Monitoring of VHE blazars with H.E.S.S.

M. Zacharias on behalf of the H.E.S.S. Collaboration

Monitoring the non-thermal Universe
Cochem, Germany
07.12.2016

High Energy Stereoscopic System

H.E.S.S. since 2012

- Located in the Khomas Highland, Namibia
- 1800m a.s.l.
- 4 telescopes with $\sim$ 12 m mirrors
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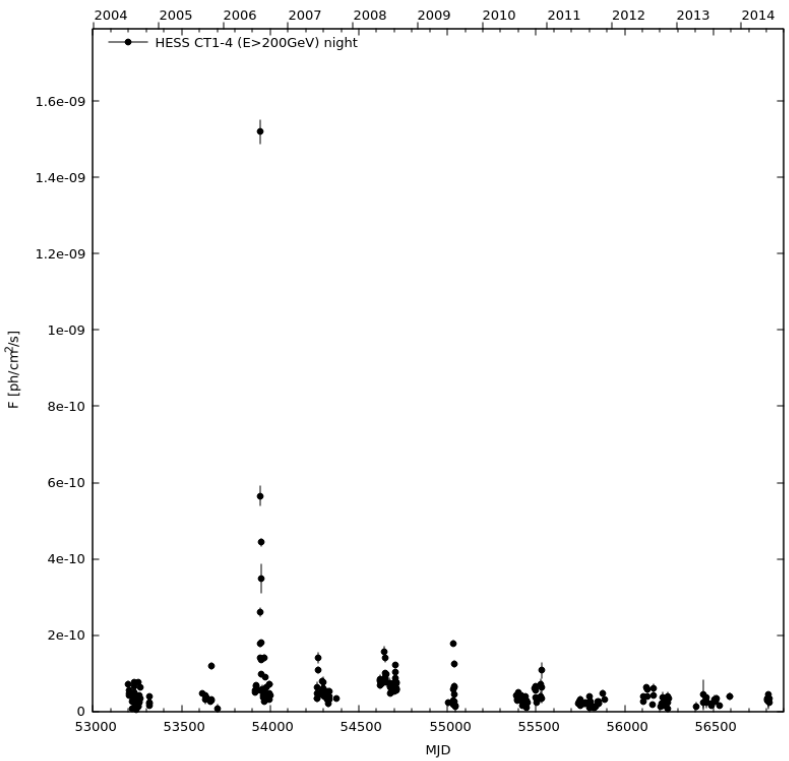
  - PKS 2155-304 (since 2004)
  - PKS 1510-089 (since 2015)

PKS 2155-304: Introduction



VHE lightcurve (nightly avg) of PKS 2155-304 since 2004

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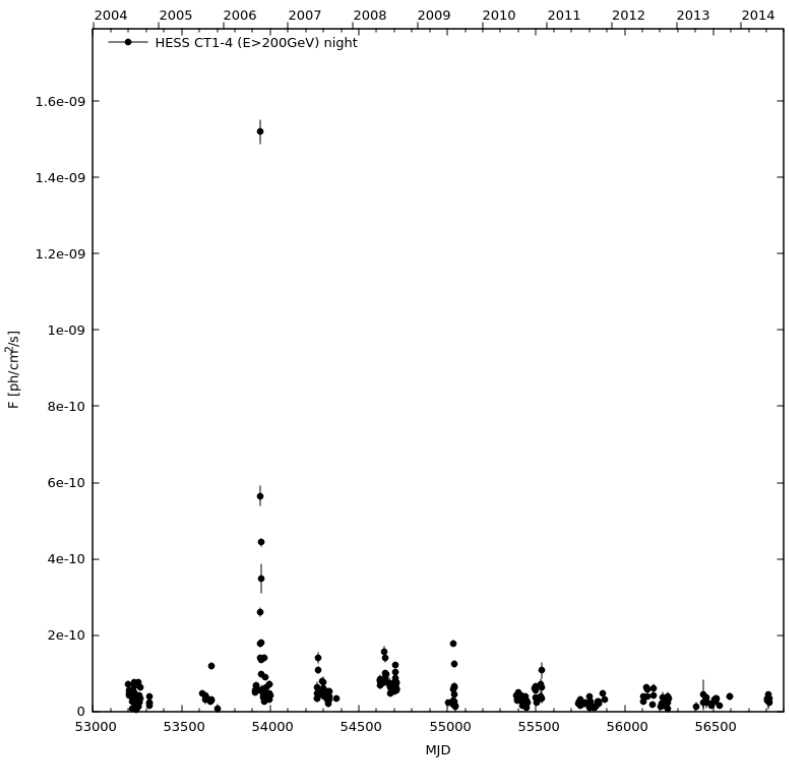

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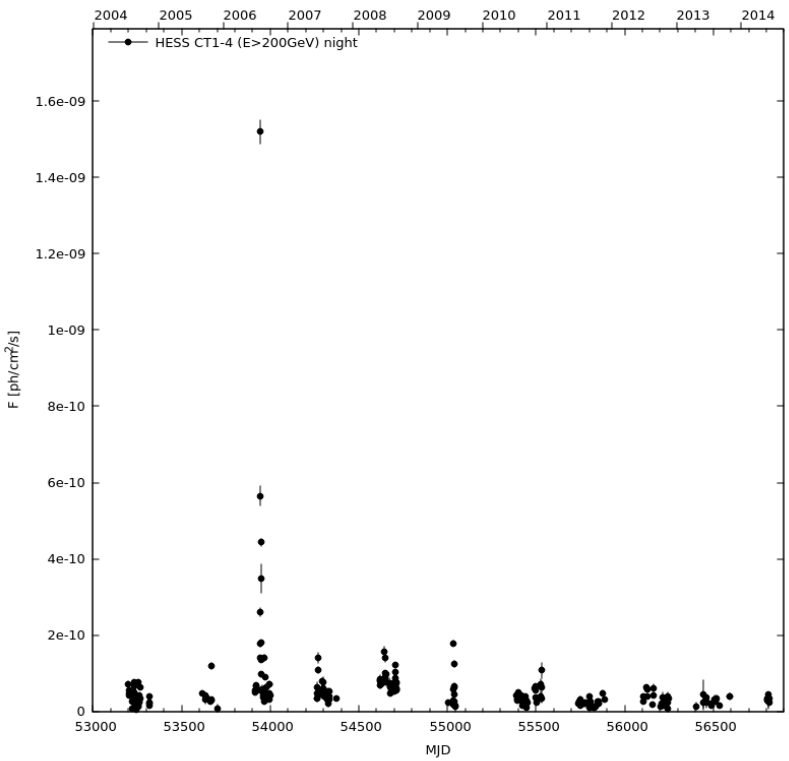

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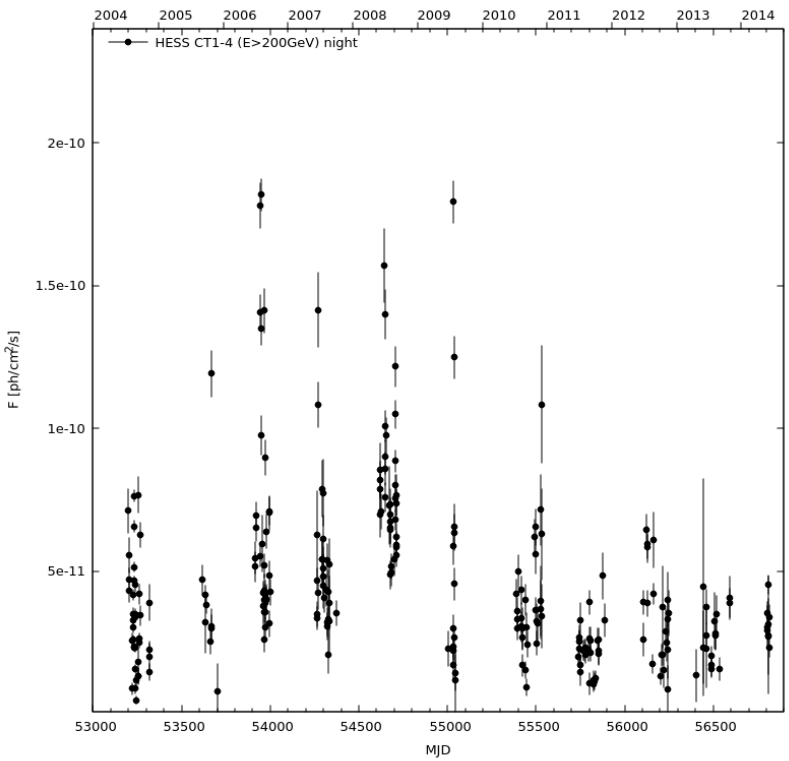

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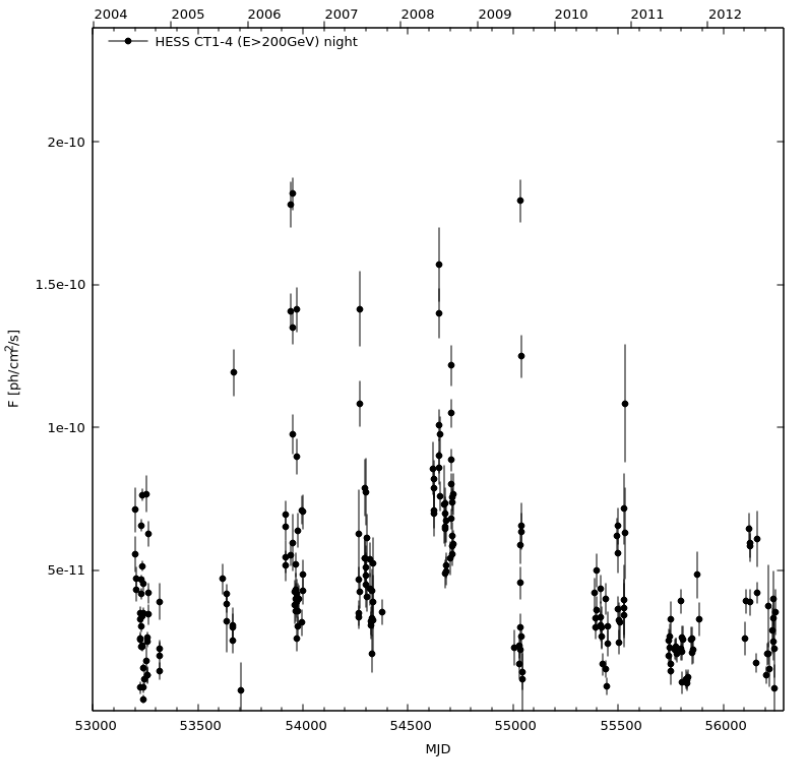
- Detected in every observation run ($t_{run} \sim 28$ min)
- Strong flare in 2006 ($\sim 100\,x$ brighter than avg)
- Variability even in low state
- Based on work by Jill Chevalier

(H.E.S.S. Collaboration et al., arxiv:1610.03311)

PKS 2155-304: Long-term variability



VHE lightcurve (nightly avg) of PKS 2155-304 from 2004 to 2012 (excl. flare)

- Data from 2004 to 2012, excl. 2006 flare, $t_{live} \sim 330$ hrs
- Only mild indication for spectral variability
- Clear flux variability:
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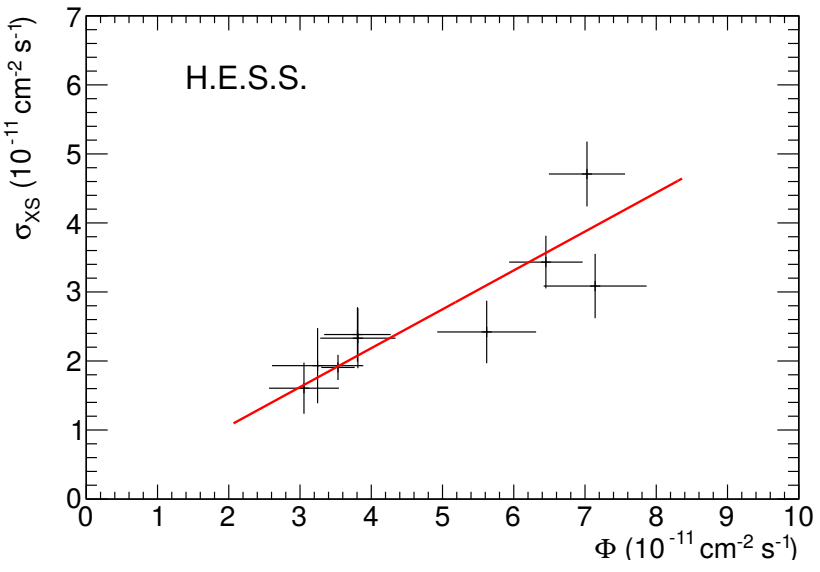

Excess RMS vs flux (20 nights per bin)

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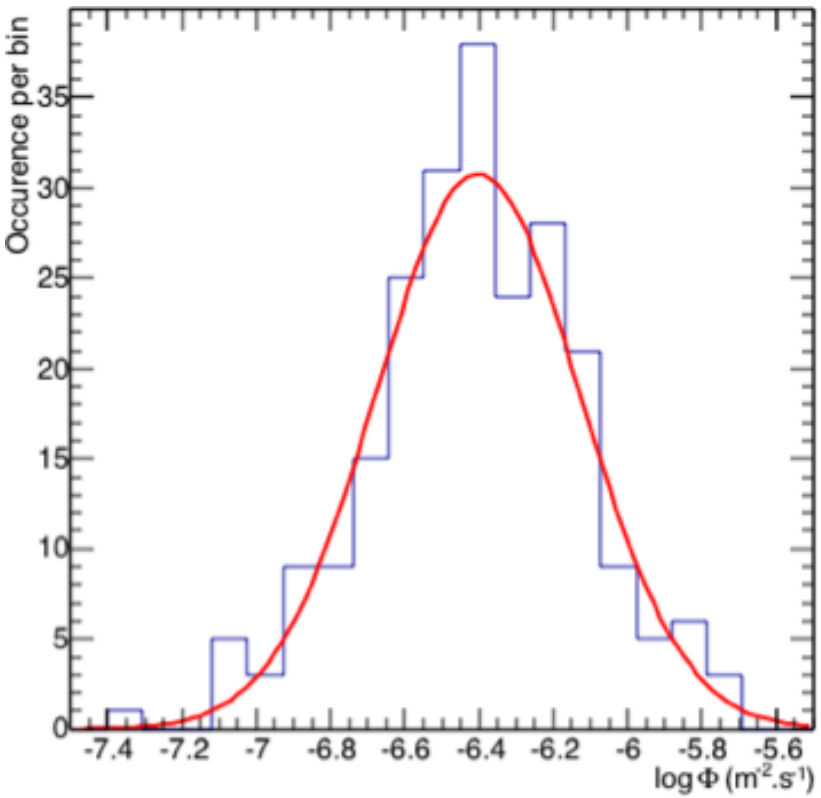

Log-flux distribution

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- Flux follows a log-normal distribution

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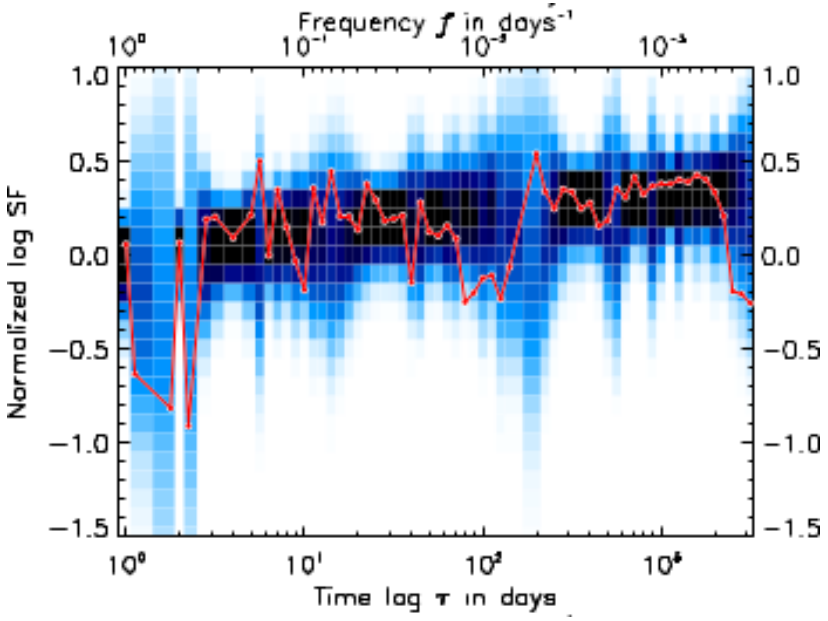

First-Order Structure Function vs. time lag in days (red), Simulation (blue)

- Variability characterized by power-law noise
- Index: $\beta = 1.10^{+0.10}_{-0.13}$ (flicker noise)

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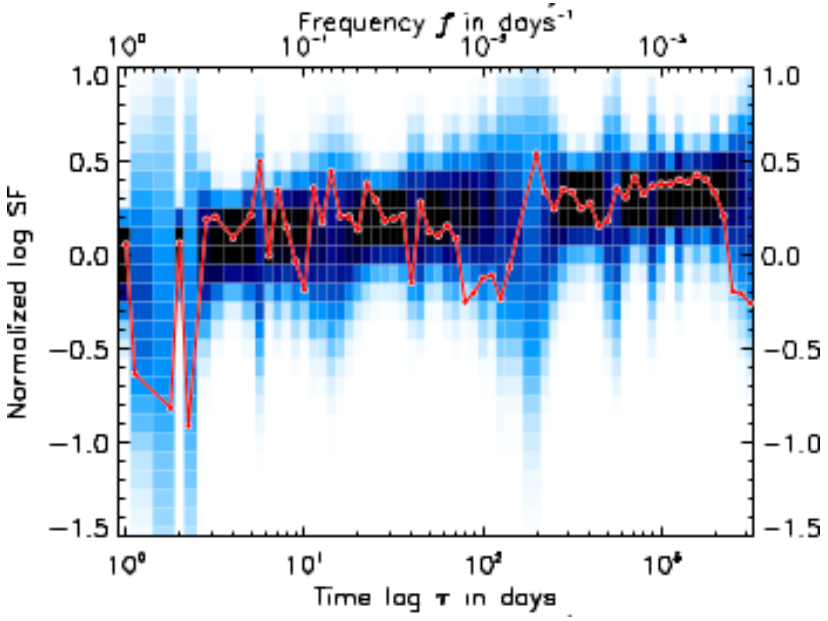

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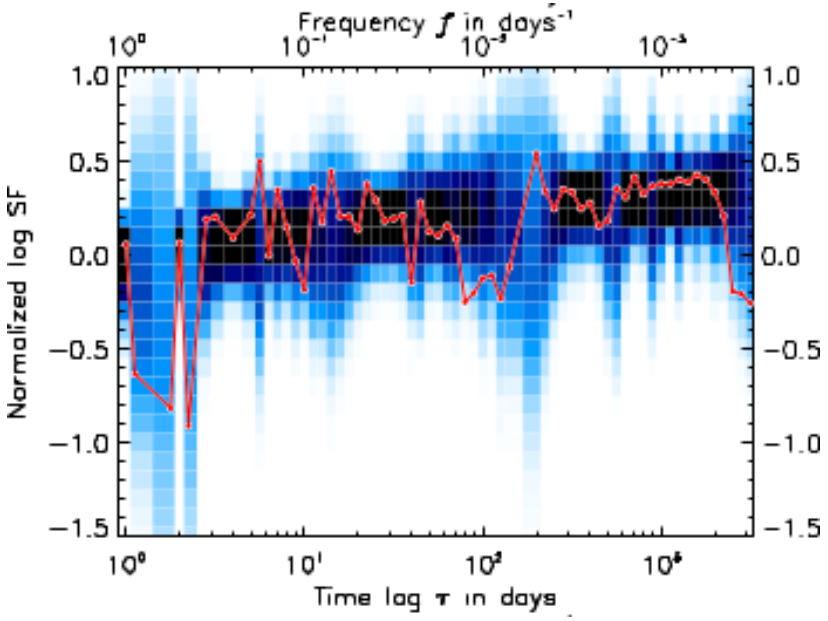

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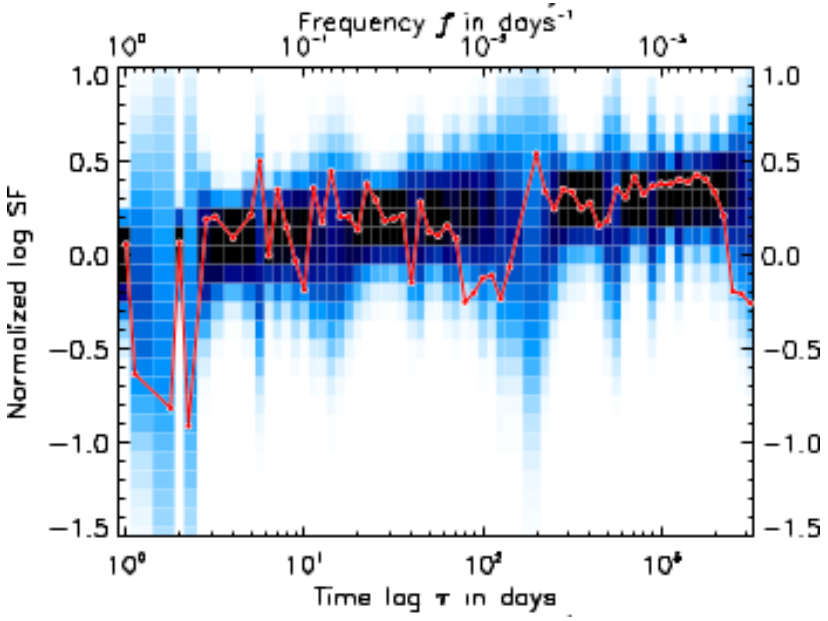

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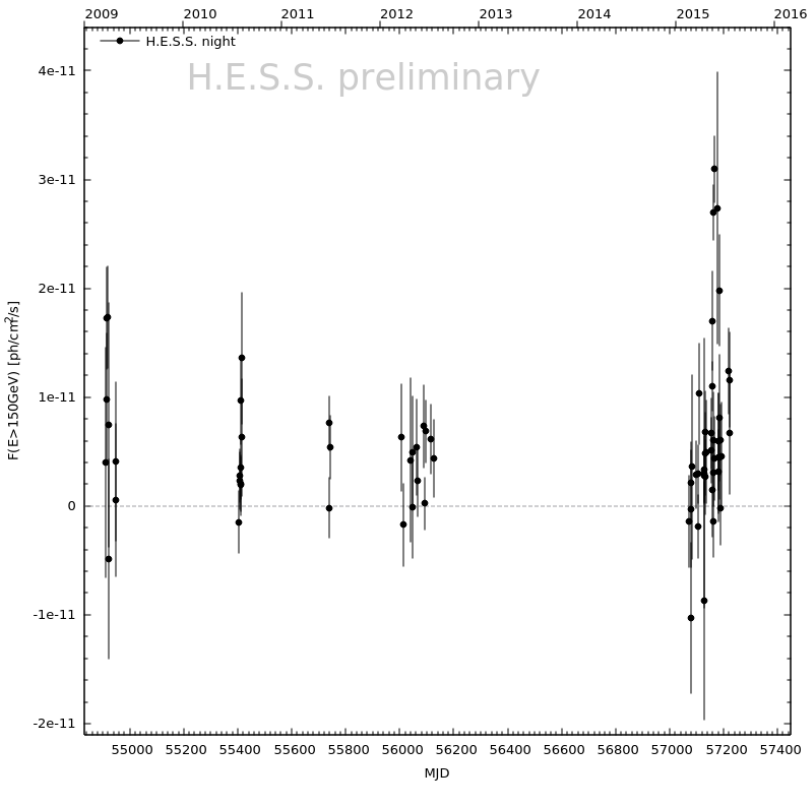
- The quiescent state is characterized by
  - variability, i.e. fluctuations around an average state instead of a real "ground level"
  - multiplicative (self-boosting) processes
- $\Rightarrow$ Variability could be related to accretion disk processes
- Similar trends for the 2006 flare ($\rightarrow$ broken PSD)

PKS 1510-089: Introduction



VHE lightcurve of PKS 1510-089 from 2009 to 2015 (nightly avg)

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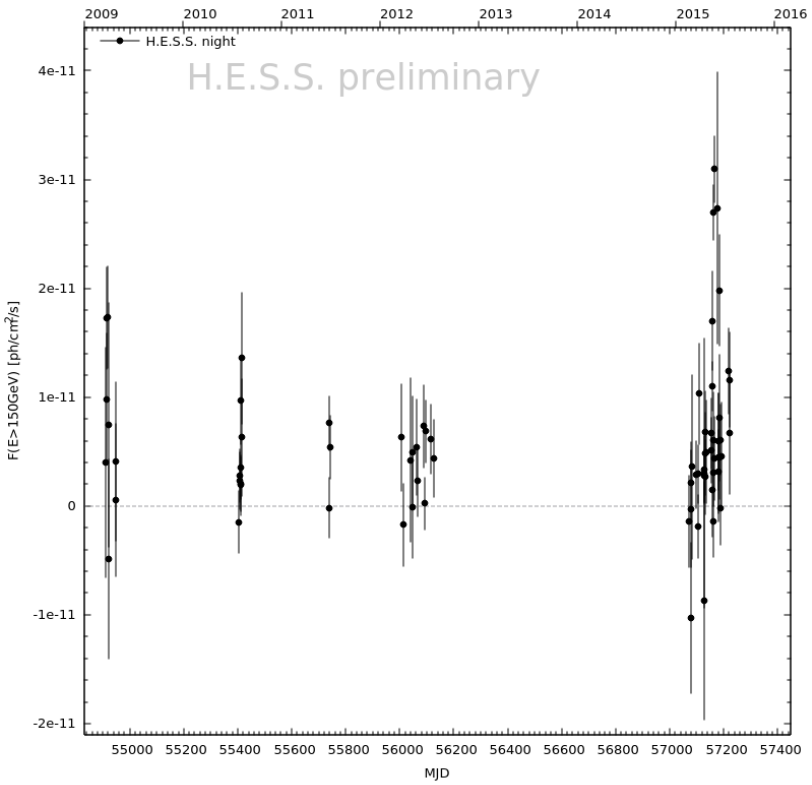

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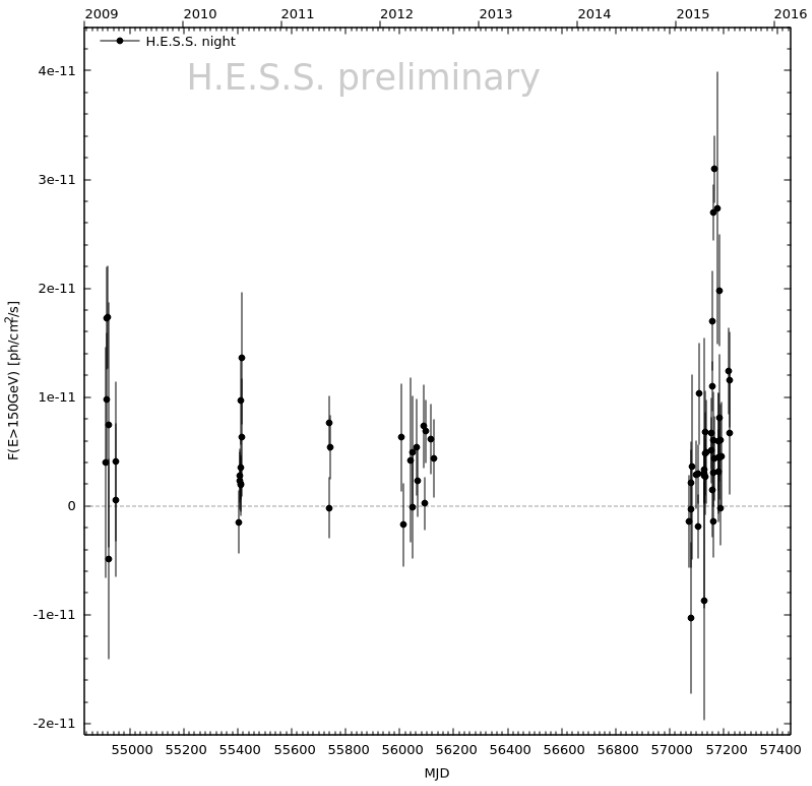

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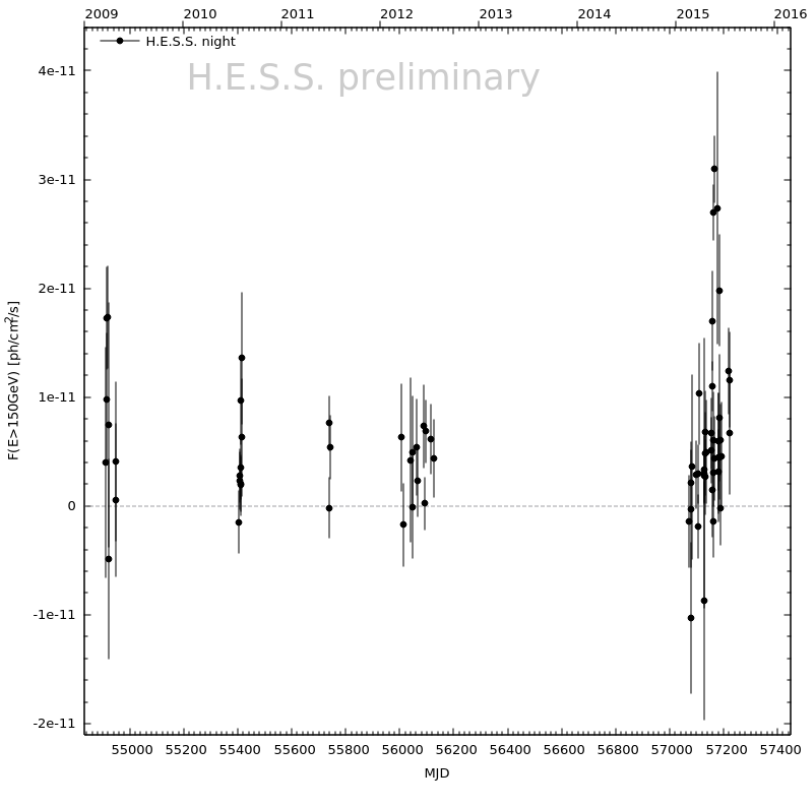

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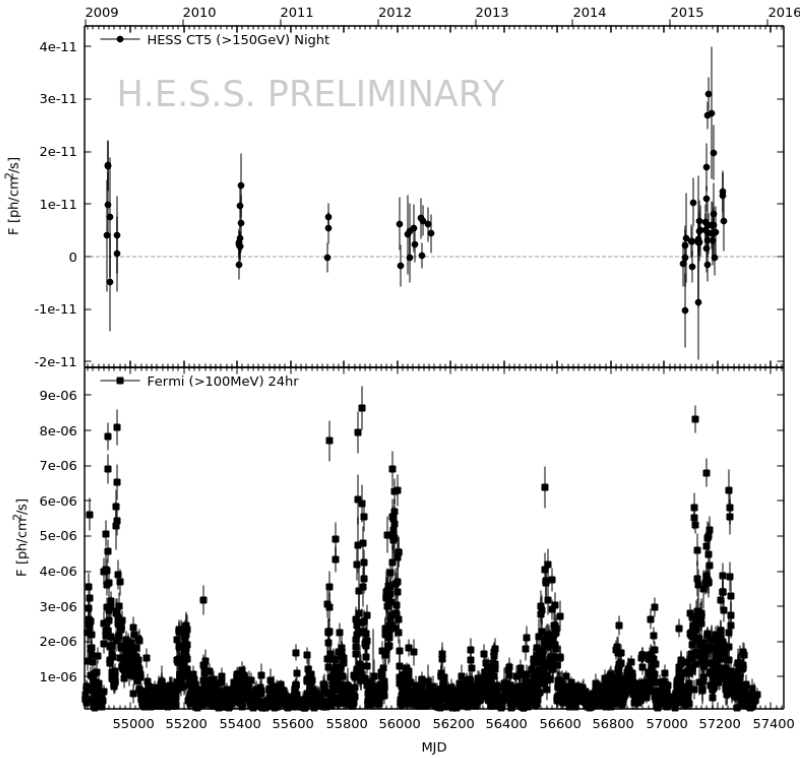

VHE and HE lightcurve of PKS 1510-089 from 2009 to 2015 (nightly avg)

- Strong variability in VHE and HE bands
  - $F_{var}^{VHE} = 1.0 \pm 0.2$
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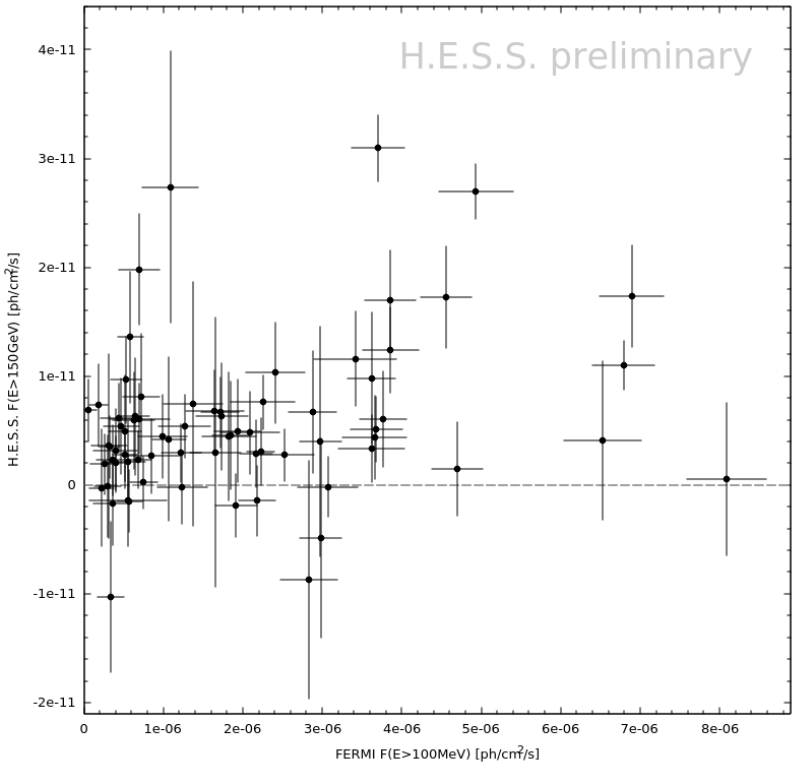

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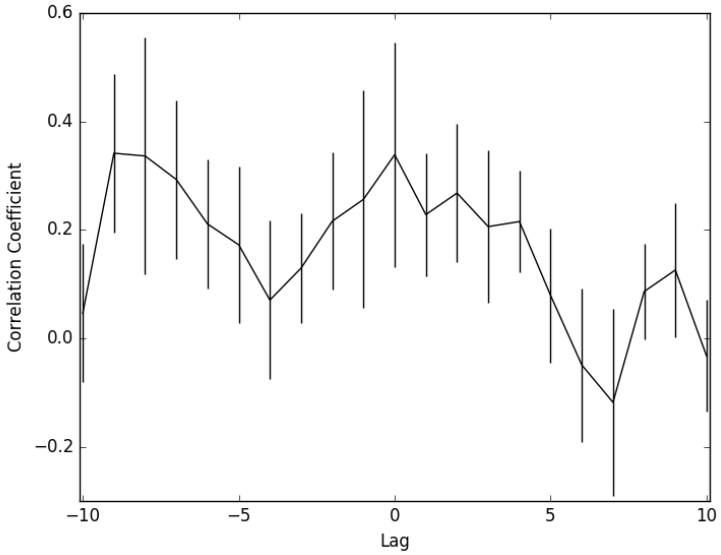

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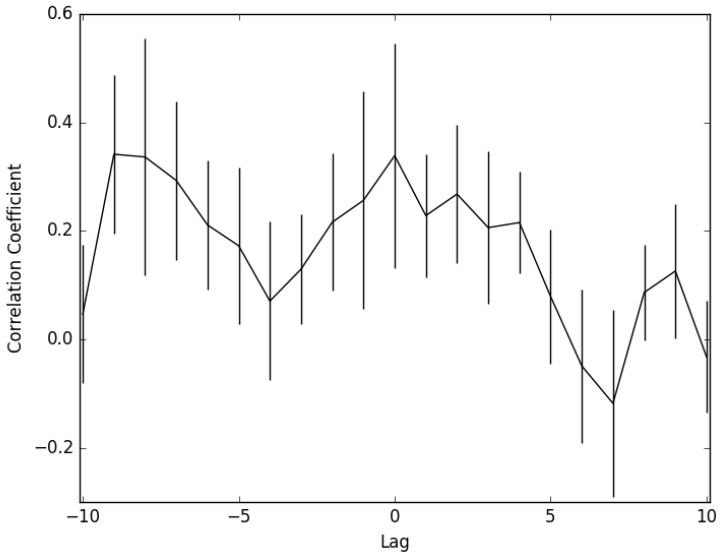

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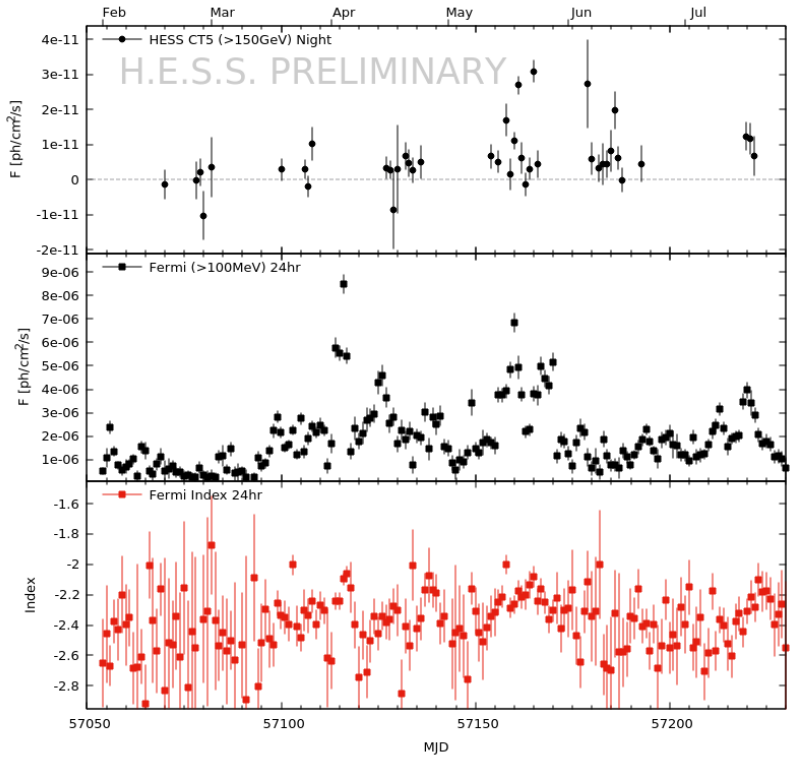
- Disadvantage at VHE: Big gaps in data, Source not easy to detect

PKS 1510-089: Monitoring in 2015



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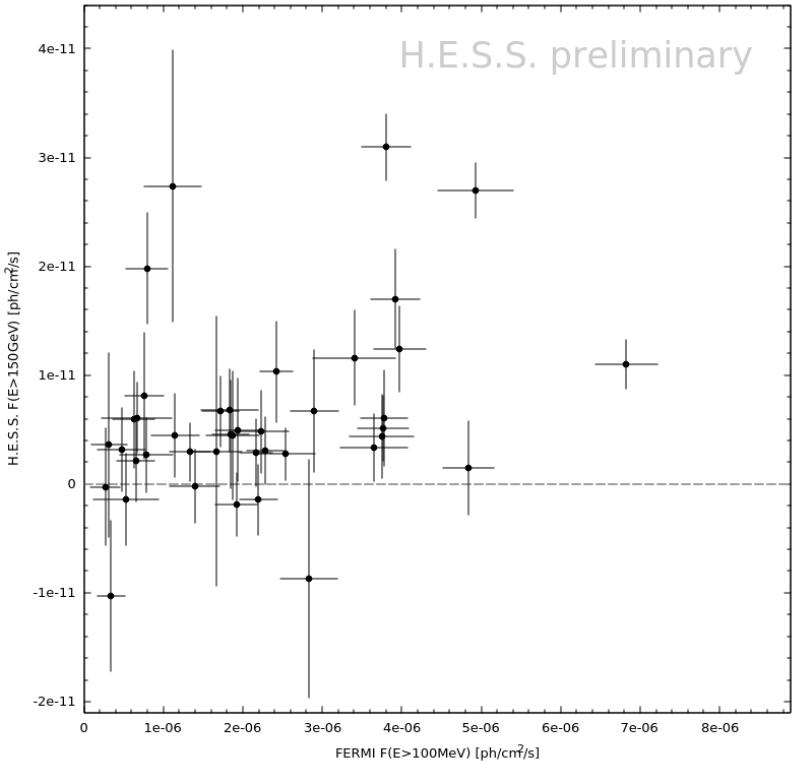

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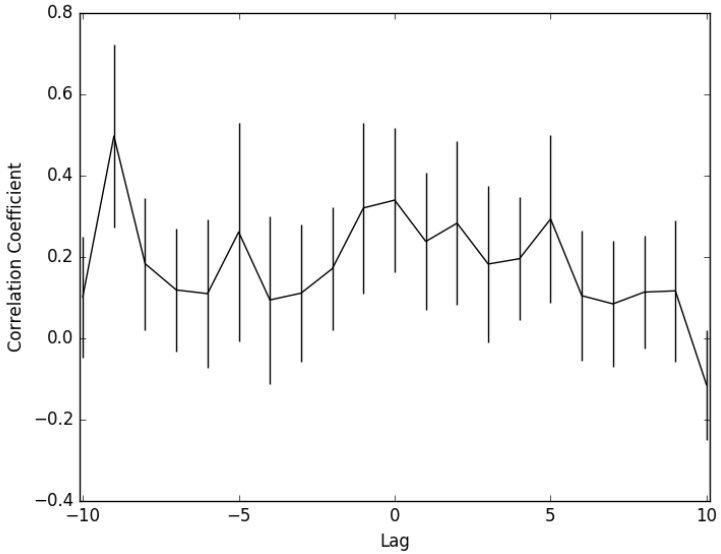

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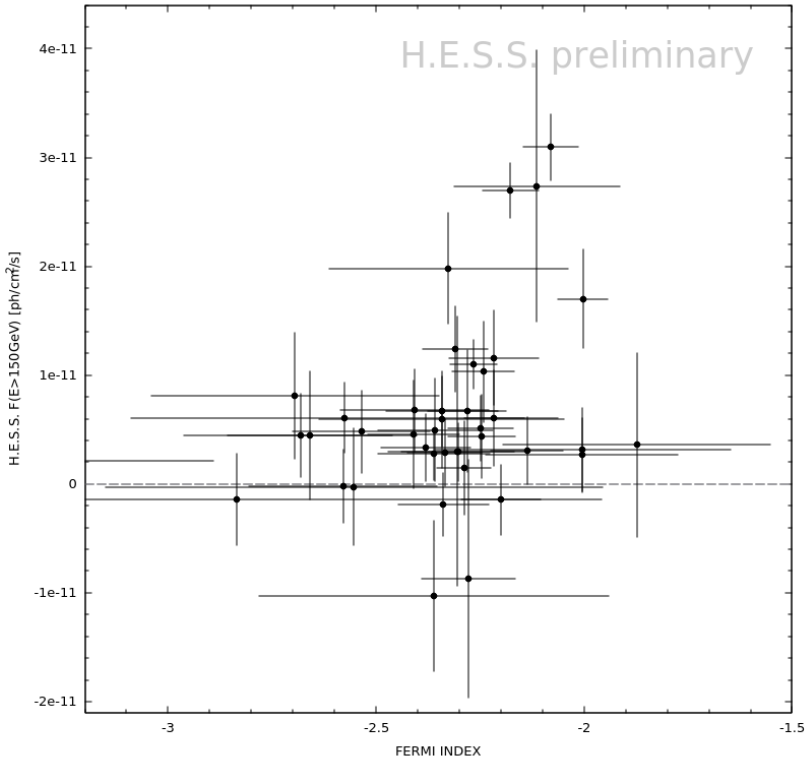

VHE flux vs HE index scatterplot with nightly binning of 2015 data

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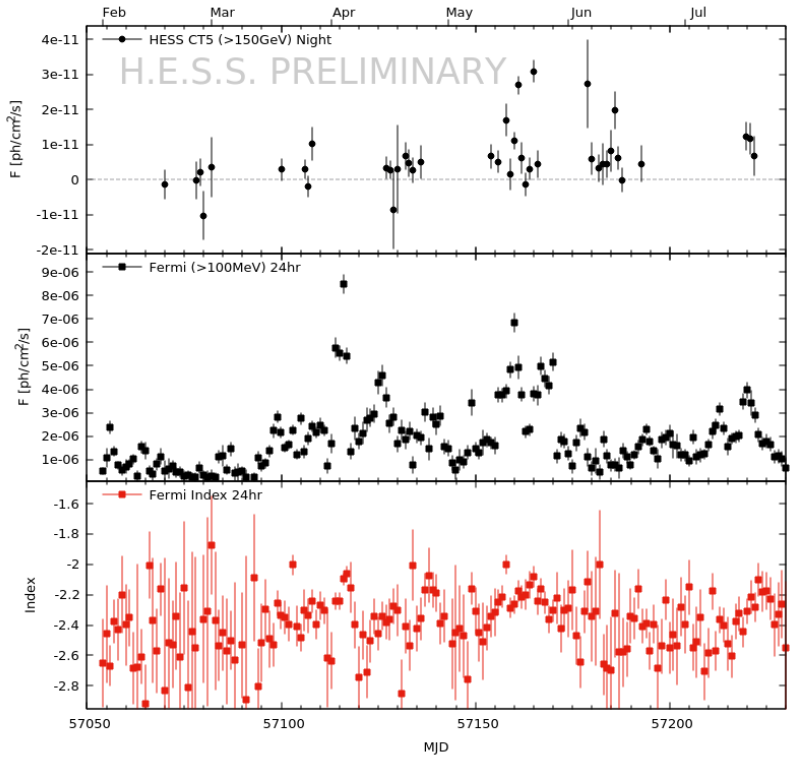
- There seems to be a trend that the HE index is harder for higher VHE flux

PKS 1510-089: Interpretation



VHE and HE lightcurve and HE spectral index evolution of PKS 1510-089 in 2015 (nightly avg)

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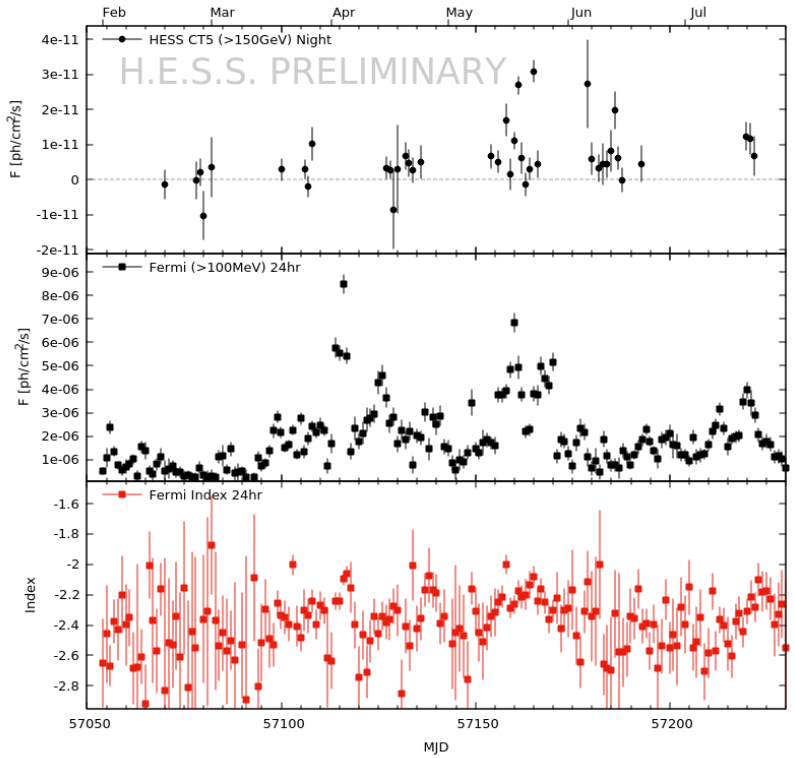

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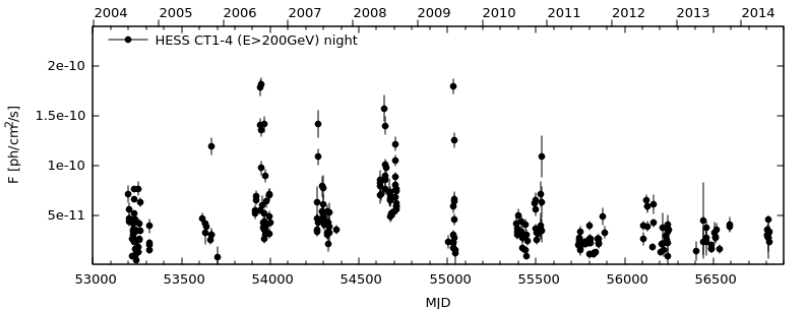
- VHE detection during a flare implies a flaring region at the outer edge or beyond the BLR
- Past behavior resulted already in different interpretations:
  - HE bump a combination of IC/BLR and IC/torus
    (A&A, 567, A113)
  - 2 separate zones necessary
    (ApJ, 760, 69; MNRAS, 431, 824)
  - Modeling required to derive more details
- Log-normality claimed in the optical, X-ray and HE band

(ApJL, 822, L13)

Summary



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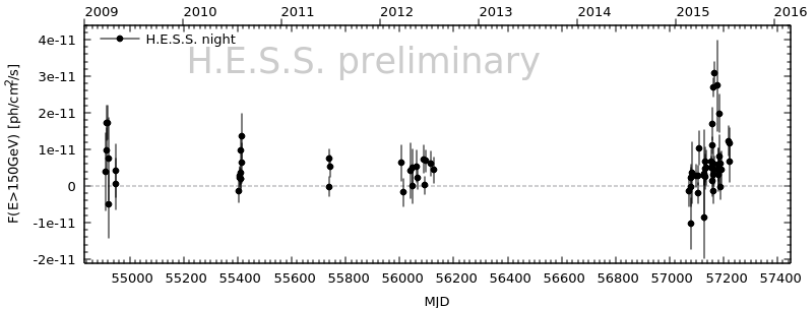

VHE lightcurve of PKS 1510-089 from 2009 to 2015 (nightly avg)

VHE monitoring with H.E.S.S. resulted in several key findings:

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  - Detection of a broken PSD
  - Jet behavior linked to accretion disk processes?

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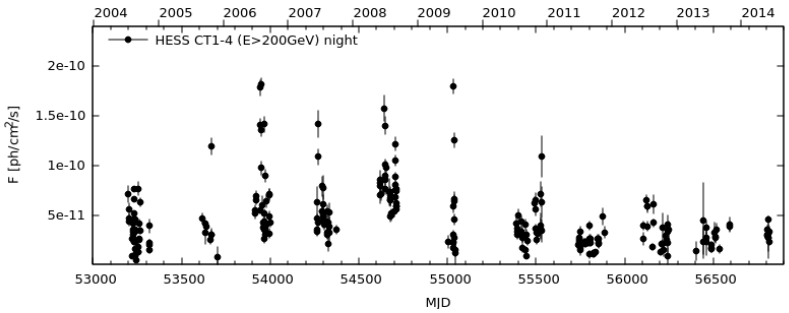

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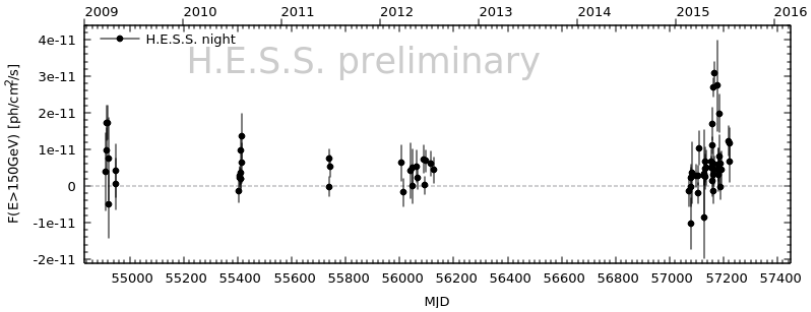

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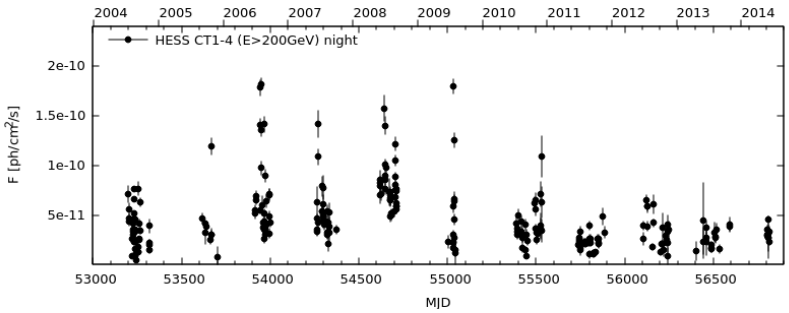

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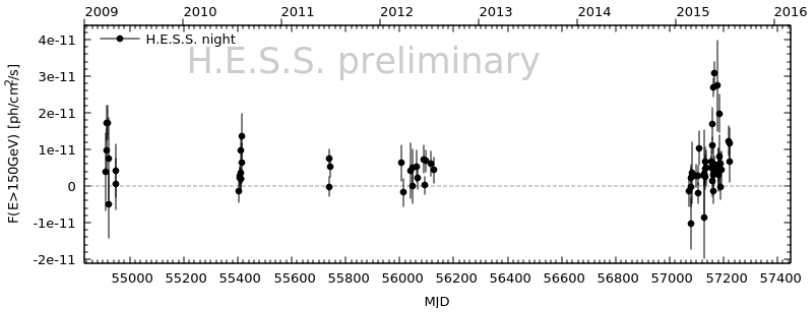

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- Monitoring continues

Summary

Thank You!

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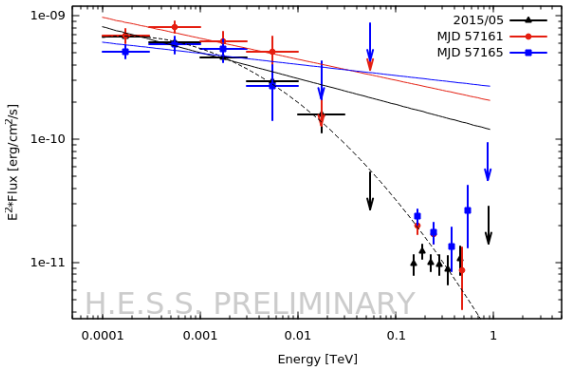
Backup

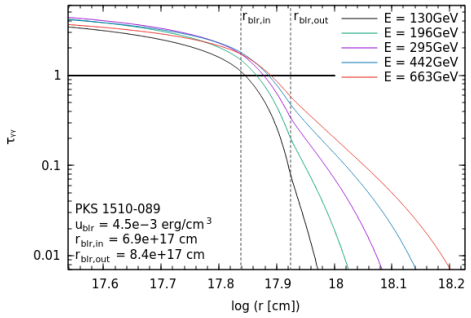
Backup: Equations

- Fractional Variability: $F_{var} = \sqrt{S^2 - \sigma_{err}^2}/\bar{\Phi}$
  S: Variance, σ_{err}: mean error, $\bar{\Phi}$: mean flux
- Excess RMS: $\sigma_{xs} = \sqrt{S^2 - \sigma_{err}^2}$
- Structure Function: $SF(\tau) = (1/N) \sum_{i=1}^{N} [\ln \Phi(t_i) - \ln \Phi(t_i + \tau)]^2$
  for N pairs of times $[t_i, t_i + \tau]$
- Minimum Variability time: $T_{min} = ((\Phi_1 + \Phi_2)/2) \times |t_2 - t_1|/|\Phi_2 - \Phi_1|$

Backup: Absorption in PKS 1510-089



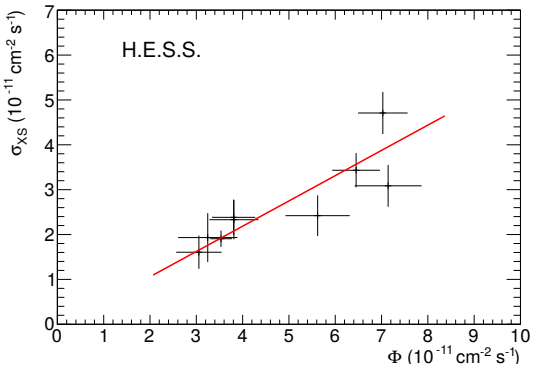
γ-ray spectrum of PKS 1510-089 during the May 2015 flare arXiv:1611.02098



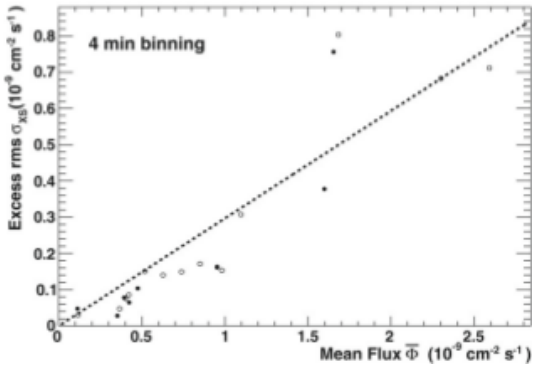
Expected absorption of VHE emission by BLR radiation arXiv:1611.02098

- Fermi spectra compatible with log-parabola
- Fermi extrapolation not compatible with H.E.S.S. spectrum
- Under the assumption that the H.E.S.S. spectral points are the result of an absorbed power-law of the Fermi spectrum, the emission region can be placed within the BLR
- The variability time scale locates the emission region outside the BLR
- Emission region most likely around the edge of the BLR

Backup: The 2006 flare of PKS 2155-304



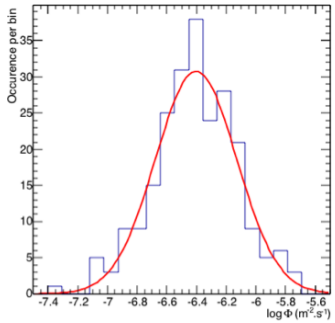
Excess RMS vs flux (20 nights per bin)



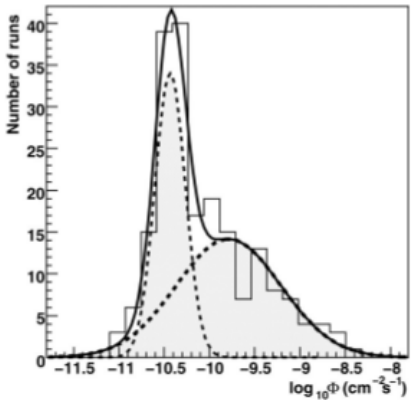
Excess RMS vs flux of the 2006 flare (4min per bin) (A&A, 520, A83)

- Evidence for different excess RMS correlations
  - low: $\sigma_{xs} \sim 0.6\Phi$
  - flare: $\sigma_{xs} \sim 0.3\Phi$

Backup: The 2006 flare of PKS 2155-304



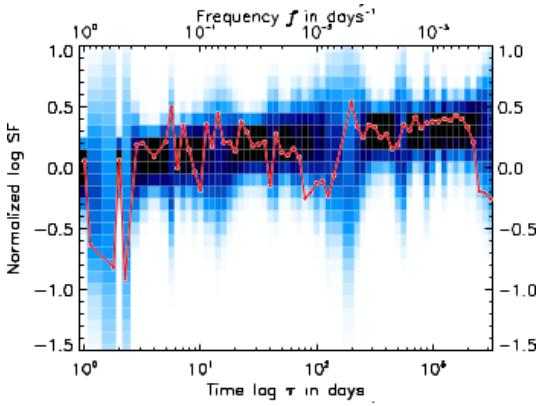
Log-flux distribution (nightly fluxes, excl. 2006 flare)



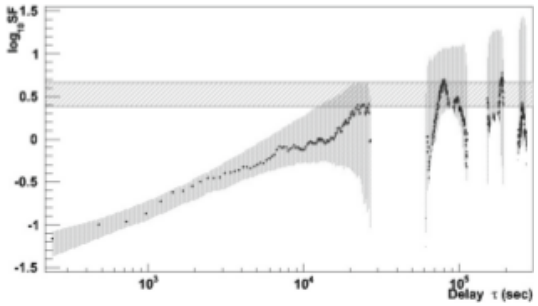
Log-flux distribution (run-wise fluxes, all runs 2005-2007) (A&A, 520, A83)

- Evidence for different excess RMS correlations
  - low: $\sigma_{xs} \sim 0.6\Phi$
  - flare: $\sigma_{xs} \sim 0.3\Phi$
- Evidence for 2 log-normal states

Backup: The 2006 flare of PKS 2155-304



First-Order Structure Function vs. time lag in days (red), Simulation (blue)



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  - low: $\sigma_{xs} \sim 0.6\Phi$
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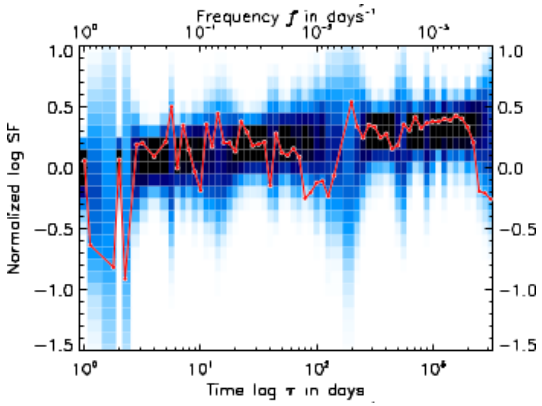
- Evidence for 2 log-normal states
- Evidence for different power-law noise states
  - low: $\beta = 1.10^{+0.10}_{-0.13}$
  - flare: $\beta = 2.0 \pm 0.2$
  - Break time: $3\,\mathrm{hr} < \tau < 20\,\mathrm{hr}$

Backup: The 2006 flare of PKS 2155-304



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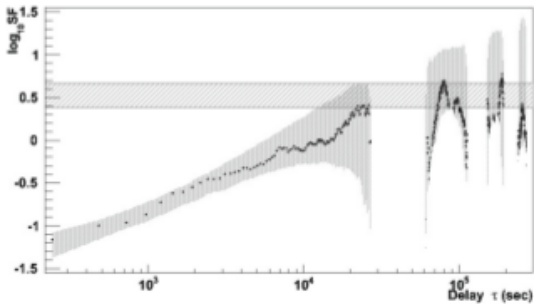

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- Evidence for 2 log-normal states
- Evidence for different power-law noise states
  - low: $\beta = 1.10^{+0.10}_{-0.13}$
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  - Break time: $3\,\mathrm{hr} < \tau < 20\,\mathrm{hr}$
- Interpretation:

  1) Differences are stationary (seen in Seyfert and radio galaxies)

  2) Quiescent and flaring state have different origins
- $\Rightarrow$ Variability could be related to accretion disk processes