HAWC GRB Alerts to GCN

HAWC GRB Alerts

Hugo Ayala

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THE HAWC COLLABORATION

1 Motivation

The HAWC Collaboration is starting to issue alerts from short timescale searches, looking for gamma-ray bursts. HAWC has the ability to monitor the TeV sky continuously thanks to its large field of view and high duty cycle [1]. With these alerts we expect to increase the ways the community can do multiwavelength and multimessenger searches. We present here a brief summary of the searches and the description of the events that we are sending.

2 Description of alert selection

Here we present a brief summary of the HAWC Burst Monitoring algorithm. The full description can be found in the thesis of Josh Wood [2].

The alert system has been implemented and it is currently running in the computers at the HAWC site. The analysis algorithm explores the ∼24 kHz of air shower events that come within 50 degrees from HAWC's zenith for any possible burst-like signal. The search is done using fixed-width sliding time windows. In each time window, all points in the sky are tested agains the null hypothesis that the air showers come from the ∼500 Hz rate of cosmic rays remaining after applying gamma-hadron separation cuts. Any significant upward fluctuation from background becomes a candidate for an alert.

The spatial search is performed in a search bins using locally smoothed $2.1^\circ \times 2.1^\circ$ square bins. (the width of the spatial bin as measured in right ascension scales with declination according to $2.1^\circ/\cos(\delta)$. Each of these search bins is further divide in 0.11° grid bins in right ascension and declination. This results in $\geqslant 90\%$ overlap between any two adjacent search bins, allowing for fine tuning on the spatial position of air shower excesses.

The current time windows that are implemented, search for background variations in 0.2, 1, 10 and 100 seconds. For each time window, the spatial search is implemented. Once this is done, the time window is moved forward by 10% of the window width and the spatial search is repeated.

We search for the best candidate in a give time window over a complete scan of right ascension and declinations from -31° to 69° for one sidereal day.

Since the search algorithm compares probabilities from multiple bins, we have take into account the trials calculation in order to select the result which is least consistent with the null hypothesis.

The reference [2] explains with more detail how this post-search false positive rate is calculated directly from search data. This false positive rate is our main quantity that we use to determine if an alert will be sent.

For the uncertainty of the position, a simple toy MC was used to look for how far the most significant bin is from the true GRB position. Depending on the number of background events, the 68% containment radius is obtained as:

$$\delta\theta_{68} = \begin{cases} 0.8^\circ & \text{if } N_{bkg} < 0.3 \\ 0.6^\circ & \text{if } 0.3 < N_{bkg} < 3.0 \\ 0.4^\circ & \text{if } N_{bkg} > 3.0 \end{cases}$$

The current threshold decided by the HAWC collaboration is to send alerts with $\leqslant 1$ event per year. This alerts will be sent as GCN notices.

3 Description of alert content

The GCN notices contains the following information provided by the HAWC collaboration:

- Time and date in universal time.
- Right Ascension and Declination in several epochs (current, J2000 and J1950) with a 68% containment angular uncertainty.
- Time window search: the size of the time window for the search.
- False Alarm Rate: rate of background events expected that are "like this alert" observed by HAWC.
- P-value: the post-trials probability value of the event .

It will also contain more information that it is useful for follow-ups. See the example in the next section.

4 Example of alert message

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////////////////////////////////////////////////////////////////////////
TITLE:           GCN/AMON NOTICE
NOTICE_DATE:     Sun 24 Feb 19 02:03:33 UT
NOTICE_TYPE:     HAWC_BURST_MONITOR
AMON_NUM:        1851300000307
SRC_RA:          220.30d {+14h 41m 13.86s} (J2000),
                 220.5000d {+14h 42m 1.02s} (current),
                 219.8014d {+14h 39m 12.44s} (1950)
SRC_DEC:         36.80d {36d 48' 02"} (J2000),
                 36.72001d {36d 43' 12"} (current),
                 37.01d {37d 00? 49"} (1950)
SRC_ERROR:       0.60 [deg, stat, 68% containment]
DISCOVERY_DATE:  18538 TJD;  55 DOY; 19/02/24 (yy/mm/dd)
DISCOVERY_TIME:  39689 SOD {11:01:29.00} UT
REVISION:        0
DELTA_T:         1.0000 [sec]
FAR:             191.41 [yr^-1]
PVALUE:          0.2748
SUN_POSTN:       337.09d {+22h 28m 23s} -9.57d {-9d 34' 34"}
SUN_DIST:        117.09 [deg] Sun_angle= 7.8 [hr] (West of Sun)
MOON_POSTN:      121.73d {+08h 06m 56s} +20.14d {+20d 08' 11"}
MOON_DIST:       98.92 [deg]
GAL_COORDS:      62.46, 64.89 [deg] galactic lon,lat of the event
ECL_COORDS:      201.47,49.08 [deg] ecliptic lon,lat of the event
COMMENTS:        Alert from HAWC Burst Monitoring
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References

[1] A.U. Abeysekara, A. Albert, R. Alfaro, et al. Observation of the Crab Nebula with the HAWC Gamma-Ray Observatory. *ApJ*, 849, 2017.

[2] Joshua Wood. An All-Sky Search for Bursts of Very High Energy Gamma Rays with HAWC. *arXiv e-prints*, page arXiv:1801.01550, Jan 2018.