



HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

Variability for ctools

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What?

- Search for variability using directly the event counts
- Minimum information required is the timestamp and coordinate of each event.
- Used for the search of variability in the H.E.S.S. Extra-galactic survey (HEGS)
- Similar method used in the Fermi All-Sky Variability Analysis.

Search for variability

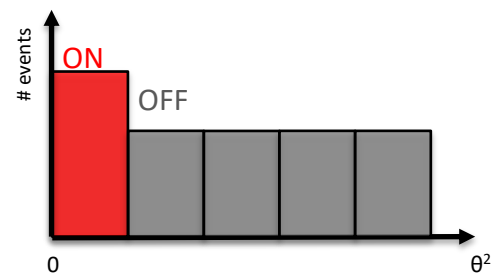
On-off method

- For example, in the HEGS:
 - Calculation of a set of maps (on, off, acceptance, etc.)
- From the maps obtained, we can for each observations at any position extract:
 - number of gamma-like events and detector's acceptance.

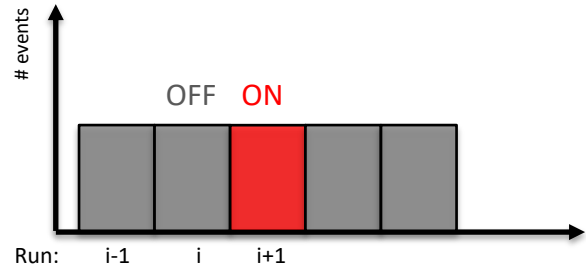
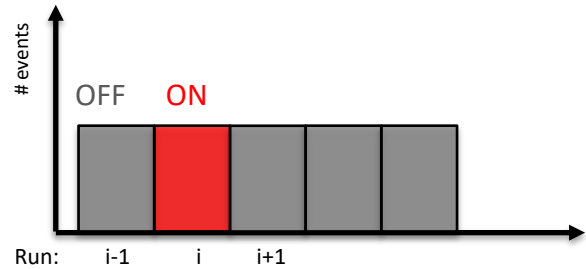
- The method is analogous to that used for on-off excess in the space-domain (significance map, θ^2 histogram).

- Compute the excess of gamma rays at a given position (pixel) and given time (run/night) with respect to other observations at same position.

Search for signal (space domain)



Search for variability (time domain)

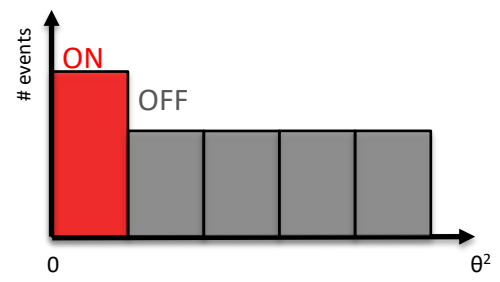


Search for variability

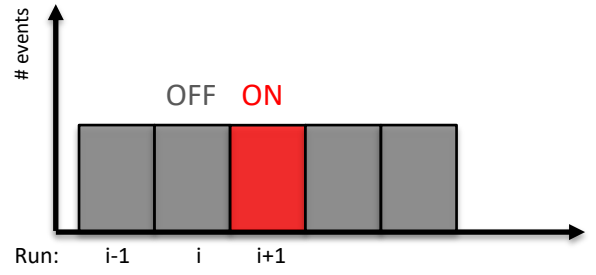
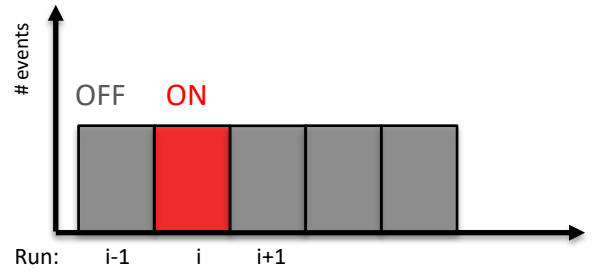
On-off method

- For N runs of observations at a given position, the excess is $N_{ex} = Non_i - \alpha_i * Noff_j$
 - Non_i = number of events in run i
 - $Noff_j$ = number of events in the N-1 other runs
 - α_i = ratio of acceptance integrated in the ON and OFF regions
- The background is estimated by iteratively computed the significance and rejecting runs with sig >4.5
- The significance of the excess is computed using eq. 17 of the Li&Ma publication (Li and Ma, 1983).
- The significance is corrected by the number of trials (number of bins).
- This method allows for blind search variability across the field of view.

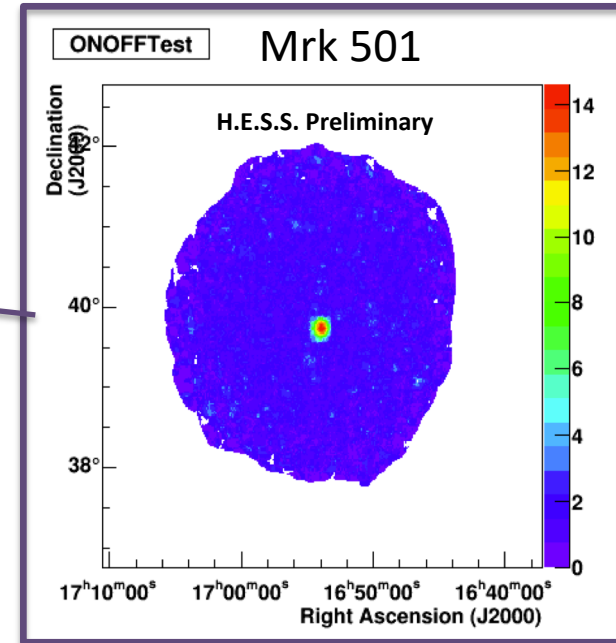
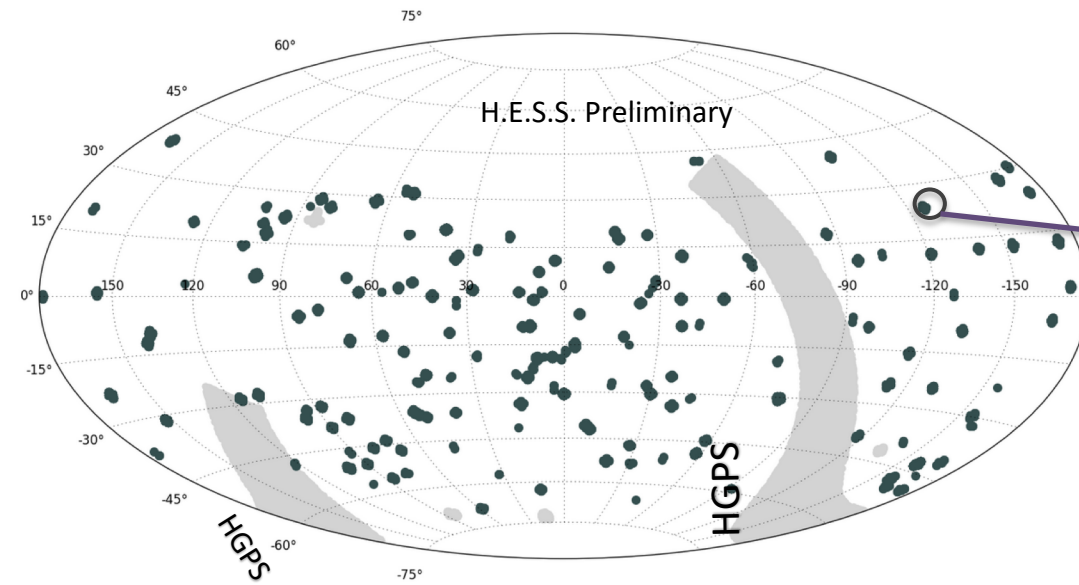
Search for signal (space domain)



Search for variability (time domain)



Variability map

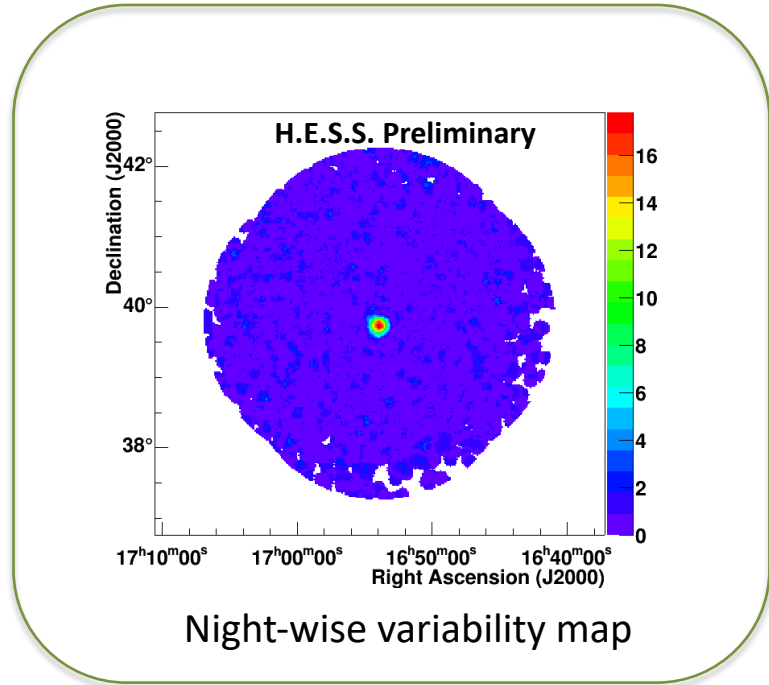
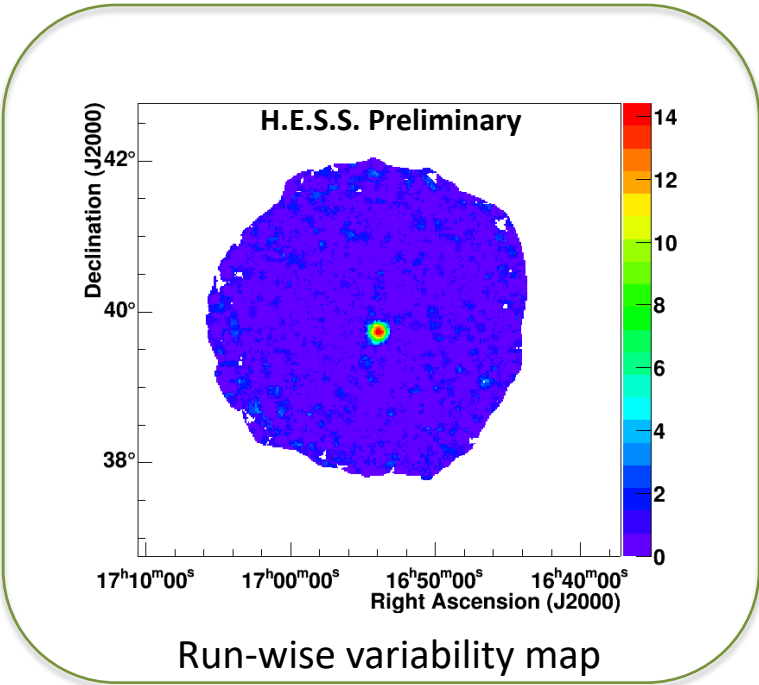


Search for variability

Variability maps

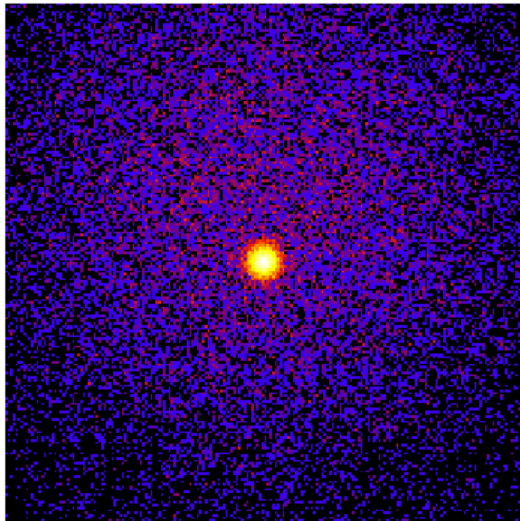
- Variability searched for:
 - runs, on period of 28 minutes.
 - nights, merging the statistics of all the run belonging to the same night.

Example of variability map for Mrk 501 for run and night scales.



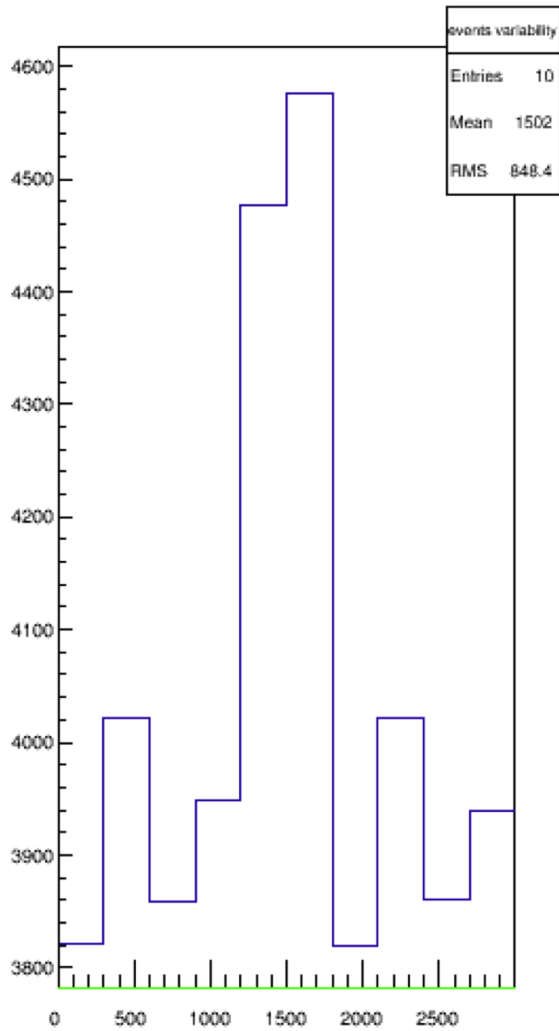
Some tests ongoing.

- Dummy script in C++ to read fit files and compute the variability
 - Using CCFITS library
- Generation of event list using ctobsim:
 - Crab Nebula.
 - Field of view of 5 deg, no coordinate selection.
 - Modified Crab model fake variability, normalization factor times 2.

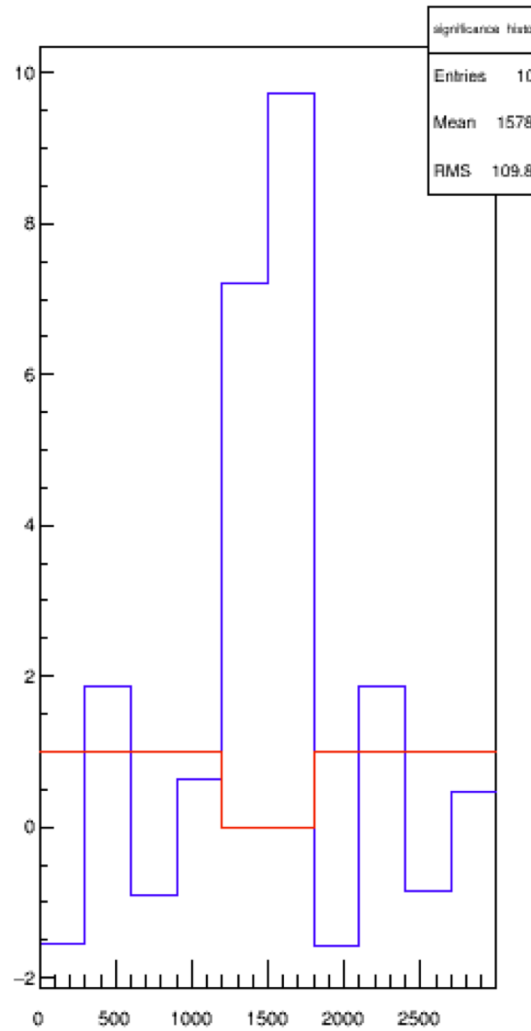


- 20 mins std Crab
- 10 mins Crab with increased flux
- 20 mins std Crab
- All output files merged using astropy libs.

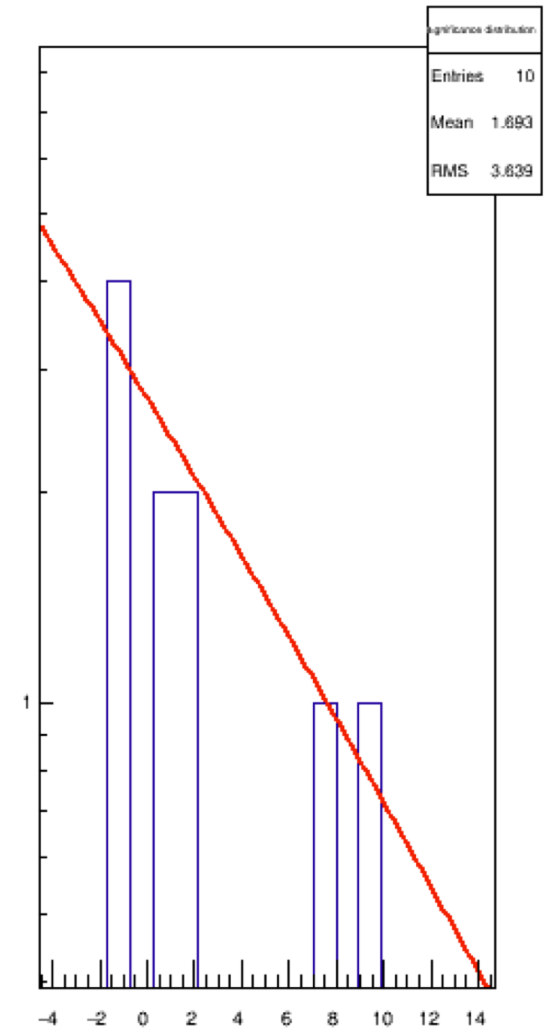
events variability



significance histo



significance distribution



Implementation in ctools?

Ideas and implementation (to be discussed with ctools experts)

- Store for each pixel and for each event:
 - Arrival time (mandatory)
 - Coordinate
 - Energy (for energy-dependant variability search)
- Maps:
 - Store events parameters in map/arrays (before variability search?)
 - Final sky map with pixel variability (for blind searches)
- Variability scale:
 - To be set by the user
 - See how to deal with gaps in arrival time (different runs/nights)