Is PKS 0625-354 another variable TeV active galactic nucleus?

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Introduction

Gamma-ray signal of TeV detected blazars and non-blazars

- Majority of active galactic nuclei detected at very-high-energies above 100 GeV belong to the class of blazars with small viewing angle
- Only ~10% of gamma-ray AGN are objects with a larger viewing angle resulting in a smaller Doppler boosting
- Known TeV variability of non-blazar active galaxies (e.g., M 87 of NGC 1275) providing important new insights into physical processes responsible for gamma-ray production and flaring events.

PKS 0625-354 – blazar or no-blazar?

- Uncertain AGN classification [see 1 and references therein]
- Kiloparsec radio morphology of a Fanaroff-Riley I radio galaxy, LINER 2
- Optical spectrum ([OIII] line luminosity) similar to BL Lac type object
- Non-variable TeV detection reported by H.E.S.S. [1]
- Parsec-scale radio map shows one-sided core-jet structure similar to a blazar [2]

MWL observing campaign in 2018

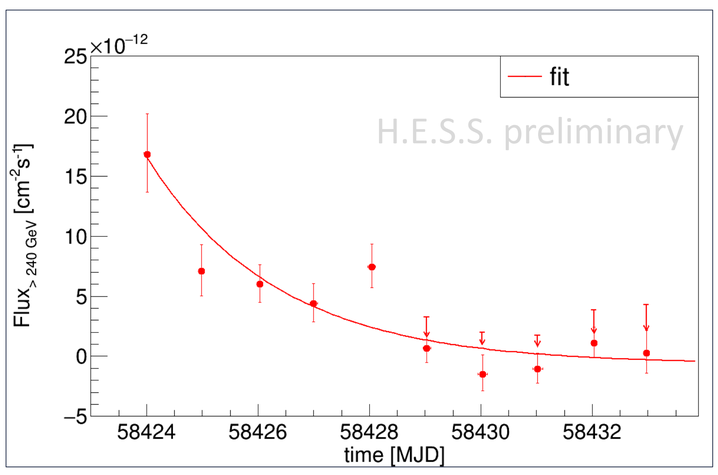
- TeV observations aiming for variability search with H.E.S.S. telescopes
- Significant signal detected in first night of campaign in November 2018 with Real-Time-Analysis
- Denser H.E.S.S. observations followed together with dedicated ATOM (optical telescope on H.E.S.S. site), *Swift*-UVOT (optical, UV) and -XRT (X-ray) observations
- Construction of simultaneous multi-wavelength spectral energy distribution including optical/UV, X-ray, GeV and TeV information

H.E.S.S. Analysis and Results

- 17.5 h of good quality data acquired within 10 nights with all five H.E.S.S. telescopes between 2018-11-01 and 2018-11-10 (dates are given before sunset)
- Data analysis done with HAP software [3]
- 8.7σ with ring-background method
- Separate spectral analysis done for all data (average 2018) between 2018-11-01 and 2018-11-10, for the flaring night on 2018-11-01 only, and for the low state between 2018-11-02 and 2018-11-10

Light curve

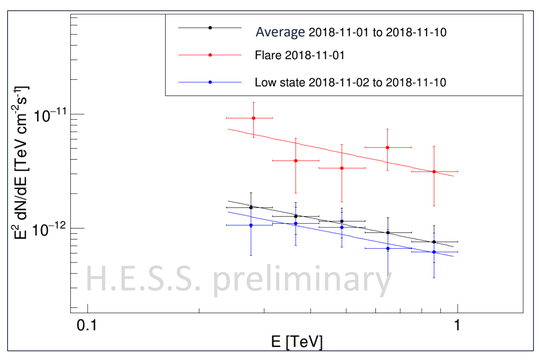
- Nightly binned light curve above 200 GeV assuming photon spectral index of 3.0
- Fit with function $F = F_0 + F_1 \times 2^{-|t-t_1|/\tau_{\mathrm{Var}}}$ to get flux-doubling time scale of $\tau_{\mathrm{Var}} = 2339 \pm 751$ min



Spectral energy distribution

- Power-law fit with $\frac{dN}{dE} = f_0 \times \left(\frac{E}{E_0}\right)^{-\Gamma}$

Emission state	$f_0 \times 10^{-12}$ [TeV^{-1}s^{-1}cm^{-2}]	E_0 [TeV]	Γ	Range [TeV]
Average 2018	$5.89 \pm 0.86_{\mathrm{stats}}$	0.44	$2.65 \pm 0.35_{\mathrm{stats}}$	0.2-1.0
Flare	$24.9 \pm 5.2_{\mathrm{stats}}$	0.44	$2.68 \pm 0.55_{\mathrm{stats}}$	0.2-1.0
Low state	$4.75 \pm 0.86_{\mathrm{stats}}$	0.44	$2.64 \pm 0.41_{\mathrm{stats}}$	0.2-1.0
2012 [1]	$0.58 \pm 0.22_{\mathrm{stats}}$	1	$2.84 \pm 0.50_{\mathrm{stats}}$	0.2-10



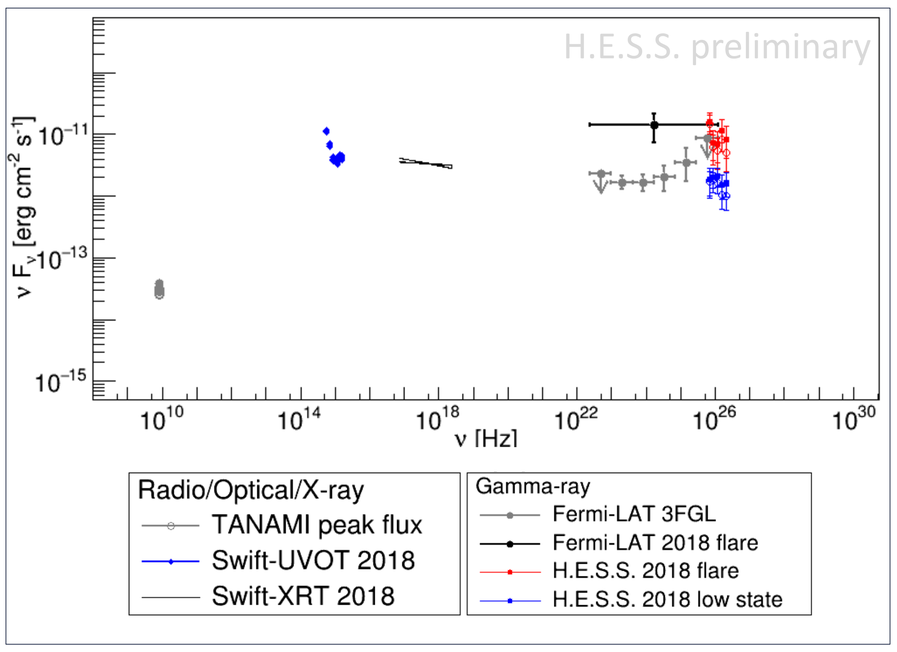
Multi-wavelength Spectral Energy Distributions

Multi-wavelength observations and analysis

- *Swift* observations organized via ToO request, three observations performed on MJD 58425, 58426, and 58427
- *Swift*-UVOT: V, B, U, UVW1, UVM2, UVW2 filters used for each *Swift* observation, data corrected for dust absorption shown in the plot
- *Swift*-XRT: average simple power-law spectrum, $F_{2-10\mathrm{keV}} = (5.03 \pm 0.20) \times 10^{-12} \mathrm{erg\ cm^{-2} s^{-1}}$ and $\Gamma_{\mathrm{X-ray}} = 2.07 \pm 0.04$
- *Fermi*-LAT: analysis for period around H.E.S.S. flare from 2018-10-30 to 2018-11-03 yields TS=11.0

Spectral energy distribution

- Multi-wavelength SED
- H.E.S.S. spectra correct for EBL absorption with EBL model [6]
- Archival radio data added from TANAMI observations [2]: peak fluxes are shown as well as the 3FGL spectrum from *Fermi*-LAT in the GeV band



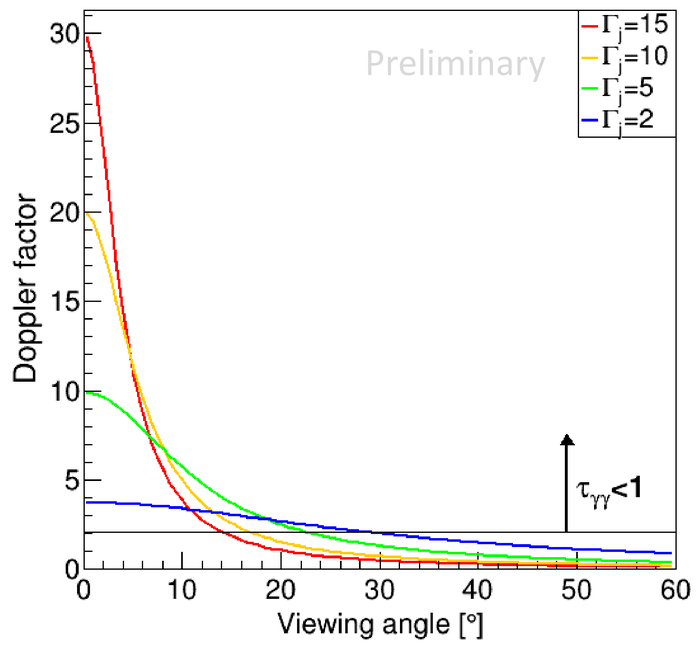
Implications of TeV variability on Viewing Angle

- Size of TeV emission region is

$$R < \delta c \tau_{\mathrm{Var}} \frac{1}{(1+z)} = 2339\ \mathrm{min} \cdot \delta c \frac{1}{(1+z)} = \delta \cdot 4.0 \times 10^{15}\ \mathrm{cm}$$

- For comparison, the light crossing time of black hole (with $M_{\mathrm{BH}} = (1.55 \pm 0.66) \times 10^9\ \mathrm{M_{Sun}}$ [4])

$$t_{\mathrm{G}} = \frac{\mathrm{G M_{BH}}}{c^3} = 1.37\ \mathrm{h} = 82\ \mathrm{min}$$



- Doppler factor as a function of viewing angle for different Lorentz factors
- Upper limit on viewing angle θ<29° for $\tau_{\gamma\gamma}$<1 for 1 TeV photons using Eq. 9 in [4]
- Compare θ<53° for viewing angle based on jet-to-counterjet ratio of parsec-scale radio jet [2]

References

- [1] H.E.S.S. Collaboration, 2018, MNRAS, 476, 4187
- [2] Angioni et al., 2019, A&A, 627, A148
- [3] Parsons & Hinten, 2014, APh, 56, 26; Parsons et al., 2015, Proc. ICRC (The Hague), 34, 826
- [4] Bettoni et al., 2003, A&A, 399, 869
- [5] Abdo et al., 2011, ApJ, 727, 129
- [6] Dominguez, et al., 2011, MNRAS, 410, 2556

Conclusions

We reveal fast VHE variability with ~1.6 d times scales. Simultaneous optical/UV, X-ray, GeV, and VHE SED shows continuation of the Fermi spectrum in VHE.

Acknowledgement

https://www.mpi-hd.mpg.de/hfm/HESS/pages/publications/auxiliary/HESS-Acknowledgements-2019.html