# Blazars as astroparticle physics laboratories: the case of KUV00311-1938

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# Extragalactic gamma ray sources: Blazars

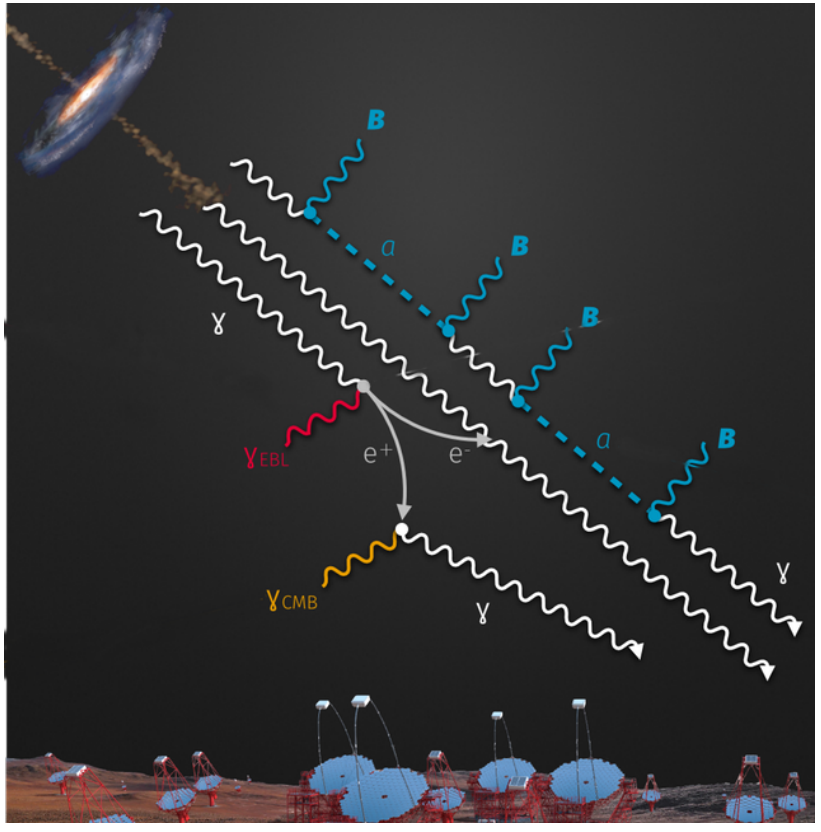
- Actively accreting supermassive black holes with relativistic jet pointing close to directly at us
- The bright jet is a strong source of non-thermal radiation
- Source of TeV $\gamma$-rays, candidate source for PeV protons

A BL Lac in the optical: Markarian 421

(Sloan Digital Sky Survey)

# Blazars: axion laboratory

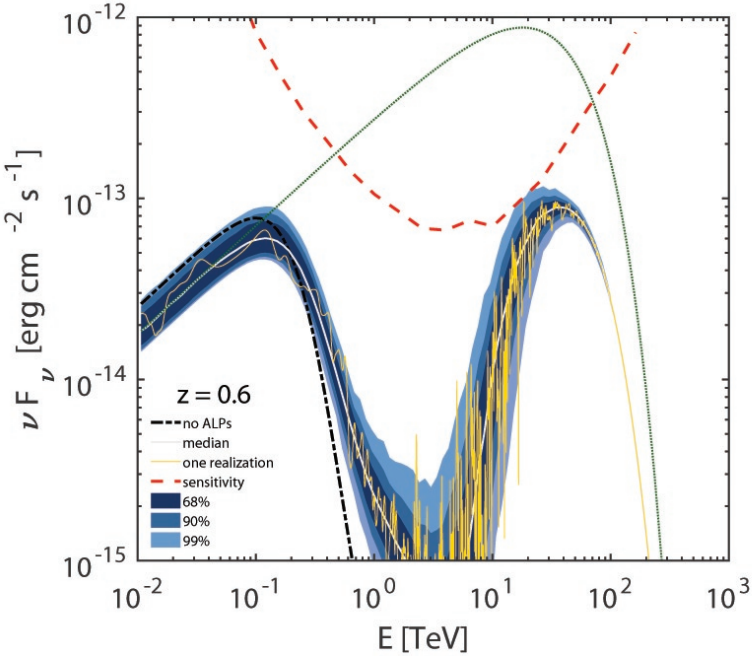
- $\gamma$-rays must traverse large distances, encountering low energy photons and magnetic fields
- $\gamma$-rays can pair-produce with low energy photons from extragalactic background light, light from the first stars
- Distant blazar suffer EBL absorption at high ($\gtrsim$ 10 GeV) energies




(www.cta-observatory.org/what-propogation-of-energetic-light-can-tell-us/)

# Blazars as a axion laboratory

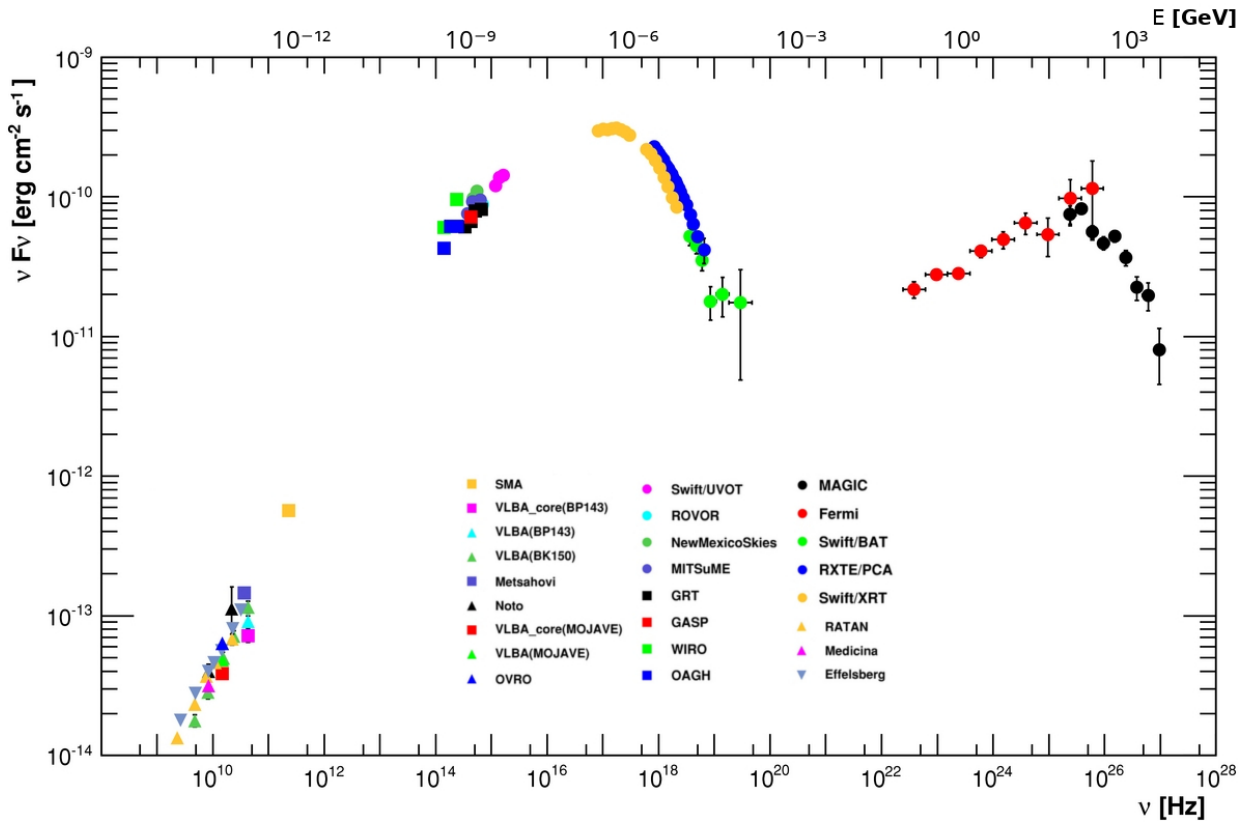
- In presence of extragalactic magnetic field, photons could oscillate into Axion Like Particle (ALP), avoid absorption, and then oscillate back in local magnetic field, giving excess
- The astrophysical magnetic fields are randomly aligned, giving imprinting extra fluctuations on observed spectra




(DOI: 10.1093/mnras/stz1144)

# Blazar "intrinsic" broad band spectrum

- Spectral energy distribution dominated by two non-thermal peaks
- Low energy peak from synchrotron radiation, high energy from Inverse Compton scattering

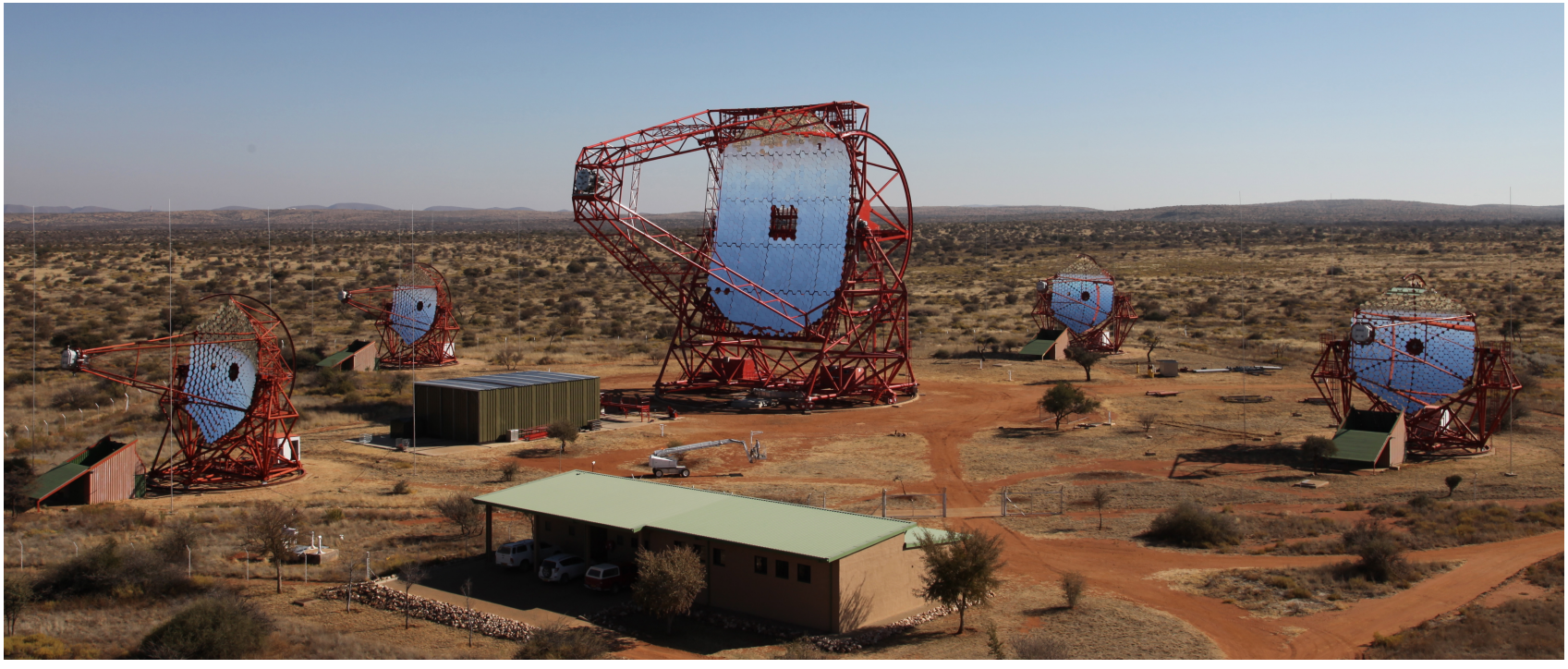



SED of nearby blazar Markarian 421

(Fermi, 2011ApJ...736..131A)

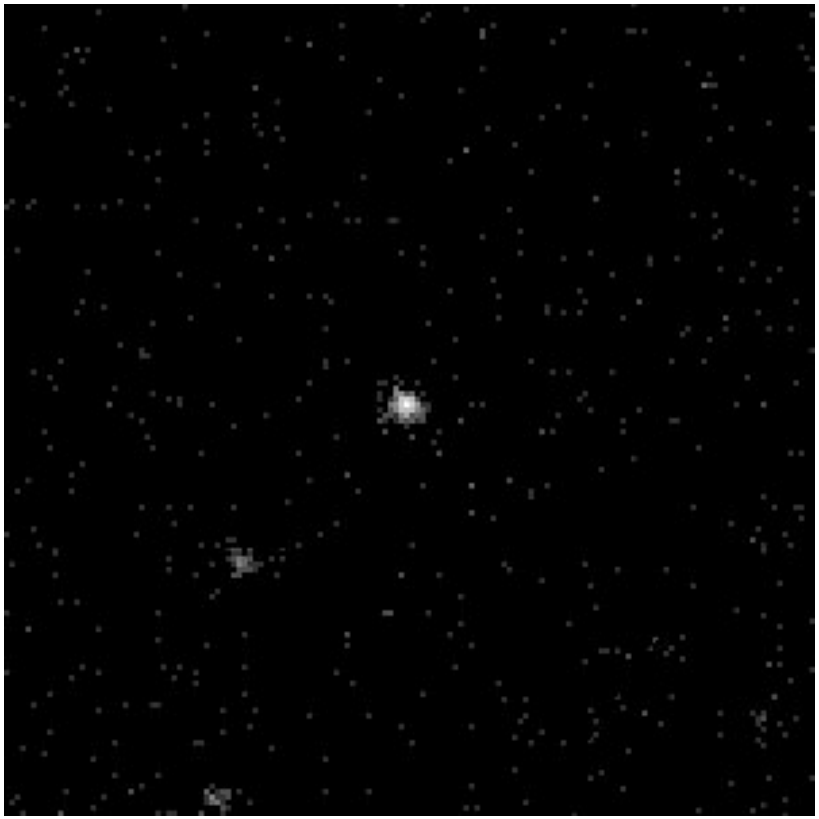
# High Energy Stereoscopic System (HESS)

- Located in Namibia, Khomas Highlands, at 1800 m altitude
- Inaugurated in 2004, consisting of four 12m telescopes
- Much bigger, fifth, telescope with higher resolution camera added in 2012 to get better low energy sensitivity
- Sensitive to gamma rays between 80 GeV and $\sim 60$ TeV



(HESS collaboration)

# My source: KUV 00311-1938



KUV 00311-1938 in X-ray

(ROSAT All-Sky X-ray Survey)

- KUV 00311 is a BL Lac type blazar, with uncertain redshift: $0.5 \leq z \leq 1.5$ (5 to 9 Gyr old)
- A bright source in the Fermi/LAT $\gamma$-ray sky
- Good candidate for observation with H.E.S.S. due to hard Fermi spectrum

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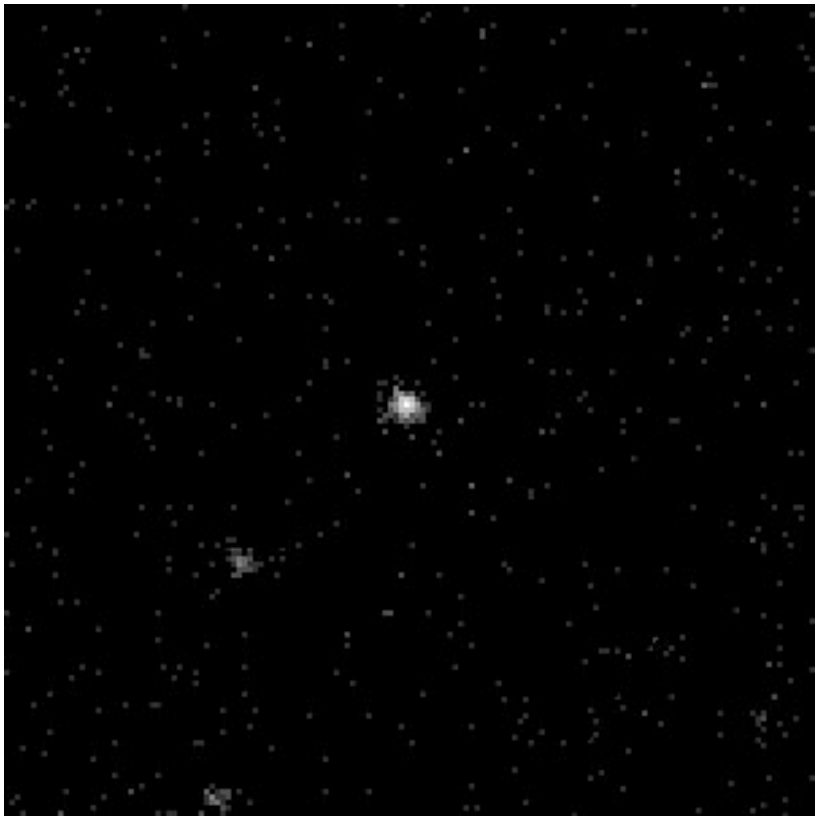

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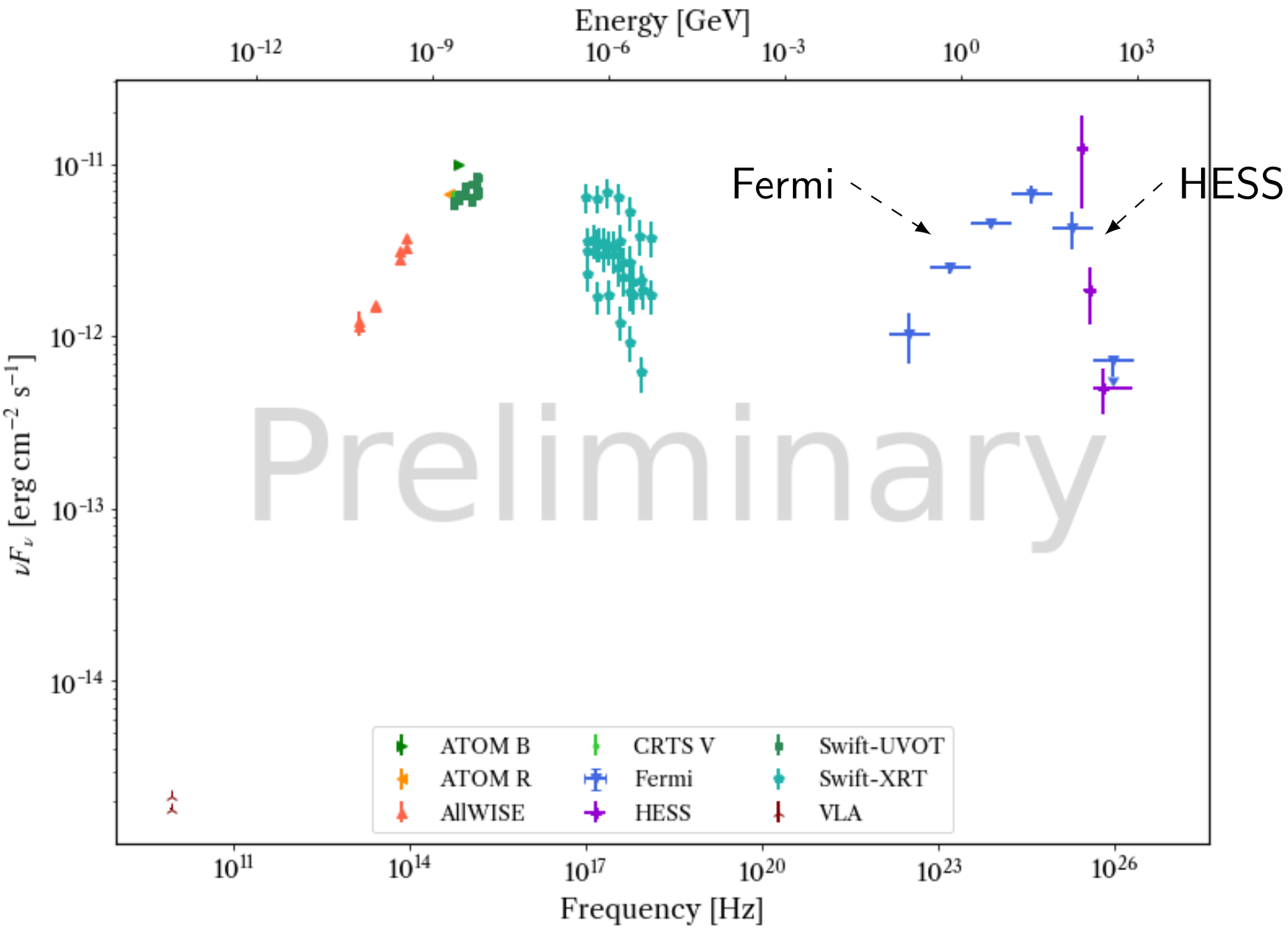
- A bright source in the Fermi/LAT $\gamma$-ray sky
- Good candidate for observation with H.E.S.S. due to hard Fermi spectrum
- In practice KUV has been hard to see, have created specialized analysis for this type of source

# KUV 00311-1938 across all wavelengths



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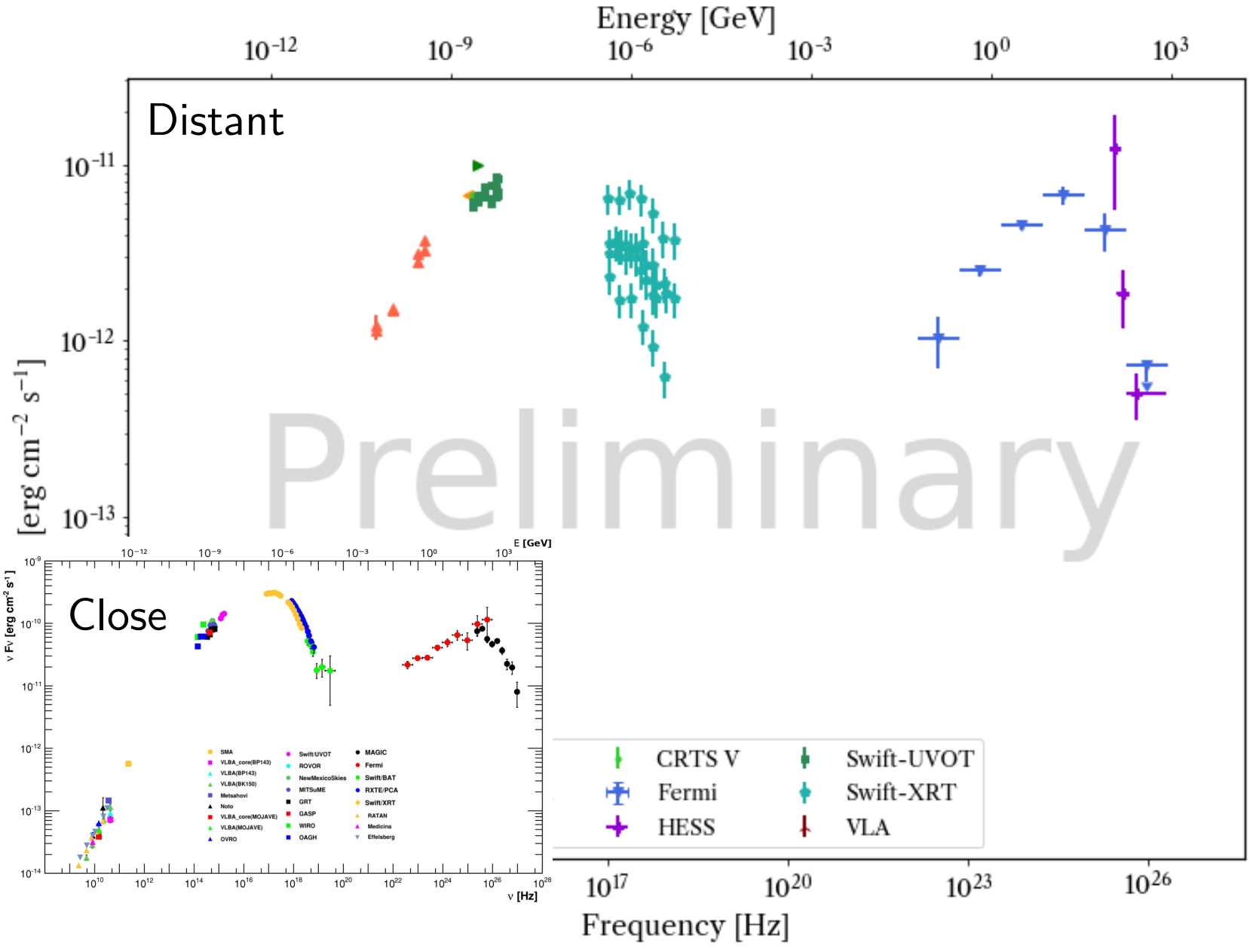

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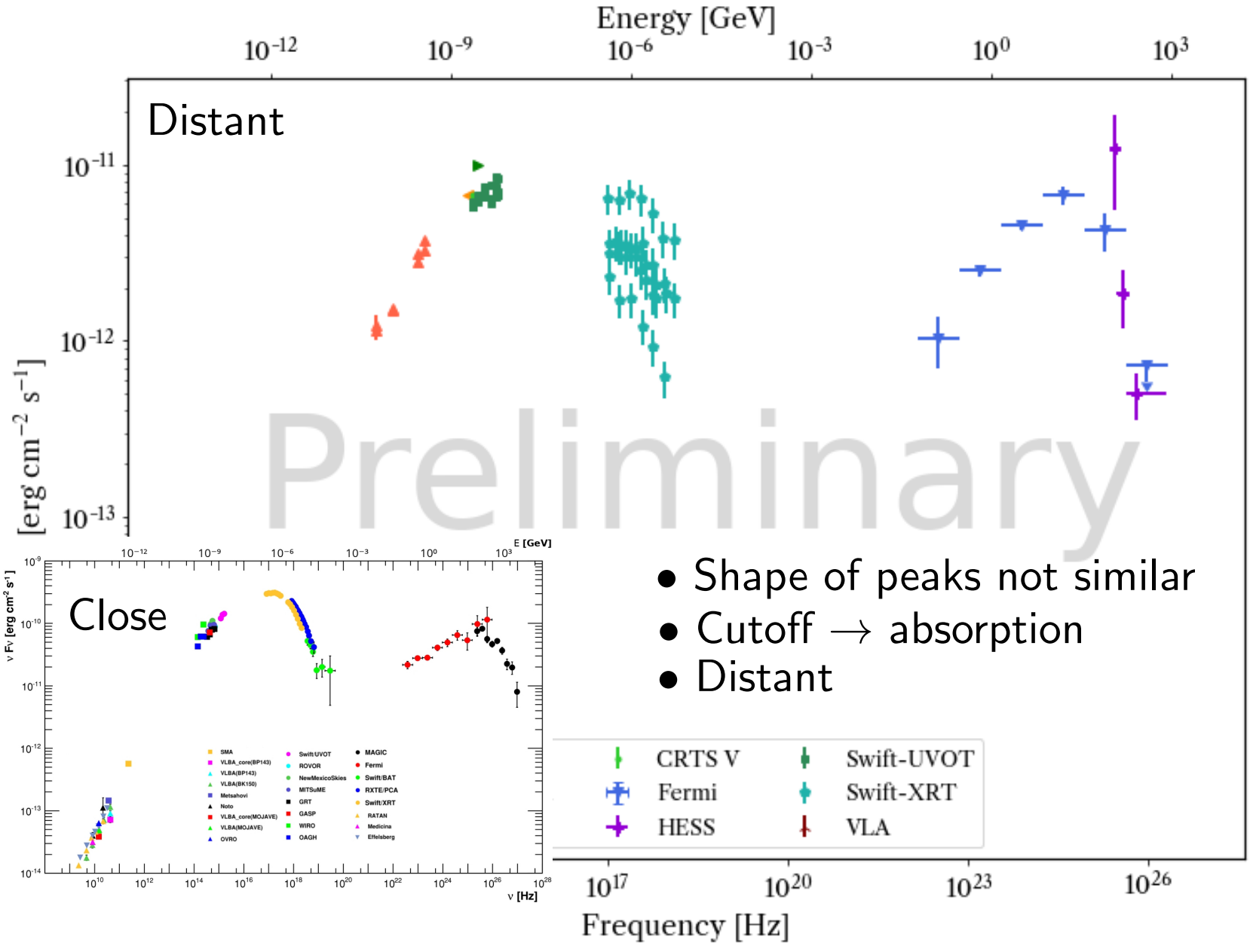
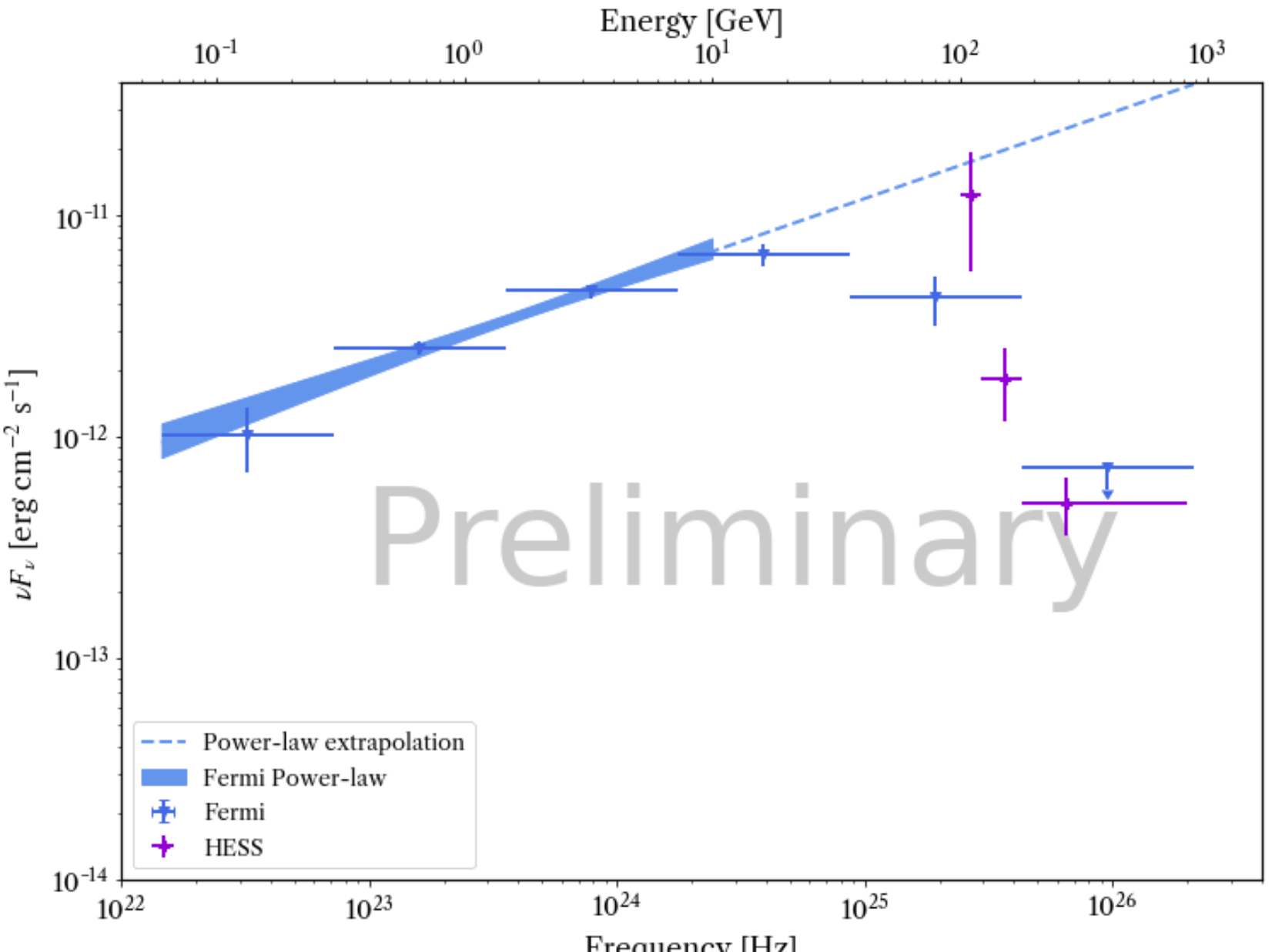


# Understanding KUV 00311-1938 across all wavelengths

- Because the synchrotron peak and high energy peak are related to the same underlying electron population in the IC scenario, peaks should have similar shape
- Sharp break in high energy peak not seen in synchrotron is clear evidence of absorption from Extragalactic Background Light
- KUV 00311-1938 is likely a fairly distant BL Lac

# KUV 00311-1938 redshift estimate



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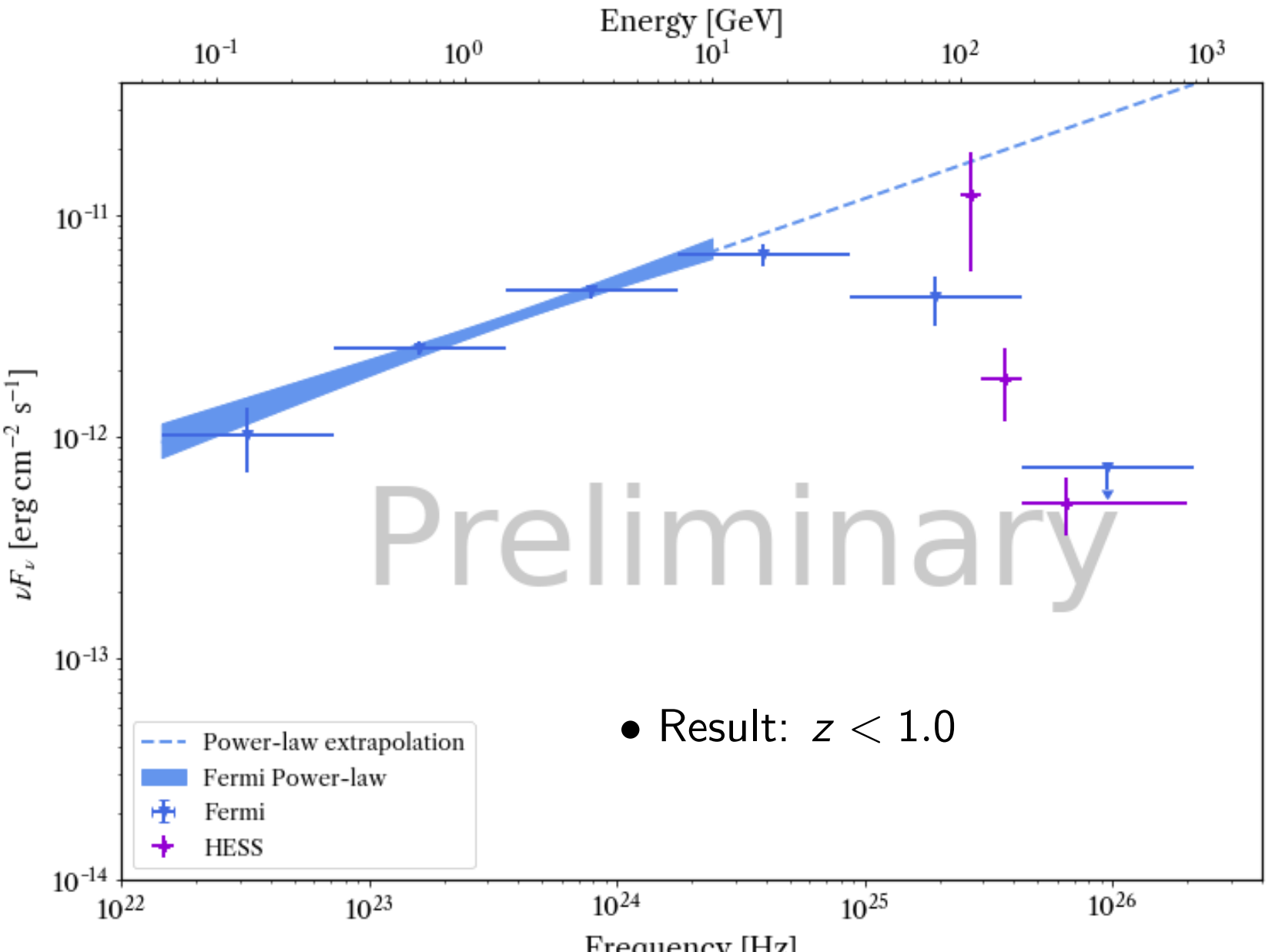


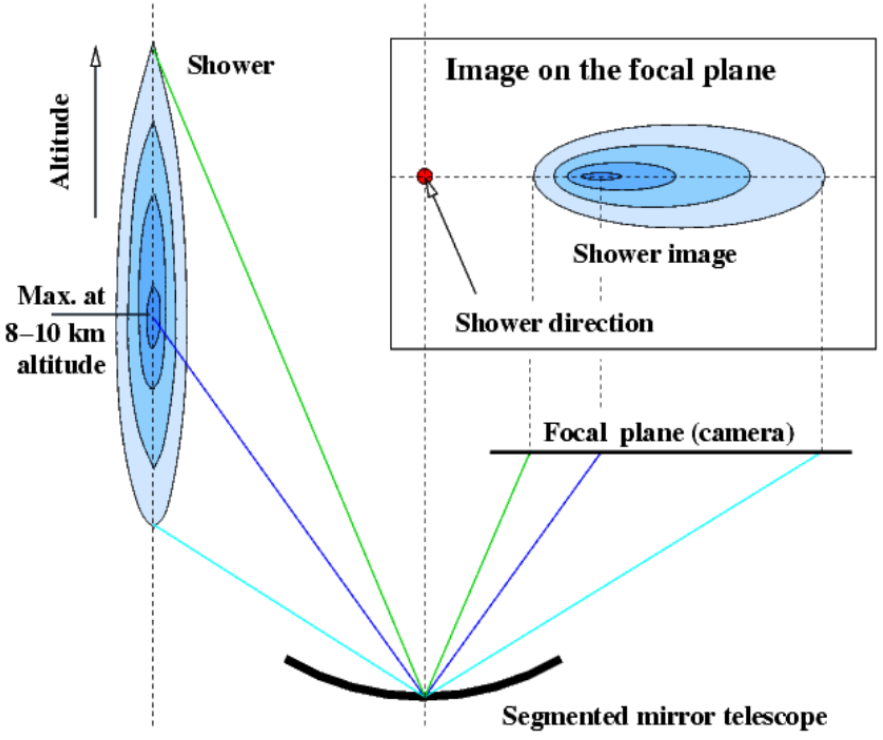

- Result: $z < 1.0$

# Conclusions

- KUV 00311-1938 has been firmly observed in the very high $\gamma$-ray range
- The spectrum shows clear evidence of large redshift: severe EBL absorption
- No hint of axion peak, lacking statistics to see increased variance
- Comparing power-law extrapolation to predicted absorption using various models of light from galaxies restricts redshift to below 1.0

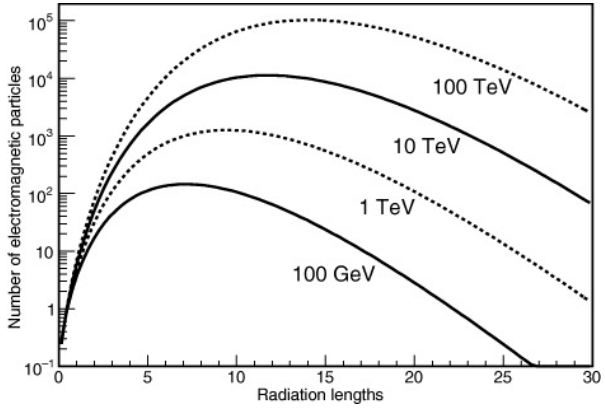
Thank you for your attention

# Imaging atmospheric Cherenkov light




(K. Bernlöhr)

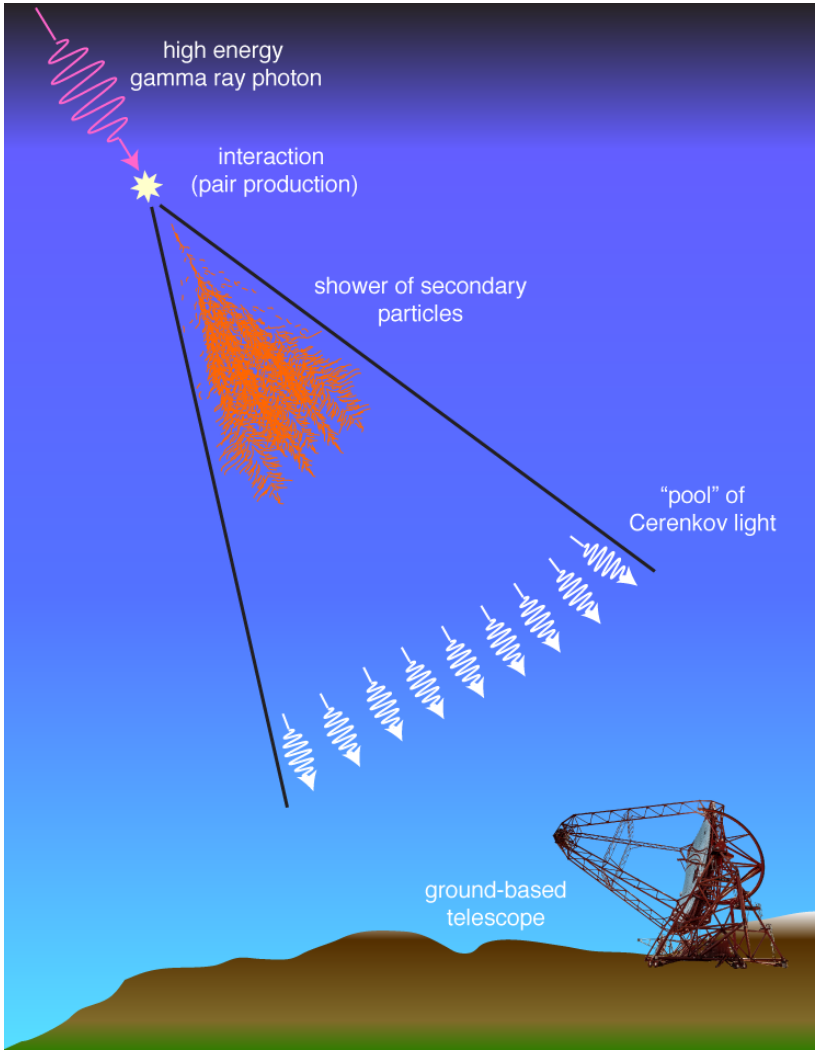
- The energy of the gamma photon influences the profile of the shower




(Sinnis, 2009NJPh...11e5007S)

# Imaging Atmospheric Cherenkov Telescopes

- High energy gamma rays hit the upper atmosphere and create air-showers
- The shower particles are relativistic and induce Cherenkov light in a narrow cone along the direction of the incoming photon
- Telescopes on the ground can take images of the air-showers using fast electronics




(Albert, doi:10.1088/978-1-6817-4269-4ch3)

# Optical depths vs EBL models