Draft version December 20, 2025
Typeset using LaTeX **manuscript** style in AASTeX7.0.1

Discovery of Microsecond Duration Radio Flashes with Small Radio Telescopes

Glen Langston,[1] K. Bandura,[2] P. Sanghavi,[3] and DSPIRA Collaboration[2]

[1] *National Science Foundation*
[2] *West Virginia University*
[3] *Harvard University*

ABSTRACT

We present the discovery of a variety of short duration transient radio events detected simultaneously by at least 3 of 7 small horn radio telescopes, when continuously observing the sky at 1421.5 +/- 3.0 MHz. The goal of these observations is to detect transient radio flashes, which are expected when high-energy cosmic rays hit Earth's atmosphere. We find a variety of radio flash patterns, including expected isolated radio flashes, a grouping of a few events, primarily seen near Sun transit, and floods of events, where thousands of flashes are seen over periods of hours. The origin of these flood events have not yet been determined, but are likely due to a variety of causes, including solar events, bursts of cosmic rays, human interference, weather disturbances, and (perhaps) communication from Extraterrestrial Sources.

The observing system is developed as part of an educational program, enabling students and hobbyists to build sensitive, yet low cost, radio telescopes. The goal of the project is to train students in astronomy, engineering, programming, and data analysis. Our educational program has the goal of creating a world-wide research program for each student to make valuable, and unique, contributions to significant astronomical studies.

Email: glen.i.langston@gmail.com

Keywords: High Energy Astrophysics (739) — Solar physics (1476) — Radio Astronomy (1338) — SETI (492)

1. INTRODUCTION

We report discovery of radio flash transient events, detected by a cluster of small horn radio telescopes that continuously monitor the sky in the frequency range 1421.5 ± 3 MHz. We have been monitoring the sky since 2019. We slowly increased the number of horn telescopes observing from 3 to 7. The horn telescopes observe with fixed azimuth and elevation for a number of days. Currently the horn telescopes are in a cluster spanning 100 meters in the North-South direction and 50 meters in the East-West direction, with three horns near the middle of the group. Here we announce the detection of different radio flash time sequences and provide a histogram plot of the number of radio flashes detected on 30 April 2025 (UTC). This date was selected because it shows three types of events. An event is declared if 3 or more Radio Telescopes detect flashes with 0.5 seconds. The flash detection rates on this day are similar to rates seen on other days of observation.

2. BACKGROUND

Groups at the West Virginia Radio Astronomy Instrumentation Laboratory (WVURAIL), the National Science Foundation (NSF), and the NSF's Green Bank Observatory have been working with high school and college teachers to develop hands-on electronics and construction tools for radio observations of Galactic Neutral Hydrogen. G. I. Langston et al. (2018) describes the horn radio telescope and hands-on experiments that students perform. The process of building and observing with radio telescopes is described on the WVURAIL web site https://wvurail.org/dspira-lessons/. The educational use of horn telescopes is described by J. L. Makous & K. Bandura (2021). The telescope construction and operation guides are provided on (G. Langston & K. Bandura 2025) site. We describe the event observing system and the statistics of radio flashes detected in G. Langston (2026).

Radio flashes originating from cosmic ray interactions with the Earth's atmosphere have been reported by several authors, including D. ARDOUIN et al. (2005) and a review by T. Huege (2016). The horn telescopes we use are strongly resistant to human interference outside the main beam of the telescope. These telescopes have high sensitivity and can detect neutral hydrogen in the spiral arms of our Milky Way galaxy in one second of observation. Note that the FWHM beams of the horn telescopes are large, greater 18 degrees, so a moderate fraction of the sky may be observed simultaneously.

3. RADIO FLASHES AND EVENT DETECTION

The flashes are very short in duration (typically less than half a micro-second). Our telescopes sample the data stream of voltages at a 12 MHz rate. A flash is detected if a single sample has a voltage that exceeds $\pm$ 7 σ of the input data RMS. When a data sample exceeds the threshold, the telescope computer records the voltages of the data stream for 2048 samples before and after that sample, corresponding to $\pm$ 0.00017 seconds before and after the event.

For gaussian distributed noise, a 7 σ event would be detected once in $\sim 3 \times 10^{12}$ samples. One day of observation at 12 MHz would yield roughly $\sim 10^{12}$ samples.

In post processing, the times of detection of all flashes from all telescopes are compared. If a set of flashes is seen by at least 3 telescopes within 0.5 seconds, then it is identified as an "event". The window for identifying an event is much wider than the sample time because of jitter in the time tag accuracy of the multi-tasking environment of the computers. The matched flashes have times that differ by a few milliseconds.

Figure 1 shows the histogram of flashes detected on the UTC day of April 30, 2025. The plot shows the UTC hours on the X-axis. The Y-axis is a histogram of the number of flashes seen by a telescope within that 10 minute time range. There is one histogram for each telescope, stacked on top of the largest number of flashes seen by the preceding telescope. Notice that a flood of events was seen near local midnight, so is not likely due to local human interference. The post processing software fits these thousands of flashes into 5 gaussian distributed groups.

Telescopes are associated with the Raspberry Pi control computer number. For these observations, the telescope numbers are 1, 3, 5, 6, 10, and 11. The telescopes are separated by 100 meters in the North-South direction and 50 meters in the East West direction. This spacing was chosen to match the cosmic ray footprint seen by other observers working at lower radio frequencies.

The telescopes observe independently, with each telescope computer separately detecting and recording flashes. In post processing, the flash times for each telescope are compared with the others. The vertical lines show matches that are grouped; if a single event match is seen, it has an "o" indicator. If an event match occurs, when there are more than 10 flashes, then the match is given an "X" indicator. The coordinates of Galactic longitude and latitude mark the event. At the top of the plot, the Azimuth and Elevation of the horns are marked, and the RA and Dec for UTC=0. The Sun RA and Dec coordinates are listed and the Sun transit is marked. For these observations, all telescopes were pointed north (azimuth=0) at an elevation of 70 degrees throughout the month. The region of observation drifts into the telescope beam due to Earth rotation. At this elevation, the FWHM beam width corresponds to roughly 2 hours of time. At this horn orientation, the outer galactic plan falls within 10 degrees of the telescope observation position from 11.5 to 20.2 hours UTC, and this time range is marked with gold asterisks. It was expected that more comic ray events would be detected in the direction of the galactic plane.

4. LISTS AND PLOTS OF EVENTS DETECTED

Observations of radio flashes have been on-going since 2019. Roughly one terabyte of events and radio spectra have been recorded. Only a small number of flashes are identified as events. Plots of the flash identification and recorded voltage sequences for 2025 are available at https:www.gb.nrao.edu/~glangsto/flashes/2025. The data are organized into month and date directories. For example, to access the plots of events detected on April 30, 2025, see https:www.gb.nrao.edu/~glangsto/flashes/2025/25Apr/25Apr30 At this link the time sequences of each of the 9 events are shown.

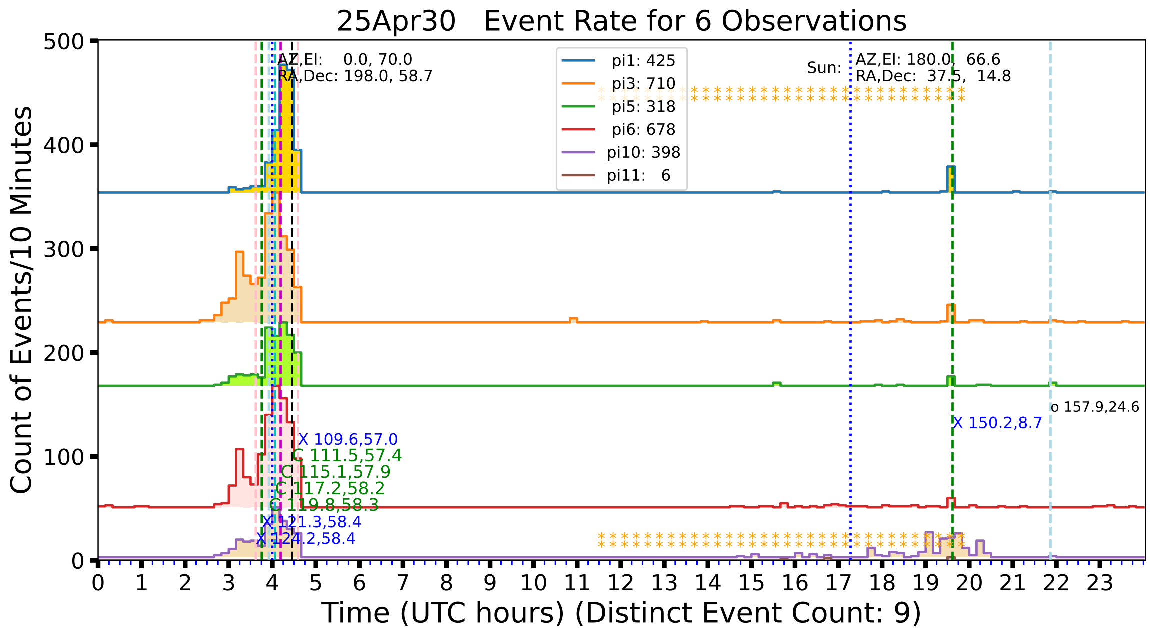

Figure 1. Histograms of transient events seen by 6 horn radio telescopes seen on April 30, 2025 UTC. The X-axis is UTC time of day (hours) and the Y-axis is the histogram of counts of transient events seen by each telescope, stacked. The histogram count interval is 10 minutes. The histogram for a telescope is plotted on top of the peak count of events of the previous telescope, revealing when telescopes see many simultaneous flashes. The dashed vertical lines mark times when three or more telescopes simultaneously detect transient events. The dotted vertical line near 17.2 UTC marks Sun transit. Note that flashes are clustered, and not randomly distributed throughout the day. **Our expectation was to detect isolated events, like the match near 21.5 hours UTC.**

5. CONCLUSIONS

We discover a variety of radio flash patterns in the 1421.5 ± 3.0 MHz band. Some of these flashes are declared "events" if multiple telescopes simultaneously detect the flashes. More observations are needed to study the statistics of the different types of events detected.

We note that searches for extraterrestrial intelligence (SETI) must guess possible interstellar communication modes. Possibility a civilization might transmit via cosmic rays, which would concentrate the transmission energy into short duration, highly detectable signals and could potentially contain much information in the event patterns. The observing method described here is complementary to our (A. P. V. Siemion et al. 2013) previous radio searches for SETI signals.

We urge students and hobbyists to build a few horn radio telescopes and make their own observations. We plan coordinated observations of the North (or South) poles once a month, so that the entire globe could search for simultaneous flashes. These simultaneous observations would place valuable constraints on radio frequency flashes originating outside our solar system.

ACKNOWLEDGMENTS

We thank the NSF for supporting this research effort, the Green Bank Observatory Staff for continued encouragement and logistic support. We especially appreciate the continued efforts of the High School Students and Teachers who participated in the WVURAIL Digital Signal Processing Instrumentation for Radio Astronomy (DSPIRA) program.

AUTHOR CONTRIBUTIONS

G. Langston developed the event detection and data reduction software. K. Bandura advised on telescope construction and created the DSPIRA program, which motivated the event detection program. P. Shanhavi developed DSPIRA teaching materials and coordinated teacher and student interactions. The DSPIRA collaboration tested observing modes and consulted on cosmic ray detection methods.

Facilities: DSPIRA Collaboration, Green Bank Observatory

Software: `analyze` - Collection of python programs to match and plot time sequences of events: https://github.com/glangsto/analyze. `NsfWatch60.py` - GnuRadio enabled software for data acquisition: https://github.com/WVURAIL/gr-radio_astro .

REFERENCES

ARDOUIN, D., BELLETOILE, A., CHARRIER, D., et al. 2005, International Journal of Modern Physics A, 20, 6869–6871, doi: 10.1142/s0217751x0503034x

Huege, T. 2016, Physics Reports, 620, 1, doi: https://doi.org/10.1016/j.physrep.2016.02.001

Langston, G. 2026, Transient Event Searchs with Horn Radio Telescopes,, in preparation https://www.gb.nrao.edu/~glangsto/flashes

Langston, G., & Bandura, K. 2025, LightWork Memo Series: Telescope Construction and Operations Guides, https://wvurail.org/lightwork/

Langston, G. I., Hearherly, S. A., Knudson, S., et al. 2018, in 2018 2nd URSI Atlantic Radio Science Meeting (AT-RASC), 1–1, doi: 10.23919/URSI-AT-RASC.2018.8471636

Makous, J. L., & Bandura, K. 2021, The Physics Teacher, 59, 38. https://doi.org/10.1119/10.0003015

Siemion, A. P. V., Anderson, D., Chen, H., et al. 2013, in 2013 US National Committee of URSI National Radio Science Meeting (USNC-URSI NRSM), 1–1, doi: 10.1109/USNC-URSI-NRSM.2013.6525027