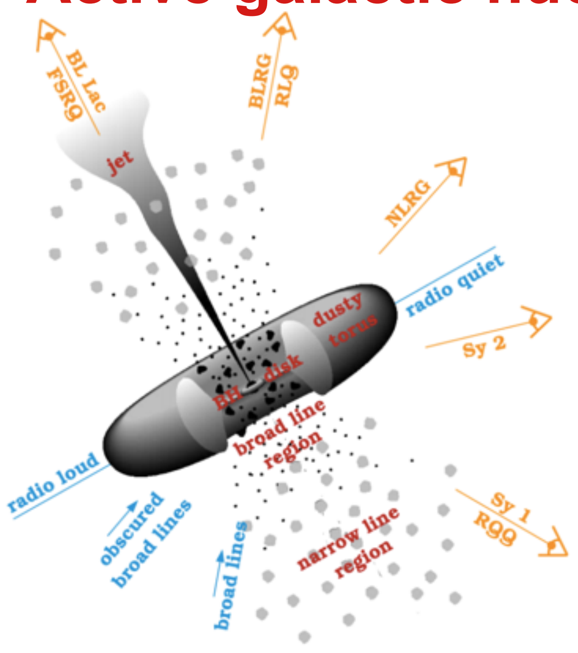
# Long term variability of the blazar PKS 2155-304

Jill Chevalier*[1]
Max Anton Kastendieck[2]
Frank Rieger[3]
Gilles Maurin[1]
Jean-Philippe Lenain[4]
Giovanni Lamanna[1]
for the H.E.S.S. Collaboration

* jilll.chevalier@lapp.in2p3.fr
1 Laboratoire d'Annecy-le-Vieux de Physique des Particules, Université Savoie Mont-Blanc, CNRS/IN2P3, F-74941 Annecy-le-Vieux, France
2 Universität Hamburg, Institut für Experimentalphysik, Luruper Chaussee 149, D 22761 Hamburg, Germany
3 Max-Planck-Institut für Kernphysik, P.O. Box 103980, D 69029 Heidelberg, Germany
4 LPNHE, Université Pierre et Marie Curie Paris 6, Université Denis Diderot Paris 7, CNRS/IN2P3, 4 Place Jussieu, F-75252, Paris Cedex 5, France

## Active galactic nuclei and blazars

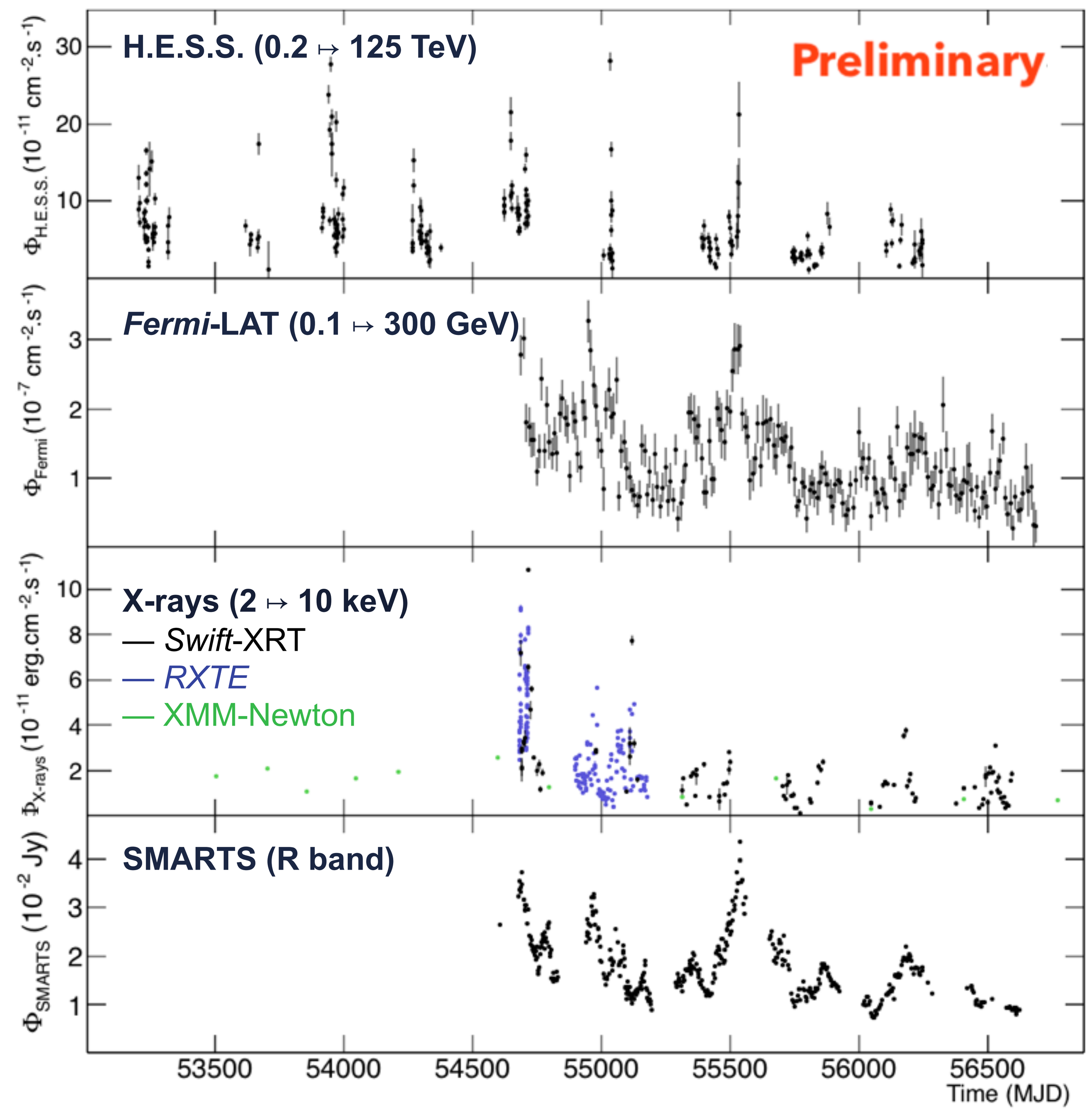


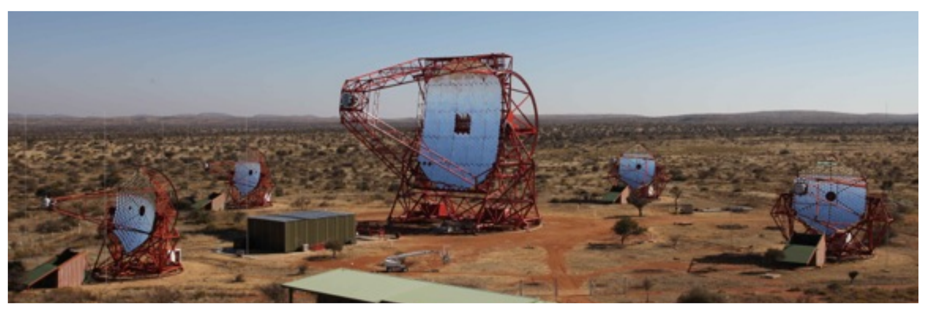

Active galactic nuclei (AGN) standard paradigm:
- supermassive black hole at the center;
- accretion disk and dust torus;
- relativistic jet.

Blazars are active galactic nuclei (AGN) with a boosted emission due to the alignement of the jet with the line of sight. They are strong gamma-ray sources which happen to be variable from radio to TeV.

Blazars can be separated into 2 sub-classes:
- Flat Spectrum Radio Quasars (FRSQ): more luminous with strong emission lines;
- BL Lac: less luminous but emitting at higher energies with weak emission lines.

- PKS 2155-304 (z = 0.116) is a high frequency peaked BL Lac (HBL) type source, one of the brightest blazar in the γ-ray sky. Its variability can be seen over the whole energy range, from radio to TeV.
- Characterizing time variability of the photon flux allows to :
  - distinguish between different acceleration and emission models (such as leptonic versus hadronic);
  - study extreme physical processes occurring in blazars;
  - study connections between the jet, the black hole and the disk.
- The present work aims to characterize the long term variability of the quiescent state of PKS 2155-304 using multi-wavelength (MLW) data. Therefore, all Target of Opportunities observations

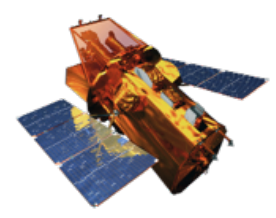


**H.E.S.S.** The High Energy Stereoscopic System is a Imagering Atmospheric Cherenkov Telescopes (IACT) investigating γ-rays from a few 10 GeV to >10 TeV.

***Fermi*-LAT** The *Fermi* Large Area Telescope is a pair conversion telescope designed to detect γ-rays from ~20 MeV to more than 300 GeV.

**SMARTS** The Small and Moderate Aperture Research Telescope System are 4 1-meter telescopes looking at optical photons.



***Swift*-XRT** The *Swift* X-ray Telescope is a NASA telescope firstly designed to observe GRB from 0.3 to 10 keV.

***RXTE*** The *Rossi X-ray Timing Explorer* was a NASA telescope meant to explore variability of X-ray sources from 2 to 10 keV.

**XMM-Newton** The X-ray Multi-Mirror Mission is an ESA telescope to monitor X-ray sources from 0.3 to 10 keV.

## Lognormality of the quiescent state of PKS 2155-304

**What is lognormality?** Lognormality appears in non-linear processes. The distribution of the physical quantity (here the flux Φ) doesn't follow a Gaussian but its logarithm does. This effect leads to flux variations proportional/ correlated to the flux itself.

Summary of the results of a Gaussian fit for the flux and the log flux distributions : lognormality is preferred to simple normality.

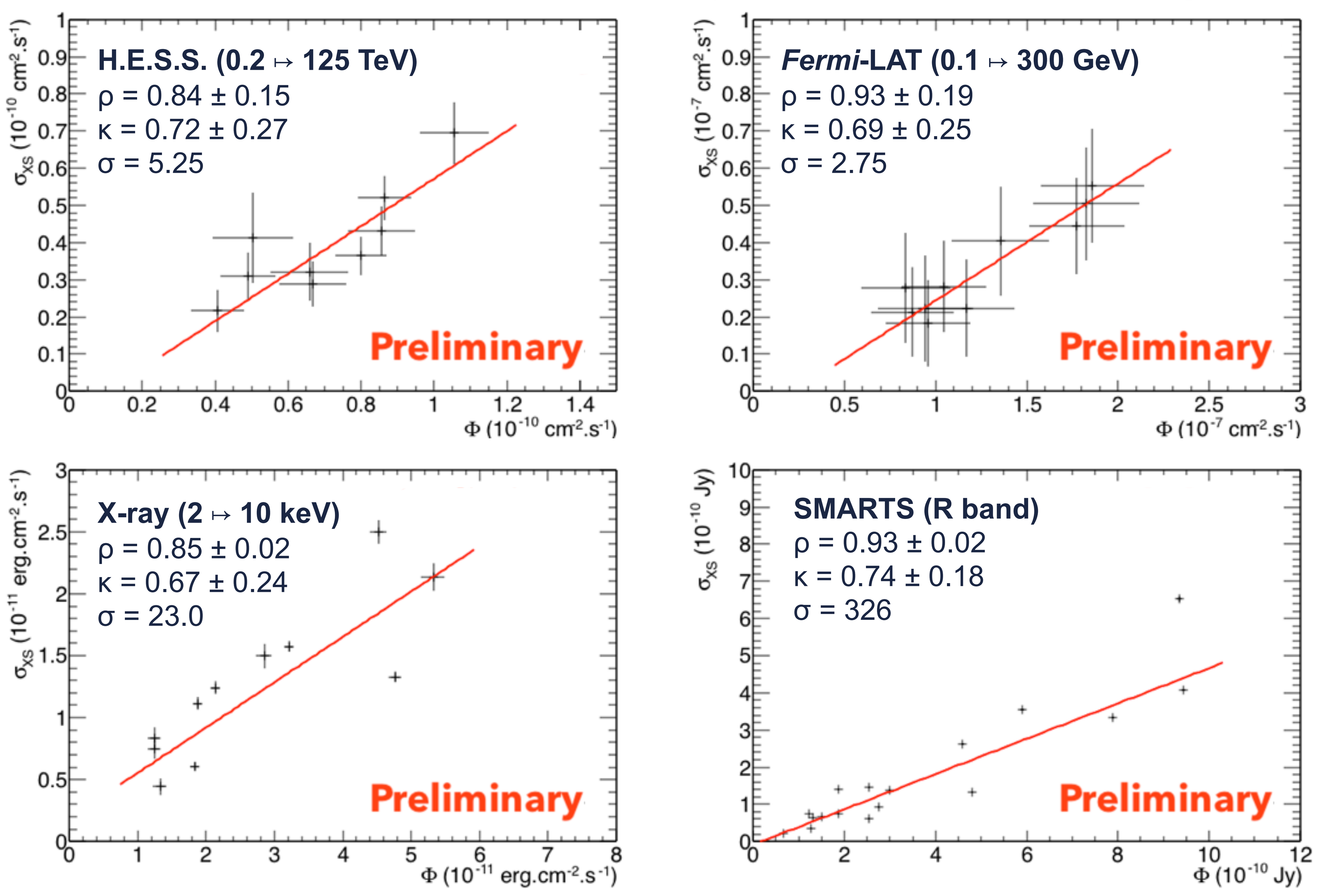
| | Φ | | log Φ | |
|---|---|---|---|---|
| | Chi2/dof | Prob | Chi2/dof | Prob |
| H.E.S.S. | 2.71 | $10^{-4}$ | 0.716 | 0.75 |
| *Fermi*-LAT | 2.51 | $10^{-3}$ | 1.36 | 0.18 |
| X-ray | 6.67 | $10^{-10}$ | 1.36 | 0.20 |
| SMARTS (R) | 5.42 | $10^{-9}$ | 0.823 | 0.62 |

"Intrinsic" excess variance — Mean square error of a bin of light curve — Variance of a light curve bin

$$\sigma_{XS}^2 = S^2 - \overline{\sigma_{err}^2}$$

Scatter plot of $\sigma_{XS}$ (Vaughan et al. 2003) versus mean flux : a correlation is found in each light curve

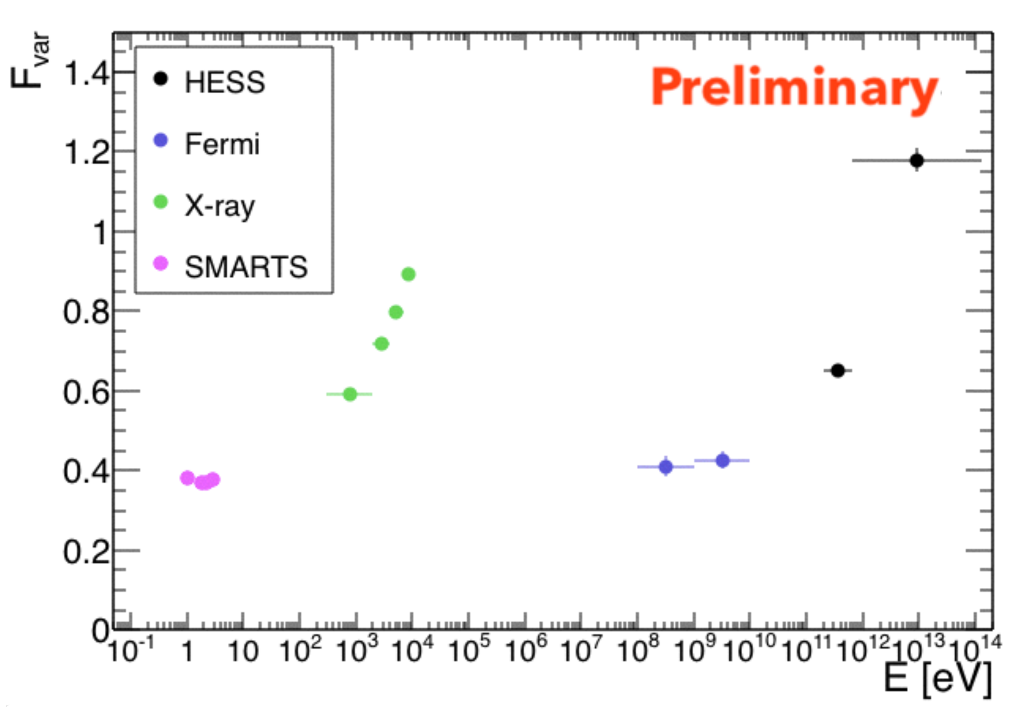
ρ: correlation factor, κ: Kendall, σ:significance




## Variability energy distribution (VED): $F_{var}(E)$

$$F_{var} = \sqrt{\frac{S^2 - \overline{\sigma_{err}^2}}{\bar{\Phi}^2}}$$

$F_{var}$ (Vaughan et al. 2003) is used to quantify the variability of the quiescent state of PKS 2155-304, it can be read as a normalized standard deviation of the light curve with correction from the error measurements.




- The variability increases in the X-ray and H.E.S.S. ranges and looks slightly constant for SMARTS and *Fermi*-LAT.
- In an SSC model of HBL, the optical+X-ray part of the SED (spectral energy distribution) is Synchrotron emission while the γ-ray part is Inverse Compton (IC). Here the same variability behavior seems to happen both in Synchrotron and IC domains.

## Conclusions/Discussion

- Lognormal behavior was first found in X-ray binaries, linking lognormality to accretion disk (Uttley & McHardy 2001). It was already found for:
  - the flaring state of PKS 2155-304 of 2006 in TeV (H.E.S.S. Collaboration 2010)
  - BL Lacertae in X-ray (Giebels & Degrange 2009)
  - Markarian 501 in TeV (Chakraborty et al. 2015)
  - the Seyfert 1 galaxy IRAS 13 244-3809 in X-ray (Gaskell 2004)
- Lognormality seems to be an intrinsic characteristic of PKS 2155-304 as it can be seen at least in TeV, in X-ray and for the first time in optical.
- The variability appears not to be the same in each probed energy ranges. The shape of the VED is important to help distinguishing between different blazars/ emission models.
- Next steps : correlation between the MWL light curves and modeling of the VED using a dynamic Synchrotron Self Compton (SSC) model.

The support of the Namibian authorities and of the University of Namibia in facilitating the construction and operation of H.E.S.S. is gratefully acknowledged, as is the support by the German Ministry for Education and Research (BMBF), the Max Planck Society, the German Research Foundation (DFG), the French Ministry for Research, the CNRS-IN2P3 and the Astroparticle Interdisciplinary Programme of the CNRS, the U.K. Science and Technology Facilities Council (STFC), the IPNP of the Charles University, the Czech Science Foundation, the Polish Ministry of Science and Higher Education, the South African Department of Science and Technology and National Research Foundation, and by the University of Namibia. We appreciate the excellent work of the technical support staff in Berlin, Durham, Hamburg, Heidelberg, Palaiseau, Paris, Saclay, and in Namibia in the construction and operation of the equipment.

lapp — CNRS — Université Savoie Mont Blanc — H.E.S.S.