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ALFABURST Initial

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ABSTRACT

The ALFABURST fast radio burst (FRB) survey has been observing commensally with other projects using the ALFA receiver since July 2015. We report on the non-detection of any FRBs from that time until May 2017. With current FRB rate models we expected to see multiple FRBs in based on the total observing time, telescope sensitivity and beam size. We discuss the implications for this non-detection FRBs in the context of recent detections with other telescopes.

Key words: radio continuum: transients – methods: observational

1 INTRODUCTION

2 ALFABURST OVERVIEW

ALFABURST is an Fast Radio Burst (FRB) search instrument which has been used to commensally observe since July 2015 with other Arecibo L-Band Feed Array (ALFA) observations at Arecibo Observatory. This system is a component of the SETIBURST back-end (Chennamangalam et al. 2017) and uses ARTEMIS (Karastergiou et al. 2015) for automated, real-time detection. During this time period an Single Pulse Search (SPS) was performed from Dispersion Measure (DM) 0 to 10000, pulse width from $256\mu s$ to 16 ms, across a 56 MHz bandwidth for all 7 beams. Detection above an Signal-to-Noise Ratio (SNR) of 10 were recorded along with an 8.4 second dynamic spectrum window around the event. If multiple events were detected in the same time window, these events were pooled together. Approximately 150k windows were recorded between July 2015 and June 2017, the vast majority of which are false detections due to Radio-frequency Interference (RFI) signals passing through the real-time RFI exciser. We detect no FRBs in our commensal survey.

A wide-feature, learned model was used to classify the event windows in order to filter out RFI and create a priority queue for visual examination. This model and the post-processing procedures are discussed in Section 3. We discuss the expected event rates in Section 4 and consider possible explanations for our non-detection result in Section 5.

From the beginning of July 2015 to the end of May 2017 ALFA has been used for approximately 1400 hours of observing, with all seven beams functional. Due to pipeline development and hardware reliability ALFABURST was active and functional for on average 350 hours per beam. The current system is setup to be reliably in use for all beams any time ALFA is active and in the correct receiver turret position. Of the survey coverage, approximately 65% of the time has been in pointings out of the galactic plane ($|b| > 5°$). Since we are searching up to a DM of 10000 the survey is still sensitive to FRBs at cosmological distances when observing in the galactic plane. But, scintillation effects can reduce the overall FRB event rates (Macquart & Johnston 2015).

2.1 FRB Survey Metric

Using the survey observing time and the ALFA beam size we can derive the FRB survey metric of square-degree hours. An ALFA beam is approximately 3.8' x 3.3' at Full-Width at Half-Maximum (FWHM) across the band. Using this beam size and the average observation time per beam the telescope-independent FRB survey coverage metric for ALFABURST as of June 2017 is 6.7 square-degree hours. This is a fairly small survey metric becuase of the small beam size. But, we are only taking into account the beam size out to the FWHM. We can take into acount the entire first sidelobes of the beams as Arecibo would be senstive enough to detect most previous FRBs in the first sidelobes. Using the parameterized ALFA beam model (Figure 1) (Heiles 2004) we can compute the FRB survey metric as a function of the minimum ALFA sensitvity (Figure 2).

Using Equation 6 of Karastergiou et al. (2015), a SPS pipeline is sensitive to pulses with a minimum flux density (in Jy) of

$$S_{min} = \mathrm{SEFD}\frac{\mathrm{SNR}_{min}}{\sqrt{D\ \Delta\tau\ \Delta\nu}} \quad (1)$$

which is a function of the telescope System Equivalent Flux Density (SEFD), the minimum SNR detection level SNR_{min} and the decimation rate D compared to the native instrumental time resolution τ, this comes from the search pipeline which averages together spectra to search for scattered pulses. ALFABURST has a native resolution of $\Delta\tau = 256\ \mu s$, effective bandwidth $\Delta\nu$ = 56MHz, and SNR_{min} = 10. The SEFD of the ALFA receiver is approximately 3 Jy across the band for all beams.

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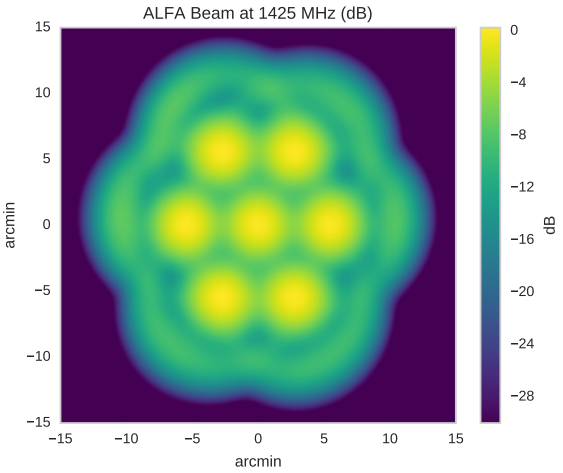

Figure 1. Primary lobe and first sidelobe model of the AFLA receiver in decibels. The sidelobes are sensitive many of the previously detected FRBs.

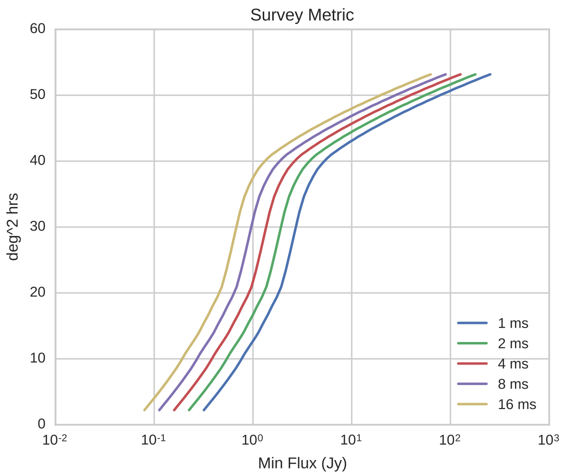

Figure 2. ALFABURST FRB survey metric for pulses of different widths, accounting for the ALFA primary beam and first sidelobe sensitivity.

Since ALFABURST was installed, the majority of ALFA observation time is allocated for the AGES (Auld et al. 2006) and PALFA (Cordes et al. 2006) surveys (Figure 3). The AGES survey pointing is off the galactic plane, thus there is little dispersion and scattering due to the galactic Interstellar Medium (ISM). PALFA is a pulsar search survey with pointings near the galactic plane. These lines of sight can introduce significant dispersion due to the ISM. We search out to a DM of 10000 which is well beyond the maximum galactic dispersion, even when Intergalactic Medium (IGM) dispersion is accounted for from sources of cosmological distances.

PALFA scheduling regularly observe known pulsars to verify timing analysis, this provides a consistent verification of our SPS to detect pulses. As the PALFA survey is performed in the galactic plane a number of high DM pulsars were observed, single pulses from B1859+03 (DM: 402), B1900+01 (DM: 245), B2002+32 (DM: 234), B1933+16 (DM: 158), among others were detected.

3 EVENT PRIORITIZATION AND CLASSIFICATION

4 IMPLIED LOW-FLUX FRB RATES

5 DISCUSSION

6 FUTURE WORK

The current SPS pipeline is undergoing a significant upgrade. The input bandwidth is limited to 56 MHz of the full 336 MHz digital band due to IO limitations. A new pipeline developed for Square Kilometre Array (SKA) Non-image Processing (NIP) will be used to process the full ALFA band. This will increase sensitivity, and improve detection rate if FRBs scintillate similar to FRB121102. An improved version of the real-time RFI exciser is currently being developed and will be deployed to reduce the false detection rate. The post-processing classifier and prioritizer model is being updated to make use of an auto-encoder to select deep features and auto-generate classes.

Over the time period ALFABURST has been active, the use of ALFA has decreased as the PALFA and AGES surveys end. The 327 MHz and L-band wide feeds are commonly used. We are generalizing the ALFA specific SPS pipeline to be used when these feeds are active, increasing our survey time and sampling a larger portion of frequency space. Additionally, our search pipeline will be duplicated for use on the Greenbank Telescope (GBT) to be commensally run with L-band observations.

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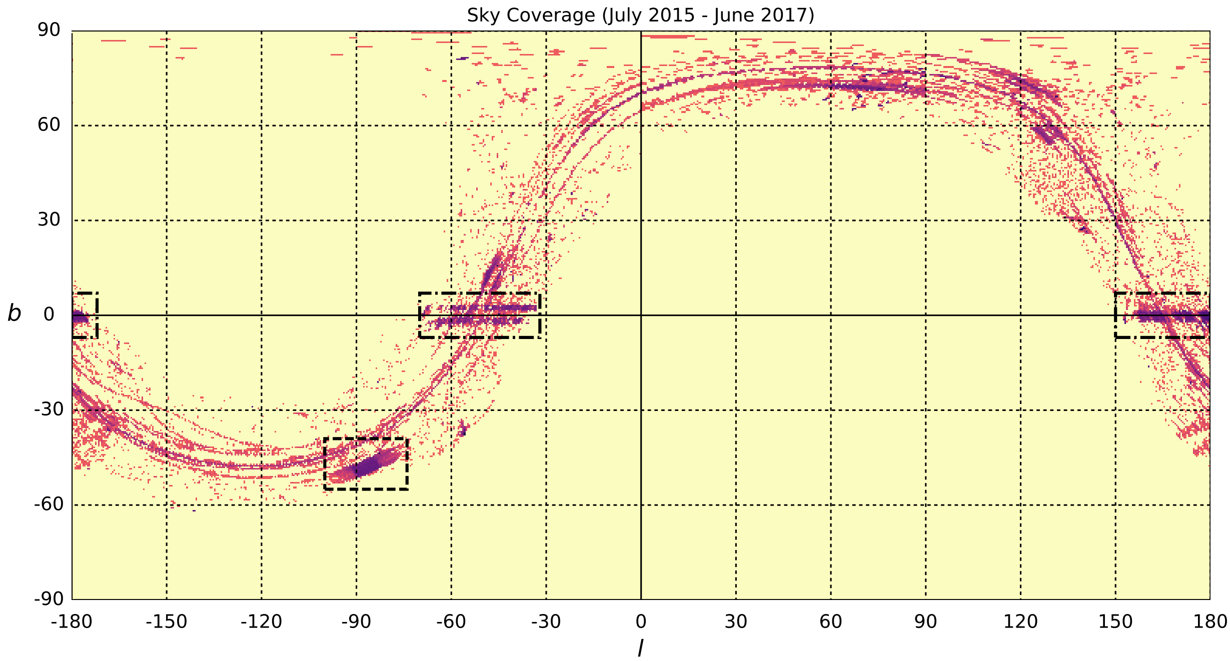

Figure 3. Sky coverage during ALFA usage between July 2015 and June 2017, shown in a Cartesian projection in galactic coordinates. Color represents total time pointing in a log scale. The majority of ALFA usage during this time was for the PALFA survey along the galactic plane (dot-dashed boxes) and the AGES survey (dashed box). The S-shaped arcs across the plot are due to fixed pointings in local azimuth and altitude.