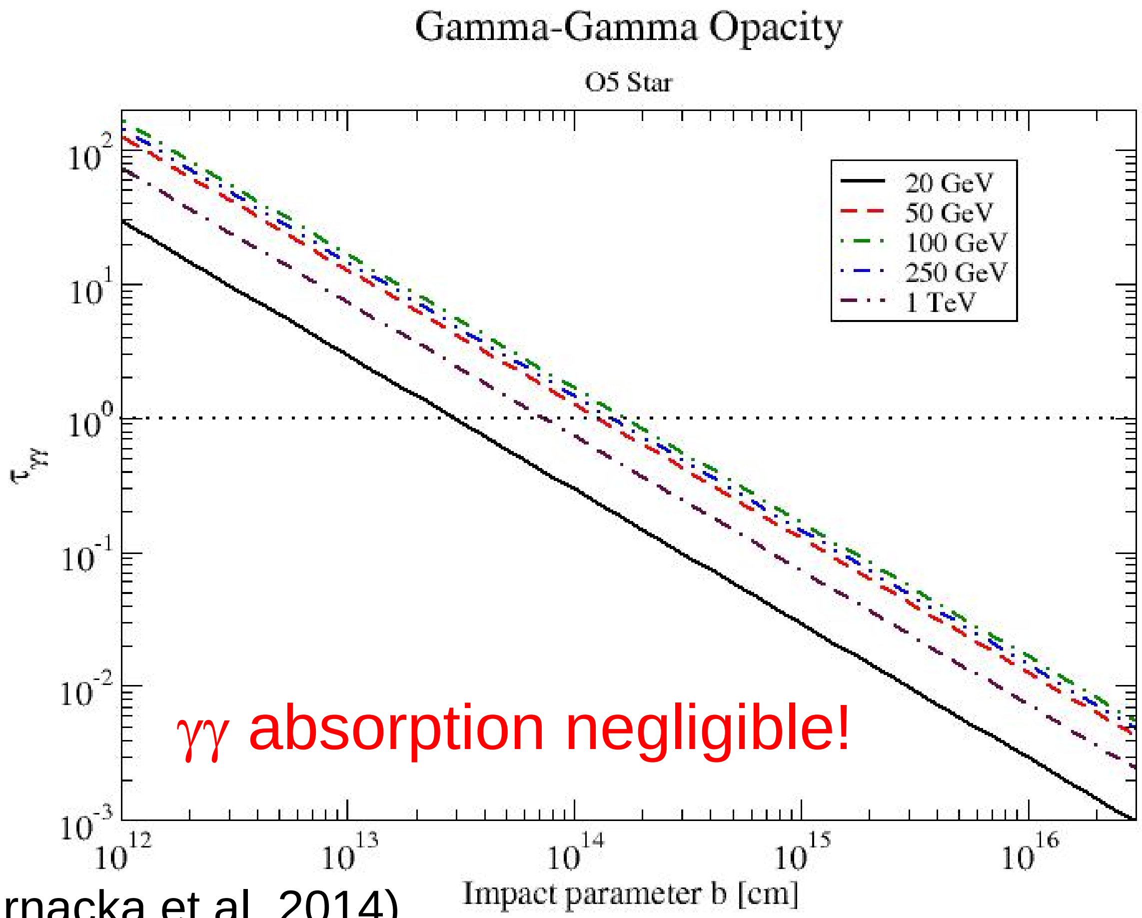
- Stars in Intervening Galaxies (Microlensing):



(Barnacka et al. 2014)

γγ-Absorption in Gravitational Lenses?

- Stars in Intervening Galaxies (Microlensing):



(Barnacka et al. 2014)

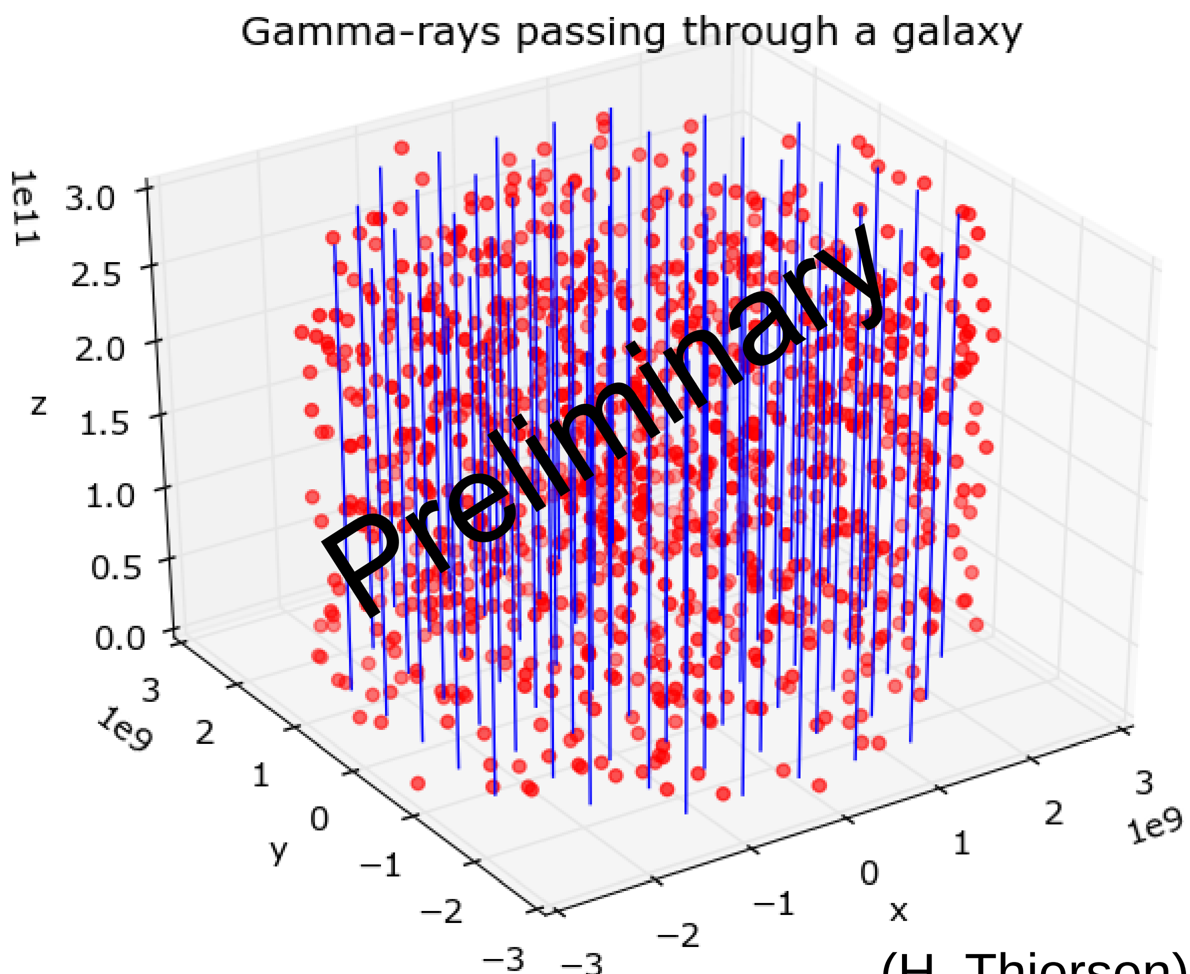
Image position:
b > 10^{17} cm!!!

=> Gravitational lensing helps γ-rays avoid γγ-absorption!

γγ-Absorption in Gravitational Lenses?

Simulations of lensed γ-ray paths through stellar field of the lensing galaxy

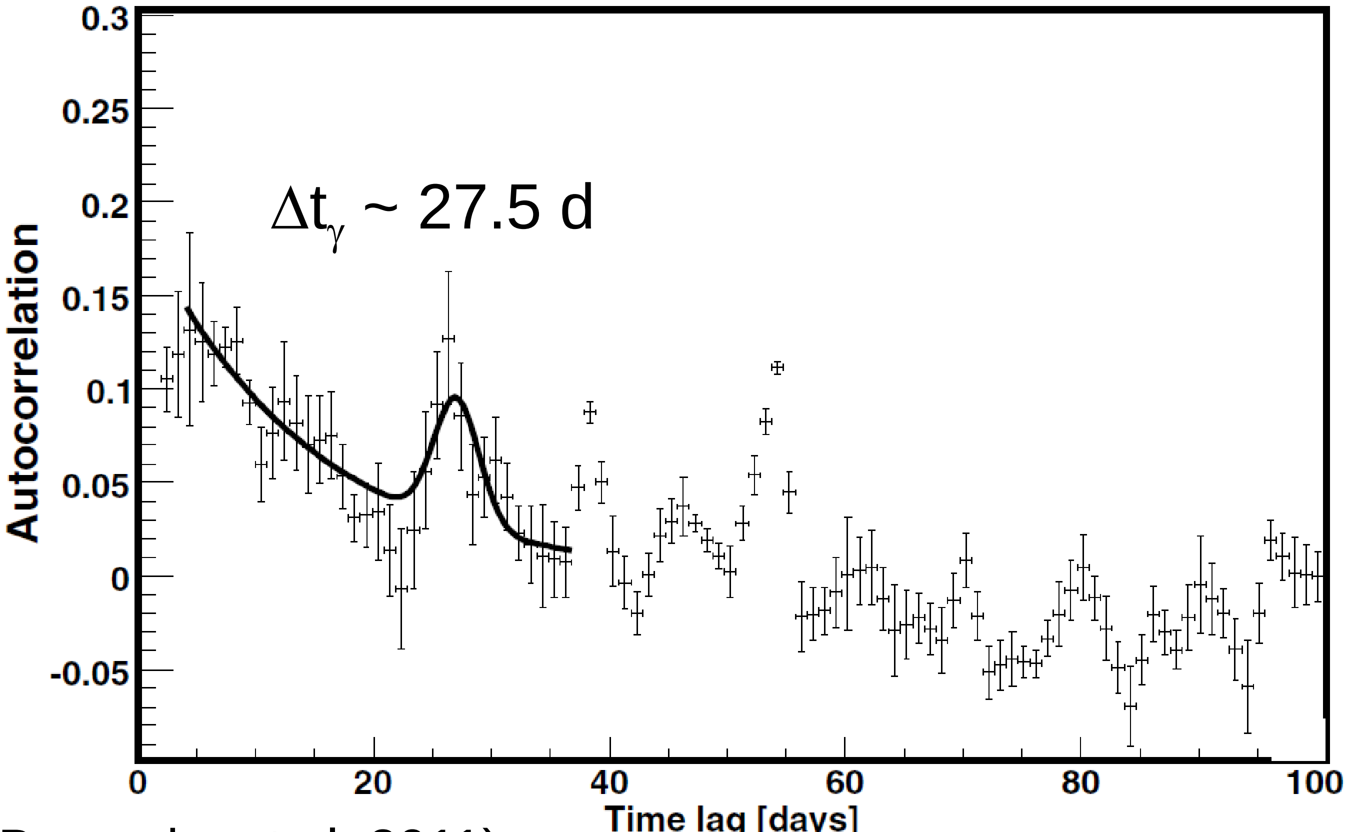
→ Preliminary: Minimum impact parameter *b* still >> γγ absorption radius!



(H. Thiersen)

Gravitationally Lensed Gamma-Ray Blazars

PKS 1830-211 (z = 2.5)



(Barnacka et al. 2011)

Lensing galaxy at z = 0.89

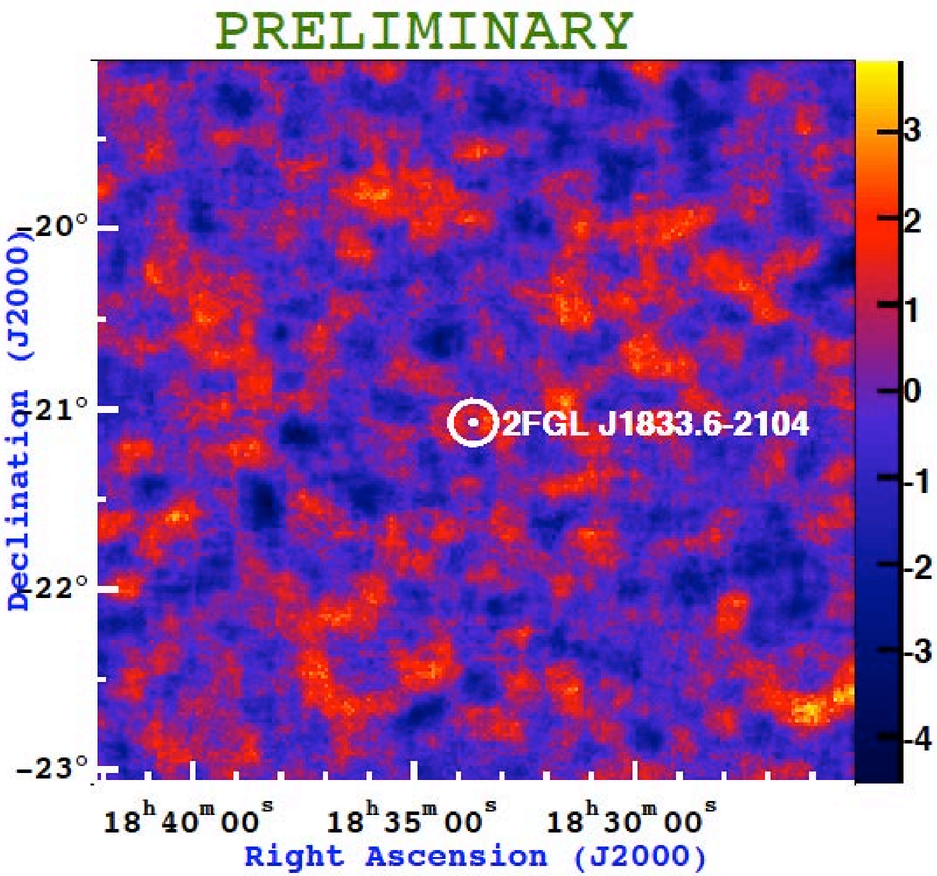
$\Delta t_{radio} \sim 26$ d

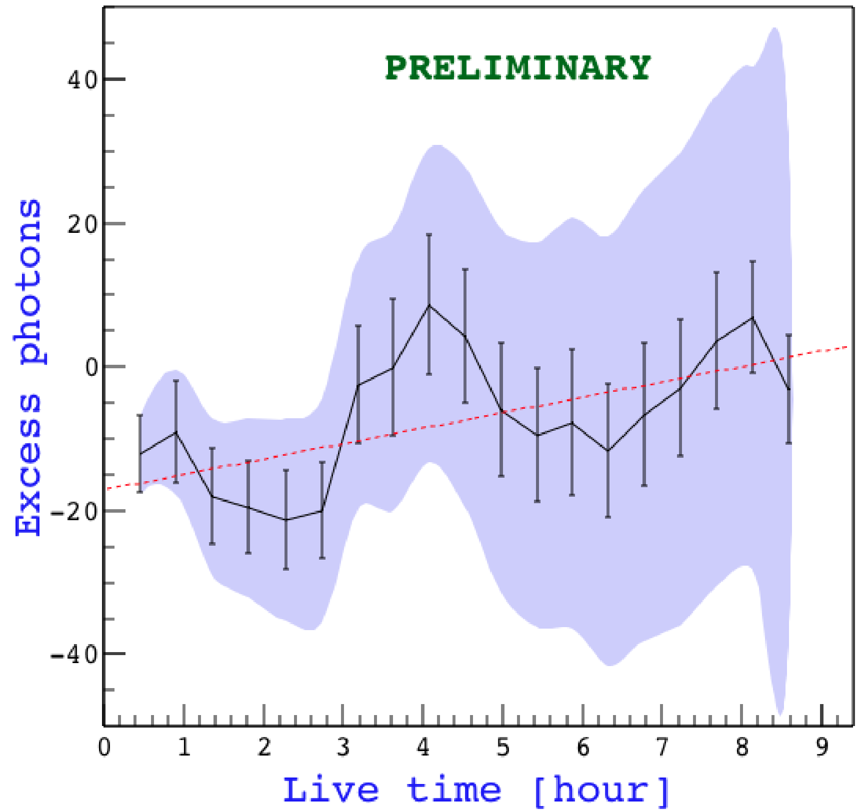
Magnification Ratio = 1.52

Fermi-LAT γ-ray flare July 27, 2014

→ H.E.S.S. observations timed to detect the delayed image flare (August 12 – 26)

H.E.S.S. Observations of PKS 1830-211

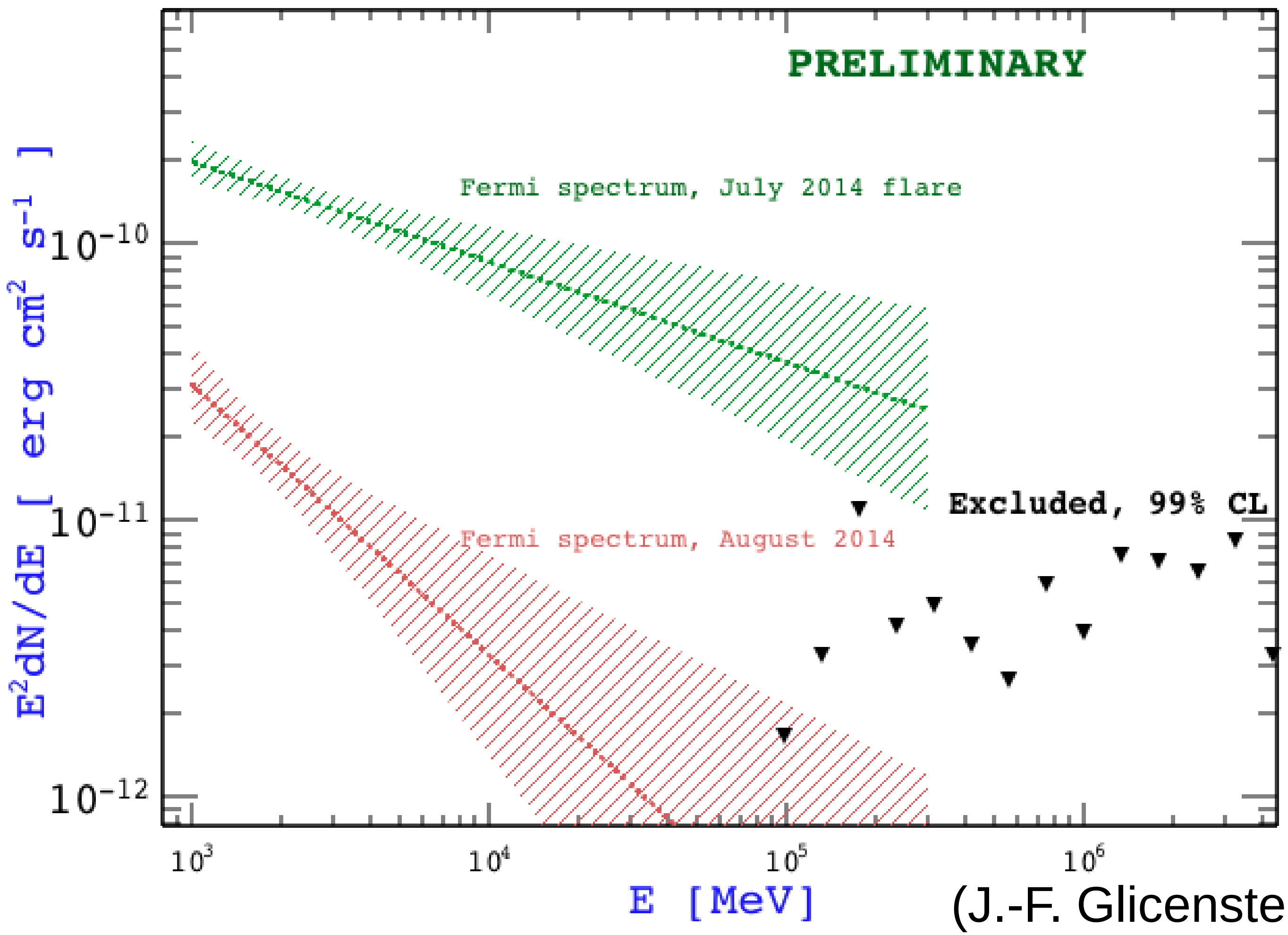




(J.-F. Glicenstein et al. 2015)

No evidence for excess
(neither in total exposure nor temporary increase)

H.E.S.S. Observations of PKS 1830-211



(J.-F. Glicenstein et al. 2015)

H.E.S.S. ULs far below extrapolation of Fermi flare spectrum

→ EBL absorption effect?

Or different locations of HE vs. VHE γ-ray production region?

Summary

- H.E.S.S. II analyses using both CT5 Mono and the full H.E.S.S.-II array are now well understood.
- Long-Term Monitoring of PKS 2155-304 reveals log-normal (multiplicative) variability
- Rapid (< 10 min) variability of Mrk 501 at > 2 TeV
- Continued discovery of new extragalactic VHE sources (incl. PKS 1440-389)
- High-quality H.E.S.S. spectra of nearby blazars constrain the SED of the local EBL
- Non-detection of lensing-delayed VHE flare in PKS 1830-211
  → Different HE vs. VHE γ-ray emission regions?