Monitoring of PKS 2155-304 and PKS 1510-089 with H.E.S.S.

Alicja Wierzcholska for the H.E.S.S. Collaboration

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High Energy Stereoscopic System

- The High Energy Stereoscopic System (H.E.S.S.) - an array of five Cherenkov telescopes, located in Namibia.
- 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 a 28 m circular dish).
- Since late 2012 observations possible in MONO (CT5) and STEREO (CT1-CT5) mode.
- Observations taken in 28-minutes runs.
- Dedicated to observing very-high-energy γ rays from Galactic and extragalactic targets.

PKS 2155-304

Collaborators: Michael Zacharias, Felix Jankowsky, Stefan Wagner.

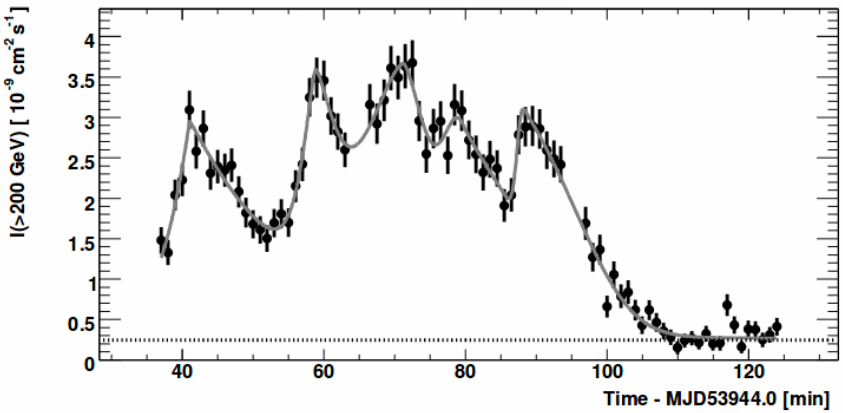
PKS 2155-304: history of the beast

- HBL blazar, located at z=0.117.
- Discovered in the radio frequencies as part of the Parkes survey.
- It was a target of several observational campaigns both in one and multi-energy bands.
- H.E.S.S. observations started in 2002 (in 2004 with four telescopes and in 2012 with five).

PKS 2155-304: VHE monitoring with H.E.S.S.

- **Exceptional flare in 2006 in VHE.**
- Gamma - optical correlation observed in 2008.
- Different activity states observed in the optical range.
- Lognormal behaviour in VHE γ rays in the longterm monitoring.

Details: H.E.S.S. Collaboration (2007), ApJ, 664, L71



- July 28, 2006 (MJD 53944).
- 1-minute bins.
- Five bursts visible.
- $I(>200\,\mathrm{GeV}) = (1.72 \pm 0.05_{stat} \pm 0.34_{syst} \cdot 10^{-9}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ equivalent to 7x $I(>200\,\mathrm{GeV})$ of Crab Nebula.
- $F_{var} = 0.58 \pm 0.03$.

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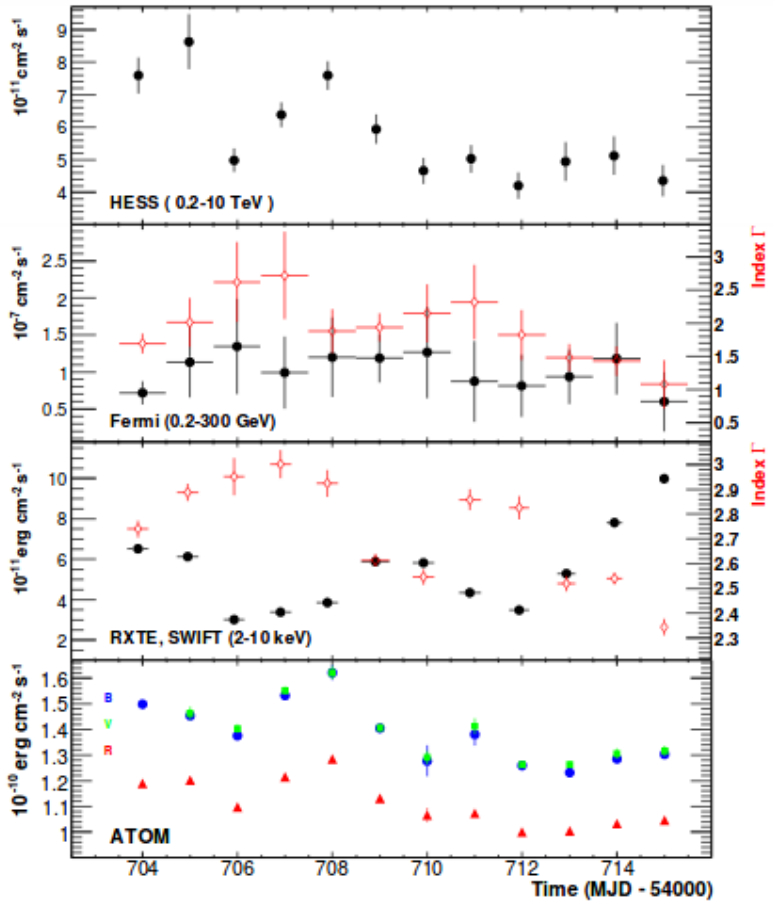

$C = 0.77 - 0.86$

Details: H.E.S.S. Collaboration (2009), ApJ, 696, L150

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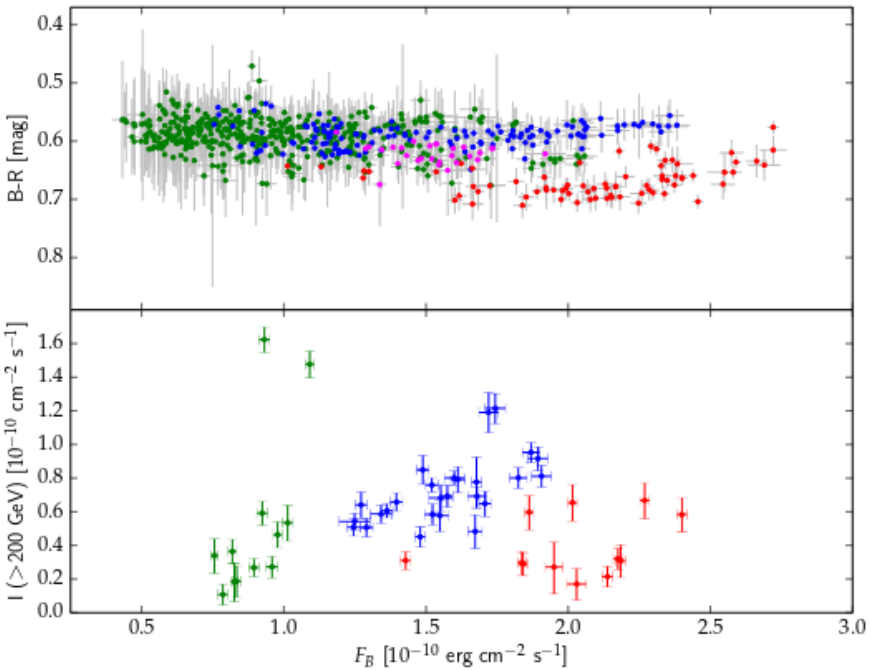
Details: H.E.S.S. Collaboration (2014) A&A, 571, A39



- 2008-2010 observations taken with H.E.S.S. and ATOM.
- Bluer-when-brigther trend is visible in separate branches.
- No clear gamma-optical correlation in short-term observations.

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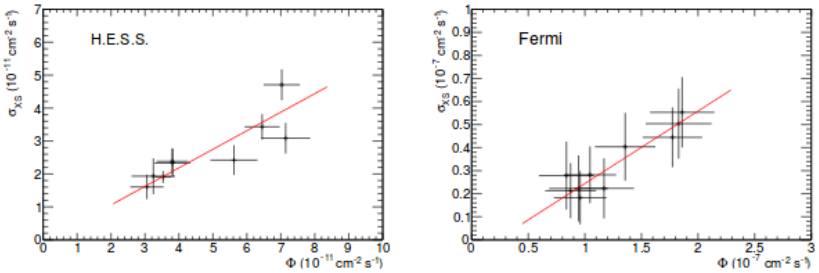
- **Lognormal behaviour in VHE γ rays in the longterm monitoring.**



- 9 years of VHE γ-ray monitoring.
- Long-term γ-ray quiescent state is consistent with a log-normal behaviour.
- Flicker noise behavour observed $\beta_{VHE} = 1.10^{+0.10}_{-0.13}$ and $\beta_{HE} = 1.20^{+0.21}_{-0.23}$.

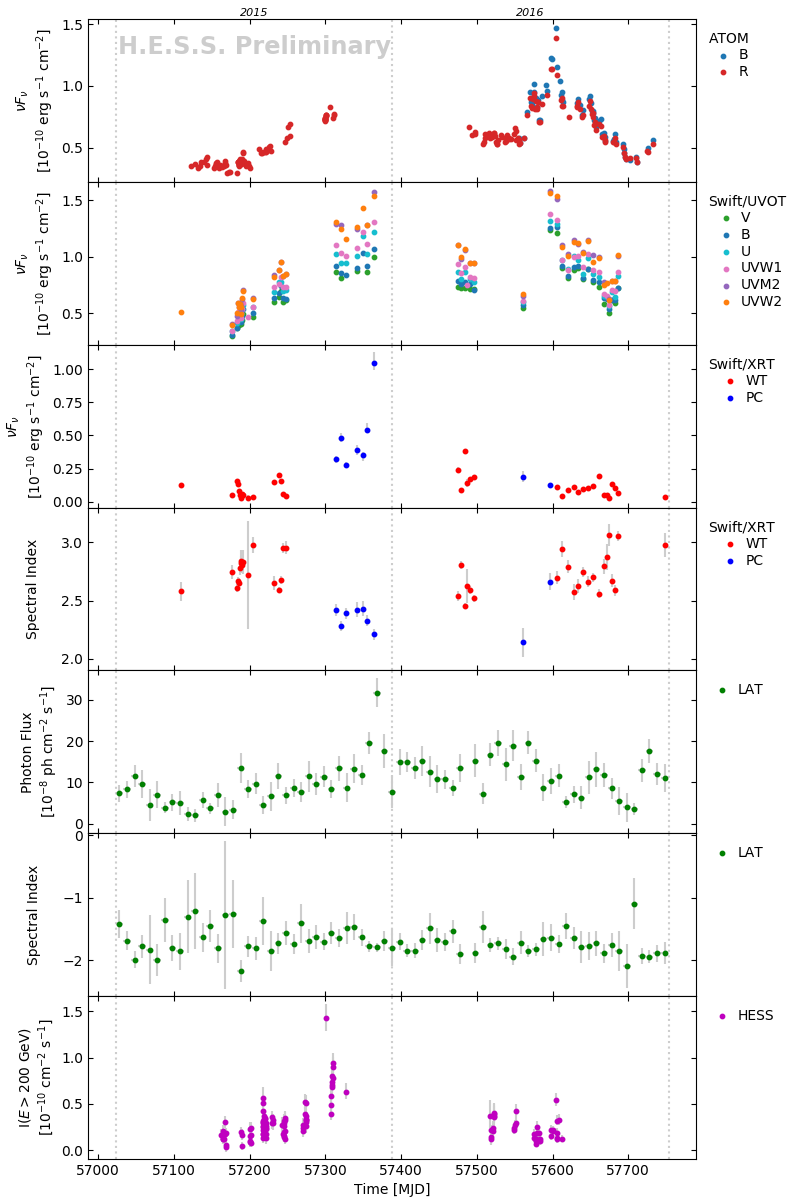
Details: H.E.S.S. Collaboration (2017) A&A, 598, A39

H.E.S.S. monitoring in 2015-2016

- Regularly monitored both in 2015 and 2016 with H.E.S.S.
- MWL support thanks to Fermi-LAT, Swift-XRT, Swift-UVOT, ATOM.
- H.E.S.S. stereo (CT1-CT5) observations include 91 runs in 2015 and 40 in 2016.

	2015	**2016**
Livetime	36	16.5
Significance [σ]	59.8	36.4
Excess	3284	1212

MWL light curve



- Variability patterns observed at all wavelengths (both is flux and photon index).
- VHE flare in 2015 corresponds to the 3x quiescent state in PKS 2155-304.
- Orphan optical outburst in 2016.

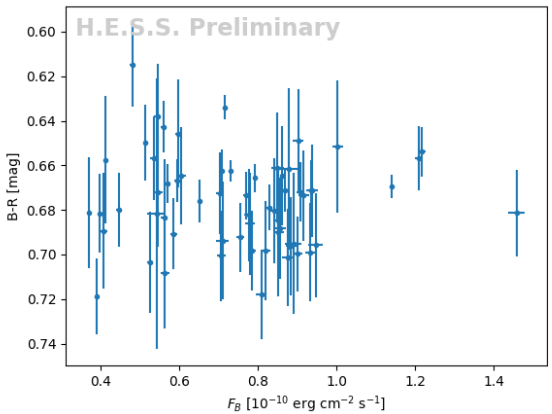
MWL variability

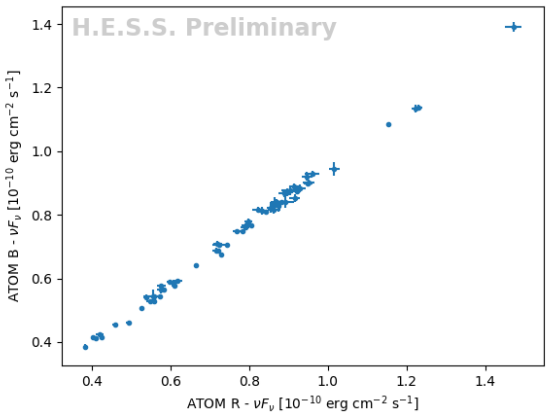
Instrument	$\mathbf{F}_{var,2015}$	$\mathbf{F}_{var,2016}$
H.E.S.S.	0.68±0.02	0.38±0.05
LAT	0.53±0.05	0.25±0.05
XRT	1.14±0.03	0.62±0.02
UVOT (B)	0.354±0.005	0.234±0.004
ATOM (R)	0.322±0.001	0.29±0.01

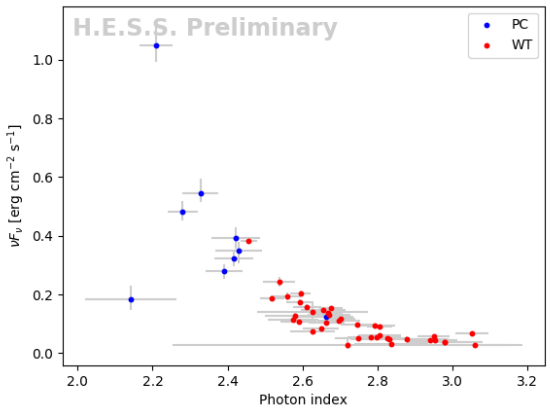
$$F_{var} = \frac{\sqrt{S^2 - \sigma_{err}^2}}{< F >}, \quad (1)$$

where $< F >$ is an average flux, S^2 is the variance, and σ_{err}^2 is the mean square error;

Flux vs index





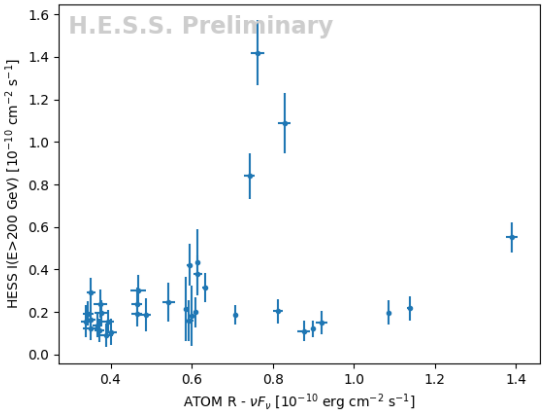


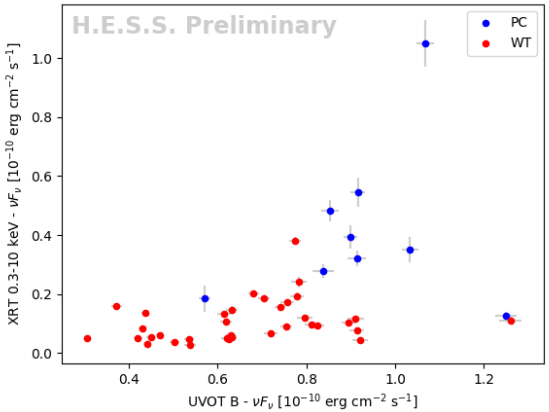
$C_{B-R,B} = 0.03 \longrightarrow$ **NO** bluer-when-brigther

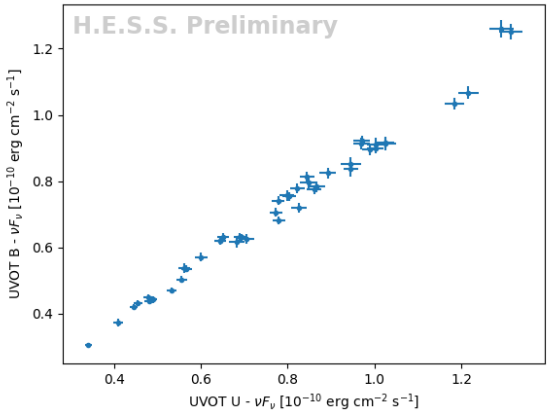
$C_{B,R} = 0.98 \pm <0.01$

$C_{XRT} = -0.75 \pm 0.05 \longrightarrow$ harder-when-brigther

MWL correlations







$C_{R,VHE} = 0.31$

$C_{B,XRT} = 0.45$

$C_{U,B} = 0.99 \pm <0.01$

MWL correlations: summary

- Harder-when-brighter trend is present in the X-ray data.
- Optical and UV data are well correlated (for all cases: ATOM vs ATOM, UVOT vs UVOT, ATOM vs UVOT).
- No global relation for other wavelengths.

PKS 1510-089

Collaborators: **Michael Zacharias (PI)**, Felix Jankowsky, Stefan Wagner,

David Sanchez, Mahmoud Mohamed.

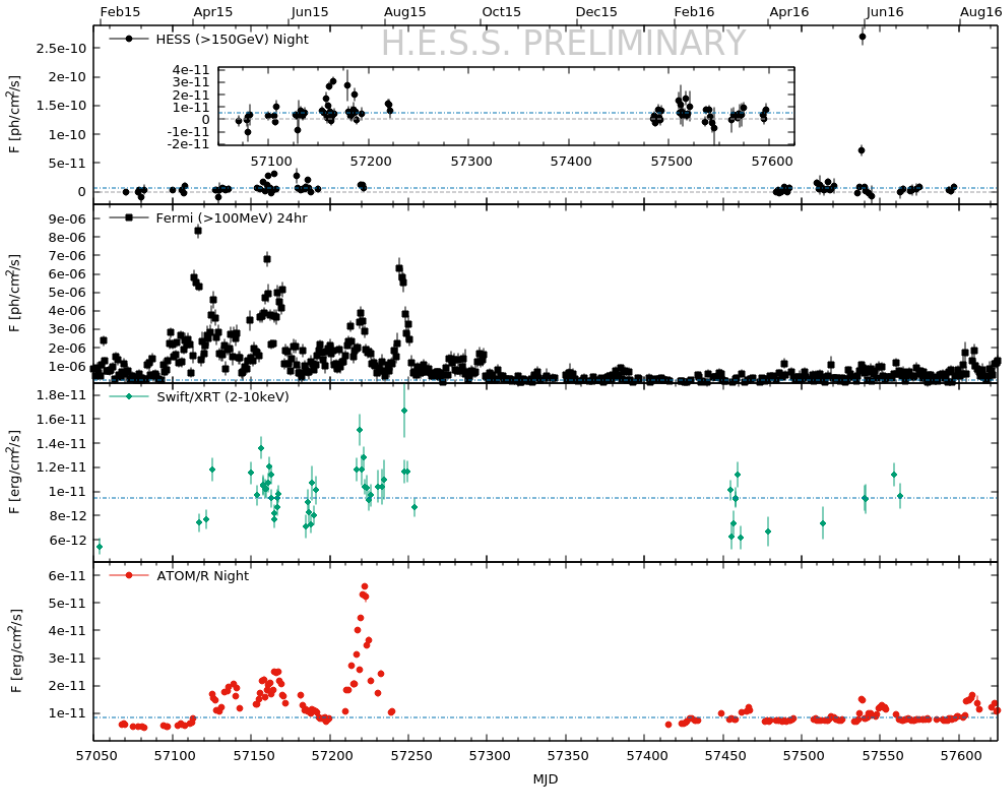
PKS 1510-089

- Detected in TeV energies as second FSRQ.
- Known for a complex multiwavelength behavior - single zone models do not work.
- The emission region is expected to be located beyond the BLR.
- MWL observations and variability studies are essential for a deeper understanding of emission observed.

H.E.S.S. observations of PKS 1510-089

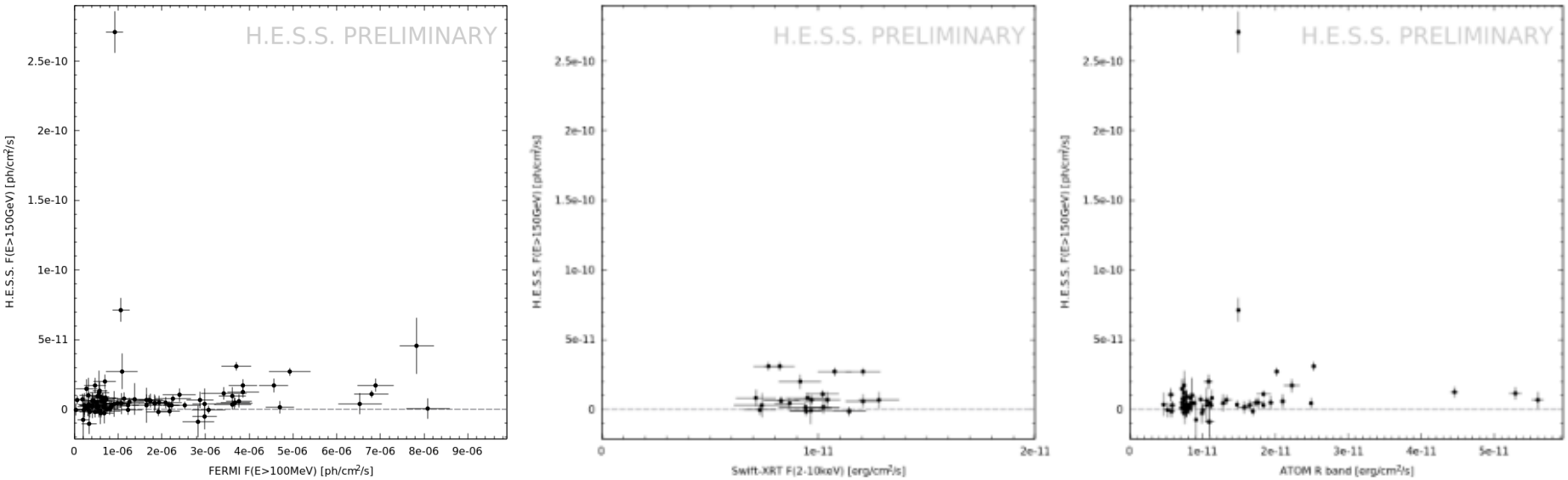
- Regularly observed with H.E.S.S. between 2009-2012.
- Intensive observations started in 2015.
- The 2015 data has been taken with the large telescope in monoscopic mode (total observation time: 66.8 hrs).
- The 2016 data has been taken with the full array (total observation time: 33.3 hrs).

PKS 1510-089 in 2015-2016



- For H.E.S.S.
  $F_{var} = 3.3 \pm 0.1$
- For LAT:
  $F_{var} = 1.11 \pm 0.01$
- For XRT:
  $F_{var} = 0.19 \pm 0.01$
- For ATOM:
  $F_{var} = 0.679 \pm 0.002$

MWL correlations



No clear relation between VHE γ rays and other wavelengths.

Summary

- MWL Monitoring: key tool to investigate variability behaviour in blazars and search for unique events.
- Both, PKS 2155-304 and PKS 1510-089, are highly variable blazars at all wavebands studied.
- For 2015-2016 data sets there is no correlation between VHE to other bands.
- For both, PKS 2155-304 and PKS 1510-089, each flare is characterized with different MWL properties.

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