Comprehensive Multi-Timespan Analysis of Known AGN

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Background

The High-Altitude Water Cherenkov (HAWC) Observatory is a ground-based cosmic ray and gamma ray observatory that operates in the Very High Energy (VHE) regime (~50 GeV to ~10 TeV). The Puebla, Mexico based detector began operations in late 2014.

Fig. 1: HAWC observatory[1]

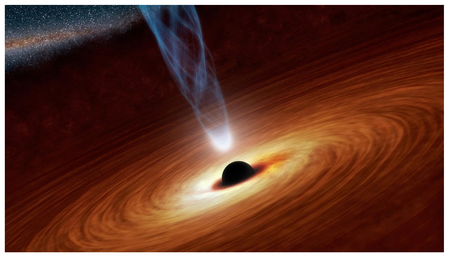

Fig. 2: Artist's conception of an AGN[3]

Active Galactic Nuclei (AGN) are supermassive blackholes powered by accretion at the center of far away galaxies. These astrophysical sources produce massive amounts of radiation and are the most common extragalactic sources that can be detected by HAWC. Only two extragalactic sources have been detected with HAWC to date (Markarian 421 and 501)[2].

Motivation

- Analysis of HAWC data from the time operations initiated in 2014 to the present has been performed with varying time scales, but a comprehensive study has yet to be performed at all possible multi-day time scales.
- Without a complete Spectral Energy Distribution (SED) for an AGN, some cannot be definitively classified by type (such as extreme blazars)[4]
- In addition, the lack of data in energies above 50 GeV may be preventing astronomers from identifying the underlying physical mechanisms that cause some AGN to emit powerful jets of radiation.
- If an exhaustive search is performed and the flux observed from the direction of the AGN is not statistically significant, it would constrain the frequency of AGN flares by flux and timescale.
- The goal of this project is primarily to determine whether HAWC has detected AGN over any multi-day time span since it began operations.
- Secondarily, if no significant detection is made, upper limits on the flux received in VHE gamma-rays from the analyzed AGN will be established. A non-detection still allows conclusions to be drawn concerning the flux and timescales of AGN flares.
- Thus, I propose a plan to perform such a study on a selection of known AGN using HAWC data.

Timespans

Checking many timespans increases the number of trials and, therefore, decreases the significance of a detection. Accordingly, it is important to minimize the number of trials by removing overly correlated timespans. For this reason, a selection of 15 timespans lengths was chosen. The timespans lengths are 1, 2, 3, 4, 5, 7, 10, $10^{1.25}$, $10^{1.5}$, $10^{1.75}$, 10^{2}, $10^{2.25}$, $10^{2.5}$, $10^{2.75}$, and 10^{3} days. In addition, the length each timespan is to be shifted is 20% of its length.

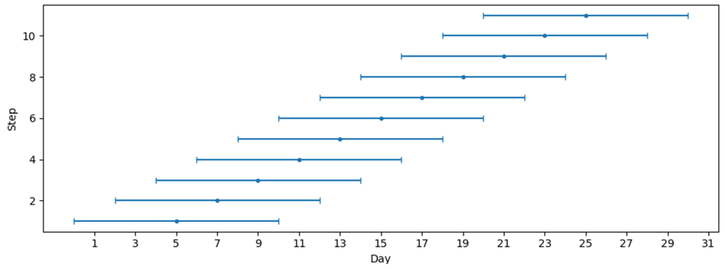

Fig. 3: An example of the first 10 timespans that would be used for the 10 day length.

Crab Check

The Crab Nebula is a strong emitter of gamma rays and, due to its proximity, the brightest source in the VHE gamma ray sky. Given its well-known flux at various energies, the crab was used to check if the analysis program was functioning properly.

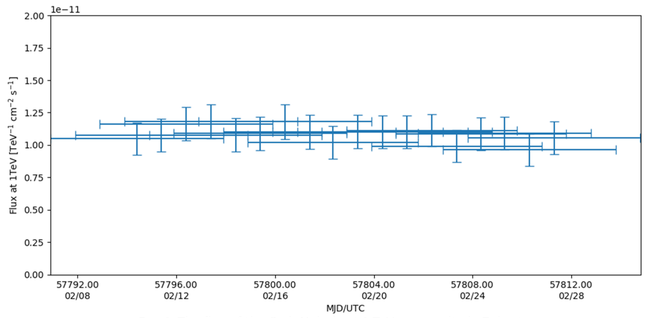

Fig. 4: The flux of the Crab Nebula at 1 TeV over multiple 7 day timespans

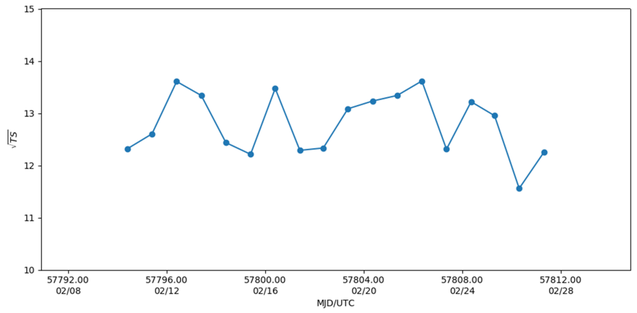

Fig. 5: The significance of the Crab Nebula over multiple 7 day timespans

False Alarm Rate

- In order to determine the significance of a result, the False Alarm Rate (FAR) must be known.
- To calculate the FAR, the background of a real map is Poisson-fluctuated thousands of time to create pseudomaps; the test statistic of the pseudomaps is then calculated.
- To be conservative, the FAR will be calculated separately for all timespan lengths.
- The FAR will be compared at different declinations to ensure it is not different.
- Figure 6 shows the FAR for the 10 day timespan length. The histogram bins represent the number of times the test statistic was observed at that level per year of pseudomap data.

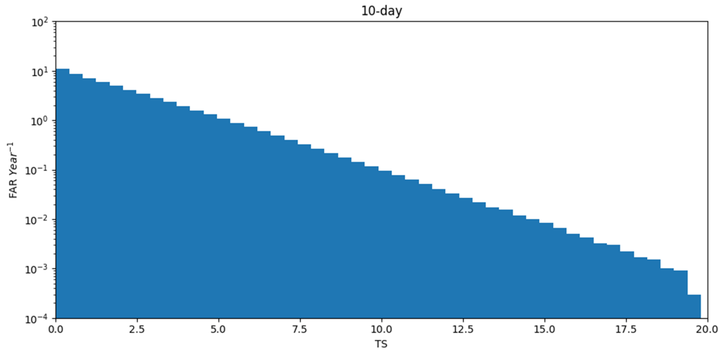

Fig. 6: The FAR at a declination of 20 degrees for 10 day timespans, calculated using 10,000 years of pseudomaps.

Conclusion

- The intent of this analysis is to perform a comprehensive analysis of past HAWC data, in an effort to either detect extragalactic sources previously not seen by HAWC, or place limits on the frequency and flux of AGN flares
- The analysis program to calculate the significance of the timespans of interest is functioning properly, as shown by the Crab Nebula check.
- The FAR has been determined for all timespan length at a declination of 20 degrees.
- Currently, I am checking the FAR is not declination dependent.
- The next step will be to run the analysis program to calculate significance on a selection of known AGN.

References

1. Goodman, Jordan. *The HAWC Observatory.* 2016.
2. Carramiñana, Alberto & González, Daniel & León, Sara & Longinotti, Anna. (2019). A survey of Active Galaxies with the HAWC Gamma-ray Observatory.
3. "Black Holes: Monsters in Space (Artist's Concept)." *Jet Propulsion Laboratory*, NASA.
4. Padovani, P. et al. Active galactic nuclei: what's in a name? A&A Rev. 2017, 25, #2.