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VLA/Realfast Detection of a Burst from FRB 180916.J0158+65 and Tests for Periodic Activity

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Abstract

We report on the detection of a burst from FRB 180916 by *realfast*/Very Large Array and present software for interpreting fast radio bursts (FRB) periodicity. We demonstrate a range of periodicity analyses with bursts from FRB 180916, FRB 121102 and FRB 180814. Our results for

FRB 180916 and FRB 121102 are consistent with published results. For FRB 180814, we did not detect any significant periodic episodes. The *realfast*-detected and other high-frequency bursts for FRB 180916 tend to lie at the beginning of the activity window, indicating a possible phase-frequency relation. The python package frbpa can be used to reproduce and expand on this analysis to test models for repeating FRBs.

References

1. Realfast Detection of FRB 180916

One of the repeating fast radio bursts (FRBs), FRB 180916, has been found to have periodic episodes of higher activity, with a period of 16.35 days (The CHIME/FRB Collaboration et al. 2020, hereafter PR3). Its bursts are clustered in a 4 day phase window with some cycles showing no bursts, while others show multiple bursts.

On April 23 at 20:11 UTC, we used the *realfast* commensal fast transient search system at the Karl G. Jansky Very Large Array (VLA) to observe FRB 180916. We detected a burst with a signal-to-noise ratio of 13 at a DM of 349.8 pc cm^{-3} (Aggarwal & Realfast Collaboration 2020, hereafter rfATel). The *realfast* system localized the burst in realtime to a location of J2000 R.A. = $01^h58^m00\overset{s}{.}634$, decl. = $-65°43'00\overset{''}{.}6331$. The position of this burst is consistent with the reported localization by EVN (Marcote et al. 2020), given the VLA localization precision of $0\overset{''}{.}8$. The details of the burst were reported in rfATel.

2. Periodicity Analysis Techniques

Since the discovery of periodicity in the activity of FRB 180916, many observatories have reported detections of bursts from this FRB (Chawla et al. 2020; Marcote et al. 2020; Pilia et al. 2020; Sand et al. 2020; Scholz et al. 2020). In total, 19 bursts have been detected at telescopes other than CHIME from FRB 180916. This, along with the bursts reported by PR3, leads to a sample of 51 bursts that have been used in the analysis reported here.

Following the procedure in PR3 and considering a period of 16.35 days, we generated the phase histogram of all published bursts from FRB 180916

(Figure 1, top panel). Most of the bursts lie within a 4 day (or 4/16 = 0.25 phase) phase window from phase 0.4 to 0.6. Our VLA detection lies at a phase of 0.3, which is the earliest phase at which a burst has been detected so far. The addition of bursts from telescopes other than CHIME makes the phase distribution more symmetric. We also generated the phase histograms at other periods within the period error reported by PR3, which resulted in a similar conclusion.

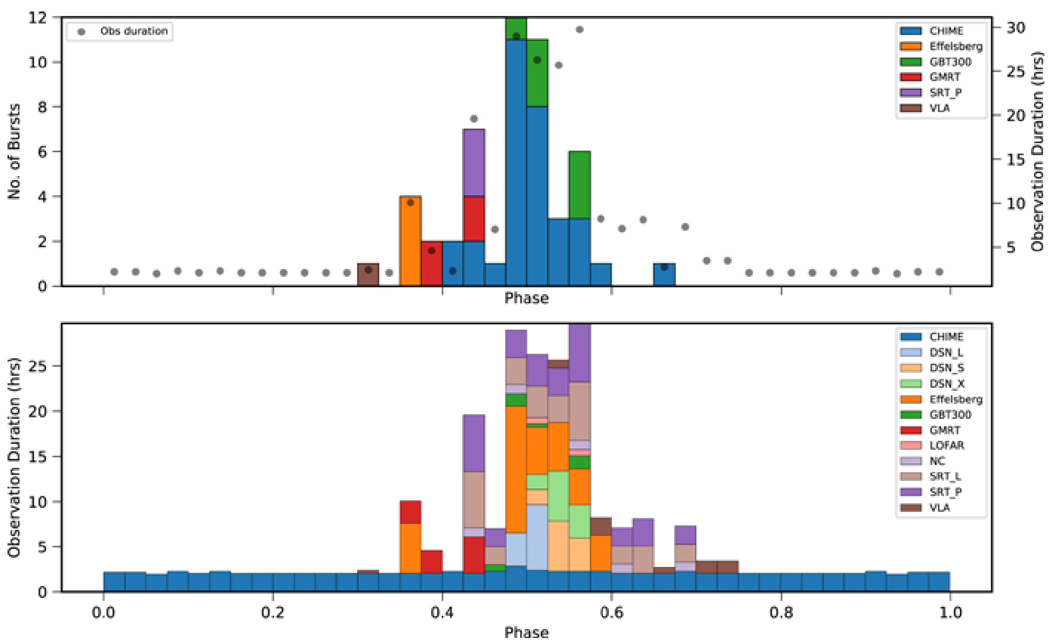

Figure 1. Burst detection and observation histograms for FRB 180916, assuming a period of 16.35 days. Different colors represent different observatories. Top: Stacked histogram of the detected bursts relative to phases for all published FRB 180916 bursts. The black dots show the total observation duration for each phase, summed for all the telescopes in the bottom panel. Bottom: Stacked histogram of observation duration with respect to phase.

We used three tests to search for episode periodicity in this burst sample. First, we used the Pearson Chi-square test done by PR3. Second, we followed the approach of Rajwade et al. (2020) to search for the period with a folded profile of minimum fractional width. We also use the Quadratic-Mutual-Information-based periodicity search technique (Huijse et al. 2018) implemented in P4J[10] to search for a period in these bursts. All three search techniques were used on all 51 bursts, and also on 32 CHIME bursts. Following PR3, we also searched for a periodicity after binning the data to obtain just the "activity days."

All the scripts developed for periodicity search and phase analysis reported here are available as a python package `frbpa`.[11] `frbpa` has various functions that can be used to search for periodicity in the activity of repeating FRBs. It can also be used to visualize the dependence of the burst MJDs and observations on phases.

3. Results and Discussion

For all the methods listed above, we recovered a period that was consistent with the results of PR3, using all the bursts and using just the "activity days." We also extended the analysis of aliasing in PR3 to include bursts from all other telescopes. As the periodicity at all the frequencies is expected to be same, the standard deviation of the burst phases should be minimum at the optimal period (or its alias), which was found to be the case at the published period.[12]

We also used `frbpa` to search for periodicity in two other active repeaters: FRB 121102 (R1), and FRB 180814 (R2). Rajwade et al. (2020) reported a period of 157 days in R1 using a sample of 235 bursts detected over a time span of 7 yr. We used P4J to search for periodicity on this sample and recovered a period consistent with their results. For R2, we used 21 bursts detected by CHIME.[13] We did not detect any significant period, using all the three techniques for periodicity search on these bursts. Moderately significant detections at activity windows of 33, 45, 90 and 138 days were observed. Further burst detections are needed to verify the periods reported for this FRB.

We also note that for FRB 180916, the bursts detected at high frequency (i.e., above 600 MHz; detected using VLA and Effelsberg) are at a lower phase value than most of the low-frequency bursts (Figure 1, top panel). This indicates that there may be a correlation between frequency and phase, where high-frequency emission is suppressed at higher phase values. Although these high-frequency observations have good coverage within the activity phases (Figure 1, bottom panel) with good sensitivity, the detections have only occurred at phase <0.4. This cannot be explained by the models which invoke an interacting neutron-star-binary system to explain the periodicity. These models predict a wider activity window at higher frequencies, as high-frequency photons are generally transmittable (Ioka & Zhang 2020).

Therefore, more high-frequency observations across different activity phases would be imperative to comment on the periodicity at high frequency. Moreover, with the detection of more bursts from FRB 180916 and other repeaters in the future, more confident analysis of plausible periodicity (and phase-dependent burst rates) in their activity would be possible.

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Facility: EVLA. -

Software: rfpipe (Law 2017), fetch (Agarwal et al. 2019), numpy (Oliphant 2006), matplotlib (Hunter 2007).

Footnotes

10 https://github.com/phuijse/P4J

11 https://github.com/KshitijAggarwal/frbpa

12 We also followed these methods after including the openly available but unpublished CHIME burst sample from https://www.chime-frb.ca, which lead to similar conclusions.

13 https://www.chime-frb.ca

Show references