A preliminary All-sky search of transients in the TeV gamma-ray sky observed by HAWC

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Abstract

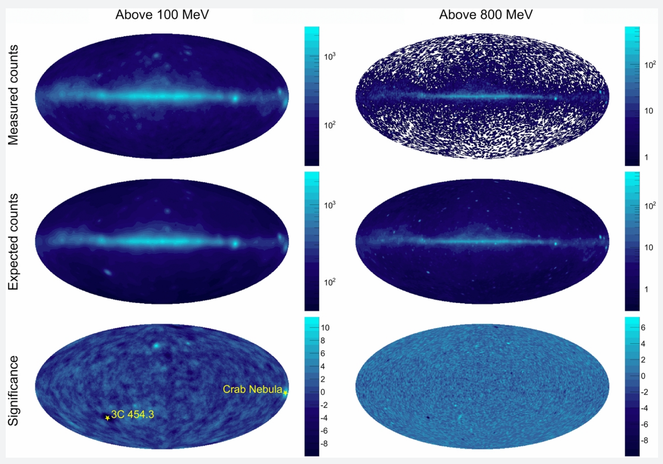
The long-term operation of HAWC provides valuable opportunities to study transient and variability phenomena in sources emitting at TeV energies. In this work, we introduce the All-sky Root around in an Unbiased way (ARU) algorithm, a tool designed to estimate the significance of deviations from constant emission on different timescales using data from ground-based gamma-ray observatories. We compute the expected sensitivity of ARU for HAWC data. Finally, we present preliminary results on flaring sources detected within HAWC's field of view

Motivation

- 10 years of long-term monitoring of the TeV gamma-ray sky with HAWC
- Are there transient phenomena faded in the long-term constant emission?
- Extend all-sky searches performed by Fermi-LAT

Previous Analysis: FAVA

- 7.4 years of FermiLAT data
- Two separate energy bins: [0.1 - 0.8] GeV and [0.8 - 300] GeV
- 4547 weekly flares corresponding to 518 variable sources: 441 blazars
- 7 galactic sources among the Crab nebula, X-ray binaries and Novae



ARU: All-sky Root around in a Un-biased way

Computing deviations and its significance

- Get expected counts for small timescales from the long-term observed emission
- Compare observed to expected counts using:

$$H_{null} = Poisson(n|b) = Poisson(n_{obs}^{ST}|\kappa_{scal})$$
$$H_{alt} = Poisson(n|s+b) = Poisson(n_{obs}^{ST}|\kappa_{obs})$$

- Estimate TS of the deviations:

$$TS = -2\ln\left(\frac{H_{null}}{H_{alt}}\right) = -2\ln\left[\frac{P(n_{obs}^{ST}|k_{scal})}{P(n_{obs}^{ST}|\kappa_{obs})}\right].$$

- Convert to Gaussian significance

ADVANTAGES

1. No spectral asumption about the nature of the emission during flaring or high-emission states
2. No special modeling of the diffuse gamma-ray emissions (galactic or even extragalactic)
3. Computationally less expensive than other search methods
4. Complement to other analysis like `gammapy` to extract spectral information

Sensitivty

We estimate the sensitivity of ARU applied to HAWC. We injected sources with a constant emission plus a high-emission (flaring) state at weekly and monthly scales. Then applied ARU to get the significance.
In total, 12000 sources where injected for each timescale. We estimate the flare flu where significance σ_{ARU} reach 5.

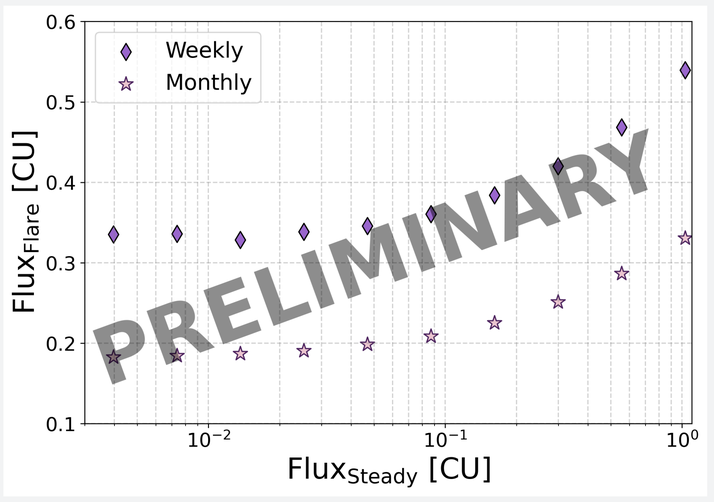
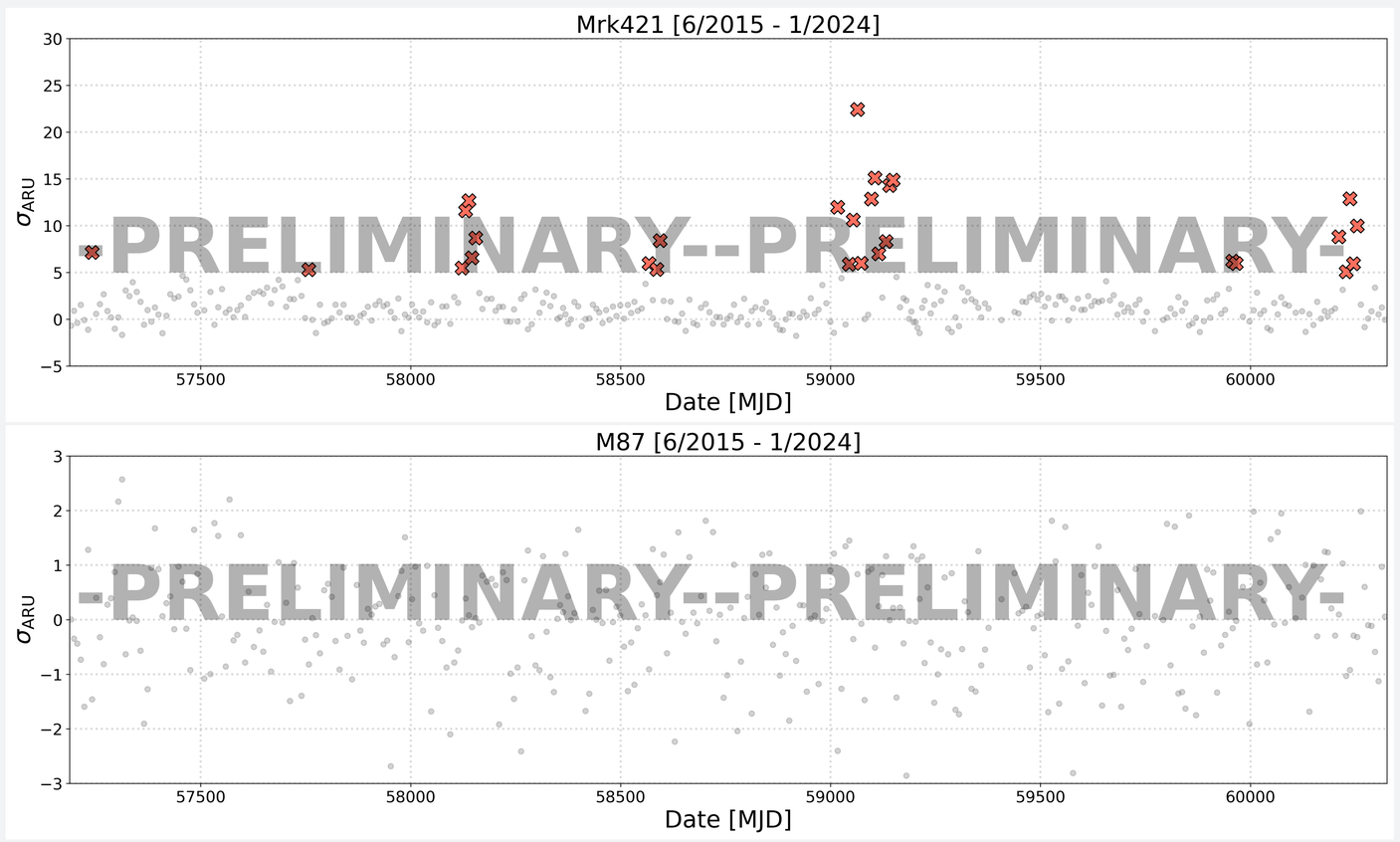


Figura 1: Sensitivity of ARU applied to HAWC data for weekly (purple diamonds) and monthly (pink stars) high-emission (flaring) states. Flux for steady and flaring components are reported in units of the Crab flux.

Preliminary Results: Temporal evolution of σ_{ARU}

1. Significance curve where created for three known variable sources (Mrk 421, Mrk 501 and M 87) and the Crab Nebula.
2. Mrk 421 [top panel] shows several periods with $\sigma_{\mathrm{ARU}} > 5$. Those periods corresponds already to high-emission states observed by HAWC.
3. Mrk 501 shows almost null variability at TeV energies, with one period. Check the QR below.
4. For most of the periods, M 87 shows significance always below 2, consistent with not observing variability or high-emission states from this source at weekly timescales.



Future work

- Finalizing and calibrating blind search algorithm
- Ongoing analysis together with `gammapy` for known sources
- This approach can be applied to other ground-based gamma-ray observatories, like SWGO

More information