Analysis methods for variable sources and application to H.E.S.S. data

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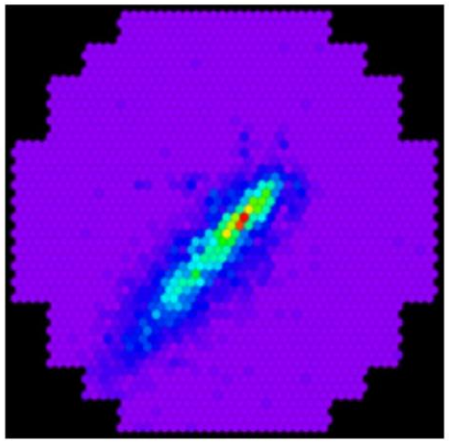
The H.E.S.S. Telescopes

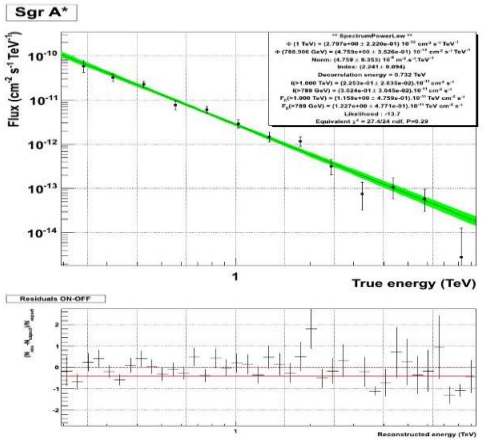
High **E**nergy **S**tereoscopic **S**ystem

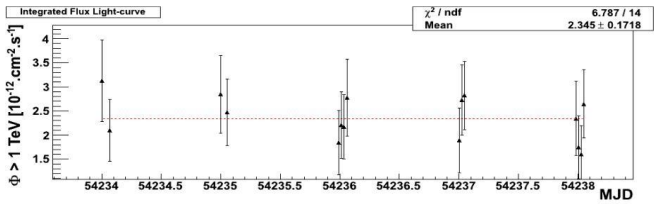
- System of 5 **I**maging **A**tmospheric **C**herenkov **T**elescopes (IACTs)
- Located on Farm Göllschau, Khoma Highland in Namibia
- 4 Telescopes with 12m mirror diameter arranged in a rectangle
- 1 Telescope with 28m mirror diameter in the middle
- Designed to detect cosmic gamma rays in the energy range of 30GeV to 100TeV

Measurements with H.E.S.S.

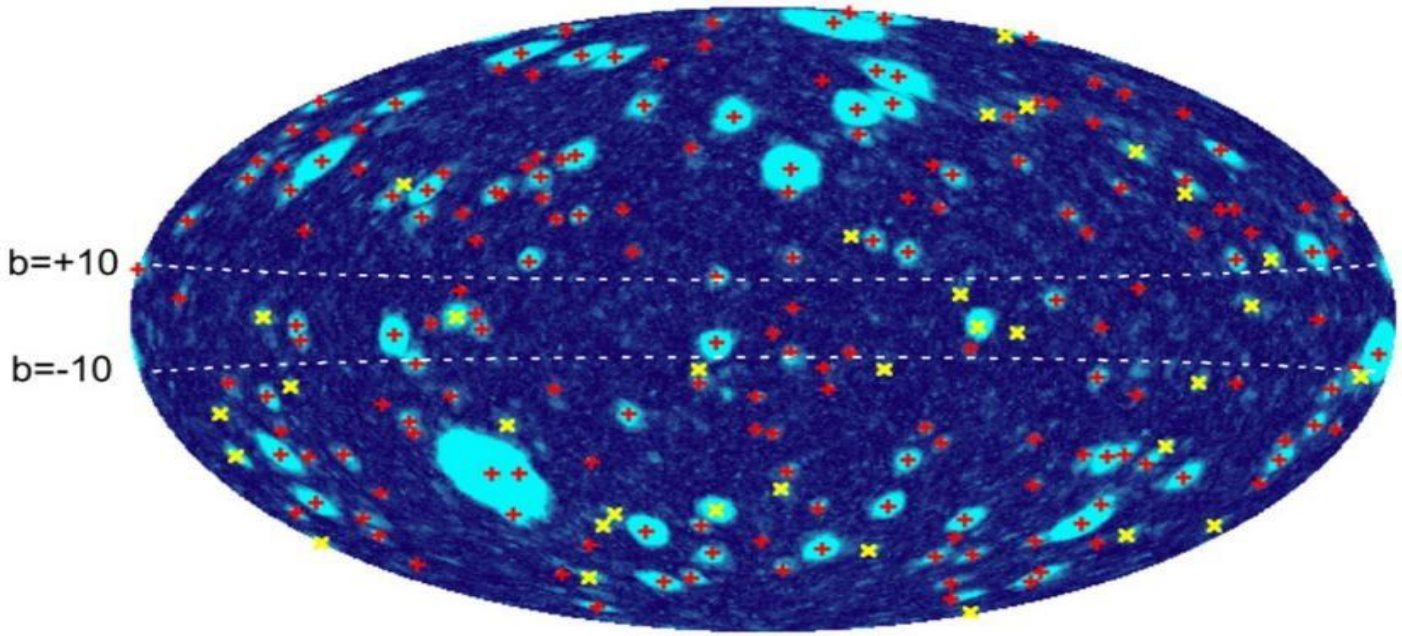
- Typical Cherekov signatures give us information about energy and direction of the primary particle
  - ➢Energy spectrum
  - ➢Lightcurve







Transient Sources



Variable sources shown in Galactic coordinates during 47 month of Fermi observations

(The Fermi All-Sky Variability Analysis: A List of flaring Gamma-ray sources and the search for Transients in our galaxy,

M. Ackermann, et al. 2013

arXiv:1304.6083)

Investigation of Transient Sources

- Binaries, Gamma Ray Bursts, Crab Flares….
- Might have occurred without being detected
  - Besides a precise hardware performance a sensitive analysis method is needed
- Development and implementation of the **Transient Analysis** in the H.E.S.S. Model++ Analysis Software

(Francois Brun – Rechercher de sources ténues ou transitoires dans les régions centrales de la Galaxie avec H.E.S.S., Thèse de Doctorat, Sept. 2011)

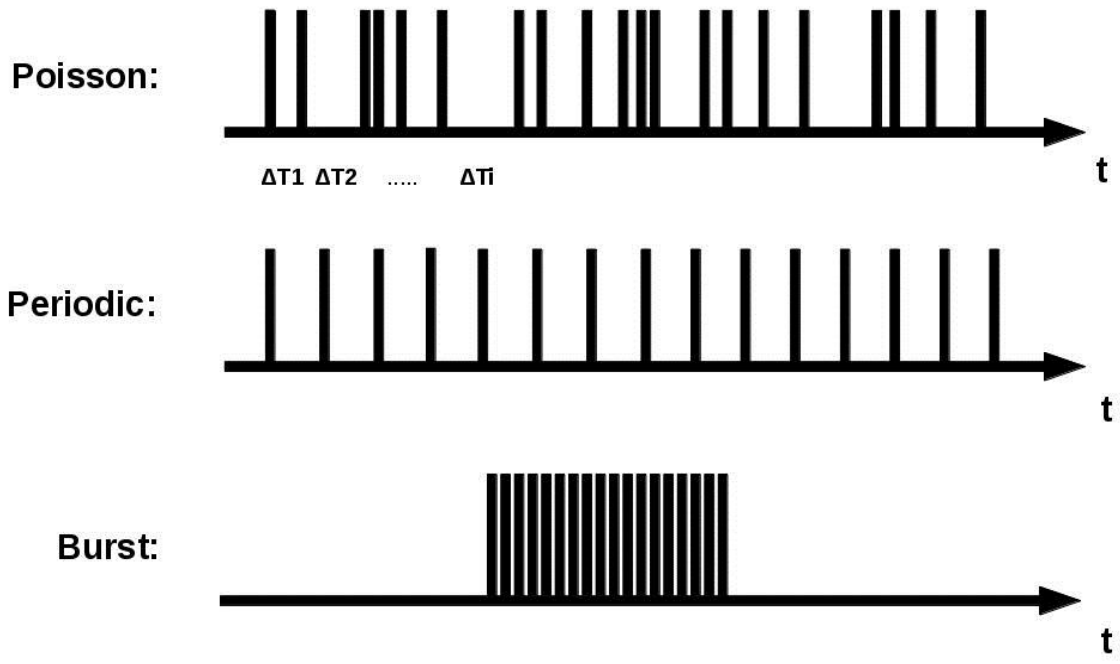
What do we analyse?

- Taking data from a transient source, for example **PKS 2155-304**, one of the brightest active galaxies in the sky

  (**flares in 2006&2007**)
- Performing the basic analysis chain: background subtraction, energy cuts…..
- To use the Transient Analysis we are basically interested in the **arrival times** of gamma events an the **time intervalls** between two events

ExpTest

(A fast unbinned test on event clustering Poisson processes, J.Prahl, 1999, arXiv:astro-ph/9909399)



ExpTest

- Consideration of the time intervals between 2 gamma events $\Delta \boldsymbol{Ti}$
- Derivation of an estimater that compares the time intervals to their mean:

$$M_N = \frac{1}{N}\sum_{\Delta Ti \leq C^*}\left(1 - \frac{\Delta Ti}{C^*}\right) \text{ with } C^* = \frac{1}{N}\sum \Delta Ti$$

$M_N \to \frac{1}{e}$ for Poisson distribution

$M_N = 0$ for Periodic distribution

$M_N \to 1$ for Burst

Running ExpTest

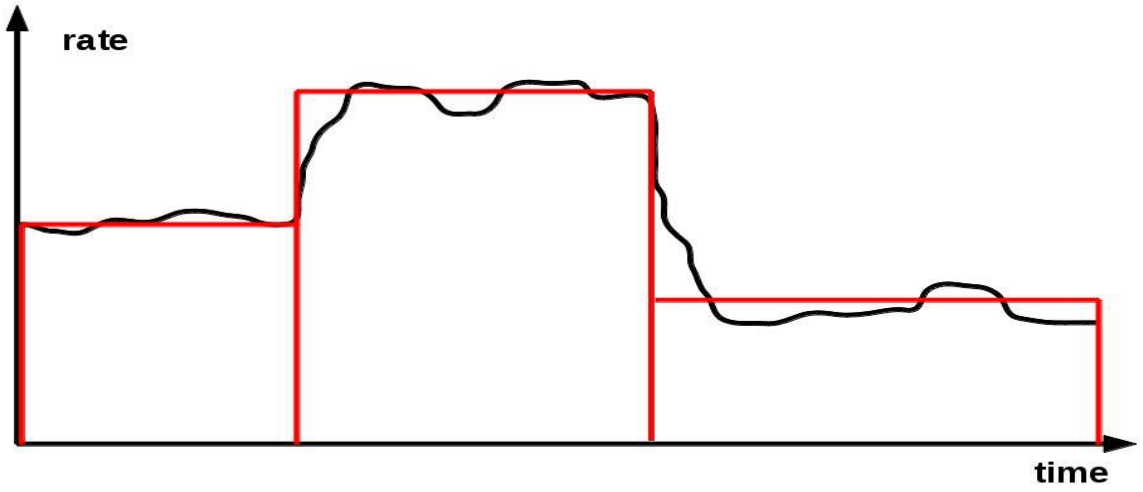
- ExpTest is more sensitive for a **smaller number of events**
  - Running ExpTest:

    Performance of the ExpTest in a **small time window** of a fixed size, running over the whole data set
  - Obtaining the maximal significance from the individual windows

Bayesian Blocks

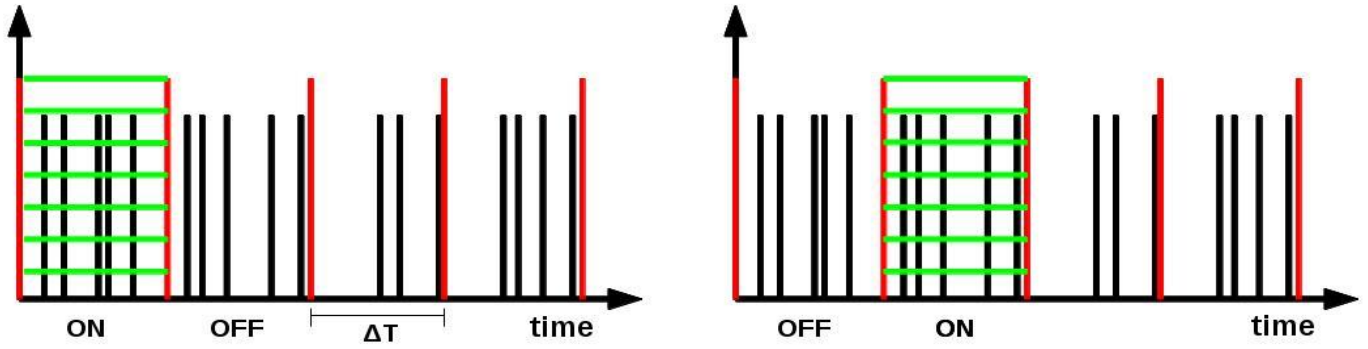
(Bayesian Blocks, A New Method to Analyze Structure in Photon Counting Data, D.Scargle, 1997, arXiv:astro-ph/9711233)

- Estimation of a „Block Distribution“ that fits best to the data
- Size of the blocks must be choosen carefully



ON / OFF Test

- ON region with a defined size is shifted through the whole data set
- Significance calculation with Li&Ma Method for each ON position

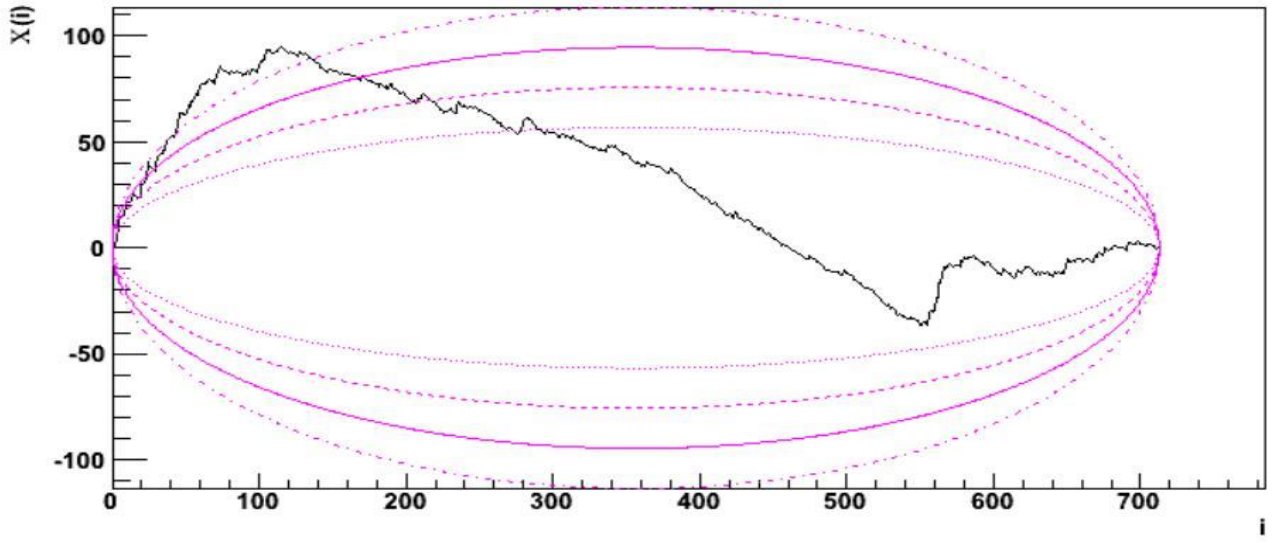


(T.-P. Li and Y.-Q. Ma. „Analysis methods for results in gamma-ray astronomy“. In: ApJ 272, Sept. 1983)

Cumulative Sum Test

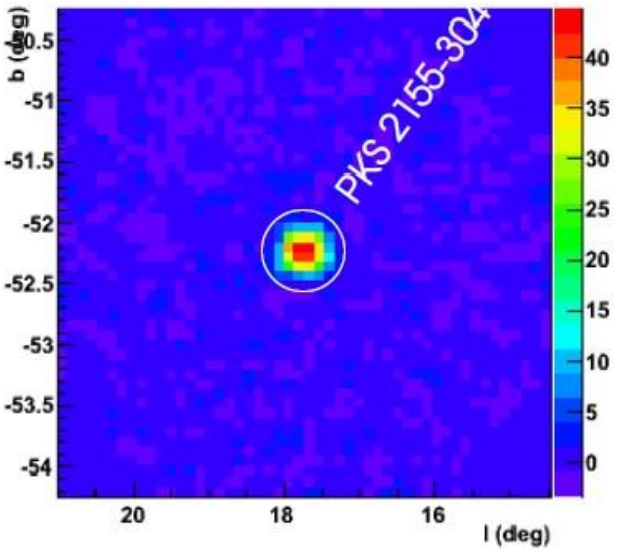
$$\chi_i = \sum_{k=1}^{i} (\Delta T_k - < \Delta T >)$$

Creation of a plot χ_i vs. i (black line), including the lines, marking 3σ, 4σ, 5σ an 6σ (purple lines):



Summary an Outlook

- Transient Tests are implemeted and working in the Model++ Paris Analysis of H.E.S.S.
- Tests applied to data of the PKS2155-304 flare in 2006 and 2007 gave reliable results
- Future work: Sensitivity studies, quantifying test statistics, applications to future measurements
- Principle search for transient
- Phenomena



(F. Brun, 2011)