Is PKS 0625-354 a radio galaxy?

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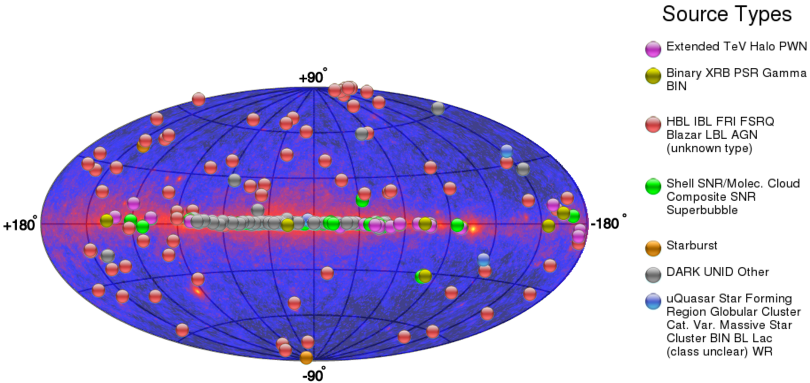
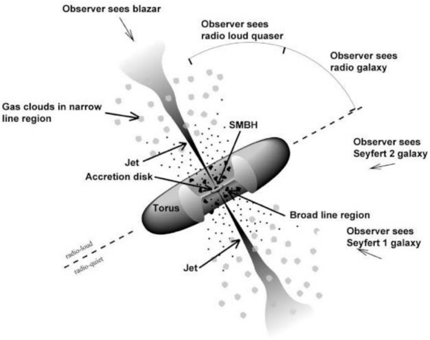
Extragalactic sky in VHE γ rays

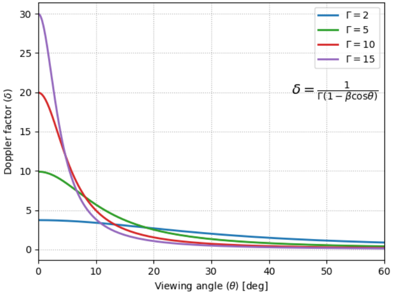


`tevcat.uchicago.edu`

Known TeV sources (up to Aug, 2018): $>$200
Blazars & RGs type sources: 75

Blazars and radio galaxies in the unified scheme





The unified model of Active Galactic Nuclei.

Credits `fermi.gsfc.nasa.gov/science/eteu/agn/`.

Doppler factor (δ) as a function of viewing angles (Θ) for different values of Lorentz factor (Γ). The formula linking δ and Θ is presented in the right, bottom corner of the figure. For blazars $\delta \gg 1$, while in the case of radio galaxies $\delta < 1$.

VHE detected radio galaxies

Source name	Type	Redshift
IC 310	FR I / BL Lac / ?	0.0189
NGC 1275	FR I	0.0176
PKS 0625-354	FR I / BL Lac / ?	0.0549
3C 264	FR I	0.0217
M 87	FR I	0.0044
Cen A	FR I	0.0018

– Only 6 RGs in TeVCat

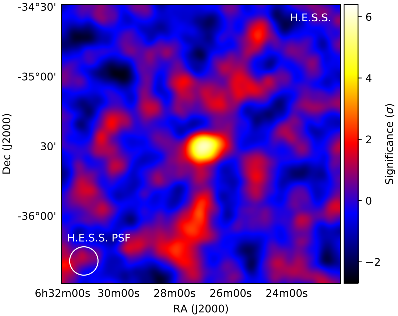
– All detected sources are FR I or its classification is not obvious.

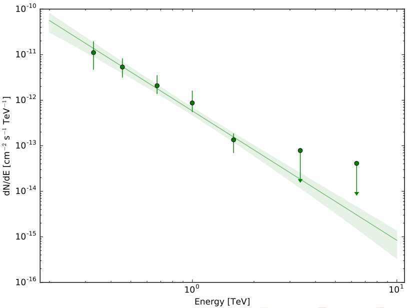
H.E.S.S. observations of PKS 0625-354

- The High Energy Stereoscopic System (H.E.S.S.) - an array of five Cherenkov telescopes, located in Namibia.
- Dedicated to observe very-high-energy γ rays
- Four 12-m telescopes (mirror area of 108 m^2 each) and one telescope with a mirror area of 614 m^2 (32.6 m by 24.3 m; equivalent to 28 m circular dish).

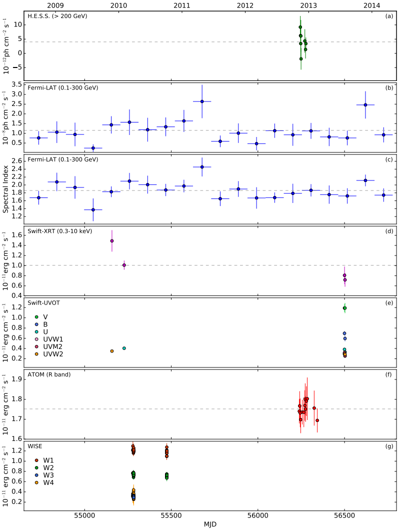
Multi-wavelength observations of PKS 0625-354

- 8 nights of H.E.S.S.I observations in November and December 2012.
- Total exposure of 5.5 h of good quality data.
- Zenith angles of 11-19°.
- The measured excess of 60.7 events corresponds to 6.1σ significance
- Spectrum characterize with the power-law distribution;
  $\Gamma = 2.84 \pm 0.50$



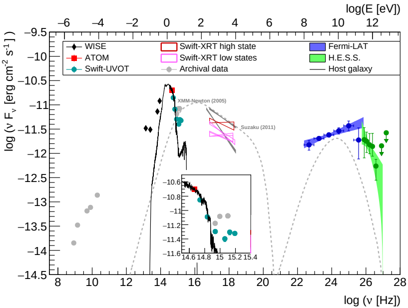


Multi-wavelength observations of PKS 0625-354



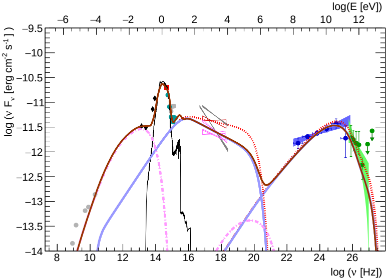
- Large set of data collected with Fermi-LAT, Swift-XRT, Swift-UVOT, ATOM and WISE.
- Variability is seen in Fermi-LAT and Swift-XRT observations.
- No flux changes in H.E.S.S. observations.
- During the period of H.E.S.S. observations, LAT flux was close to the average value.

Broadband spectral energy distribution



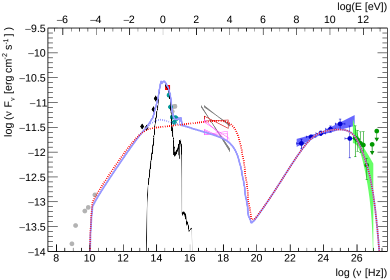
- Previous single-zone modelling by Fukazawa et al. (2015) - RG-like parameters (e.g. Doppler factor), but obtained using only weak observational constraints.
- Here, single-zone SSC model unable to reproduce γ-ray spectrum (X-ray variability).
- Host galaxy included using PEGASE 2 template.

Interpretation of SED: leptonic interpretation



- Blob-in-jet description given in Katarzynski et al. (2001) and Hervet (2015).
- The main radiating component is a Doppler boosted spherical compact blob.
- The second component stratified base of the extended jet surrounding the blob.
- Minimal variability of 4.4 h for the blob and 18.3 h for the jet.
- For X-ray variability Θ is constrained as $< 15^{\circ}$.
- SED shape favours higher Doppler factors.

Interpretation of SED: lepto-hadronic interpretation



- Low energy SED bump as synchrotron radiation from primary relativistic electrons and a high-energy bump strongly dominated by synchrotron radiation from relativistic protons.
- Asymmetry of low-energy and high-energy emission bumps are naturally reproduced.
- Large magnetic field of 100 G is needed for this model. This implies that the system is far from equipartition.

Summary: who are you PKS 0625-354

- Radio structure typical for FR I sources.
- RG in 0FGL with a spectral slope $\alpha > 0.5$ @178-408MHz.
- Flux and frequency of the synchrotron peak in SED typical for BL Lac objects.
- The redshift of 0.055 is high comparing to other RGs. If it is a RG, this would imply extremely powerful jet.
- Both scenarios tested need a significant Doppler boosting of emission zone in order to reproduce SED. Feature of BL Lac objects.
- Wills et al. (2004) suggested a blazar-like nature of the object according to spectroscopic optical observations (OIII lines luminosity).

Summary

The classification of PKS 0625-354 is mysterious. Radio galaxy? Blazar? Mixture of both? Completely new class of source?

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Backup - models

Parameter	Value	Unit
θ	1.0	deg
Blob		
Γ	10.4	–
K	2.3×10^3	cm^{-3}
n_1	2.0	–
n_2 (low state)	3.35	–
n_2 (high state)	3.15	–
γ_{min}	1.0	–
γ_{max}	6.0×10^6	–
γ_b	4.0×10^4	–
B	4.0×10^{-2}	G
R	9.0×10^{15}	cm
Jet		
Γ	4.1	–
K	8.5×10^2	cm^{-3}
n	2.1	–
γ_{min}	1.0	–
γ_{max}	3.2×10^3	–
B_1	3.1×10^{-1}	G
R_1	1.5×10^{16}	cm
L*	3.0×10^2	pc
$\alpha/2$*	1.0	deg

Parameter	Value	Unit
General		
Γ	10.0	–
θ	5.74	deg
B	1.0×10^2	G
R	1.0×10^{16}	cm
η_{esc}	3.0	–
Electrons		
P_e (low state)	4.28×10^{39}	erg s^{-1}
P_e (high state)	4.72×10^{39}	erg s^{-1}
n_e (low state)	2.20	–
n_e (high state)	1.92	–
$\gamma_{min,e}$ (low state)	1.40×10^2	–
$\gamma_{min,e}$ (high state)	6.50×10^2	–
$\gamma_{max,e}$	4.50×10^4	–
Protons		
P_p	8.75×10^{42}	erg s^{-1}
n_p	1.90	–
$\gamma_{min,p}$	1.07	–
$\gamma_{max,p}$	2.13×10^{10}	–