Ten years of H.E.S.S. I extra galactic observations revisited

Abstract
In the past decade, the H.E.S.S. (High Energy Stereoscopic System) experiment has significantly contributed to the field of VHE gamma-ray astronomy. In particular, during the first phase of the experiment from 2004 to 2013, the extra Galactic observation program led to the discovery of more than 20 sources of VHE gamma-rays. During the observation program, some of the sky were also observed without leading to a detection. About 6.5% of the sky was observed and it is now possible to re-analyse these data with the most up-to-date analysis techniques in an uniform way. This allows for population studies, variability studies, transient searches in the observed regions and robust comparison with the latest Fermi-LAT catalogs.

In this contribution, the re-analysis of these ~2700 hours of observation is presented, together with the data products that are intended to be released to the scientific community.

Data selection and analysis procedure
All H.E.S.S. data taken between January 2004 and January 2013 are selected for this analysis. The observation runs are then grouped in RunsClusters using the D3SCan algorithm from the skillearn library [1]. After this step, some regions are removed from this study, such as the Galactic plane or the LMC. Each remaining RunsCluster defines a spatially independent region observed by H.E.S.S. The 123 selected RunsClusters are the results of ~6500 observation runs, corresponding to ~2700 hours of observation and covering ~6.5% of the sky.

The analysis of each RunsCluster is then performed using the Model Analysis [2] and a set of maps – significance, flux or upper limits – is derived. From these maps, values of interest can easily be retrieved. In this analysis, the flux-related products were derived assuming a Power-Law with a spectral index of ~2.

Released maps
For each RunsCluster identified on the all-sky map below, the following maps are computed: Significance, Flux, Flux Upper Limits and ON-OFF variability test. As an example, the RunsCluster presented here is the one towards the source Mrk 501.

We intend to release the maps for all the RunsClusters in FITS format.

Variability search with the ON-OFF method
We can compute a set of maps for each observation. At any given position in the map and for each RunsCluster and each observation, we have the number of reconstructed gamma-like events together with an estimation of the detector’s acceptance.

We have developed a method that uses these quantities to probe variability on the time-scale of the observations. This method is the analogous in the time domain to the standard ON-OFF method used to compute excess and significance maps [3]. This method computes the excess of gamma-rays at a given position and during a given observation with respect to all the other (excess-less) observations. The significance of the excess can then be computed from eq. 17 of the Li & Ma publication [4]. This method can therefore be used to blind-search variability across the observed field-of-views.

Comparisons with Fermi-LAT catalogs
From this analysis it can be derived how many Fermi-LAT sources have been observed by H.E.S.S. In addition, the Flux UL maps are useful to constrain the extrapolation of the flux observed with Fermi in the H.E.S.S. energy range.

216 3FGL [5] sources have been observed in this dataset. For 168 sources, the VHE extrapolation is not constraining. For 48 sources however, this extrapolation is constraining as in the two example SEDs given in the figure below:

The H.E.S.S. telescopes
FIG. 1: The H.E.S.S. Telescopes. Located in Namibia, this array of Imaging Atmospheric Cherenkov Telescopes detects very-high energy gamma rays. In its first phase (2004 – 2012), the array had 4 telescopes.

The 5th, largest, telescope was added in July 2012. The analysis presented here uses only data taken with Telescopes detects very-high energy gamma rays. In its first phase (2004 – 2012), the array had 4 telescopes.

FIG. 2: Location on the sky of the RunsClusters in equatorial coordinates. The grey areas show the observations not taken into account in this study. The Significance, Flux, Flux Upper Limit and ON-OFF test maps are shown as an example for the RunsCluster towards Mrk 501. The values put at each pixel is the maximum significance found over the observations considered in this pixel.

For N runs of observation and for a given position, the excess for each observation i is $H_{O,i} - H_{F,i}$ where $H_{O,i}$ = number of events in run i, $H_{F,i}$ = number of events in the N-1 other runs, $\gamma$ = ratio of the acceptance integrated in the ON and OFF regions

Note that the observed significance must be corrected for the number of trials (number of time bins)

References

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