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(Dated:)

Abstract

Fast radio burst (FRB) is a class of transients characterized by its miliseconds scale duration with a relatively high dispersion measure. Some of them show repetition and among those, only some of them seem to repeat regularly. This paper tries to characterize the periodicity of FRBs whose repetition seems to be limited within a certain timeframe – FRB20190915D and FRB20191106C as the chosen examples – from a 3 year dataset provided by the CHIME/FRB 2023 Catalog. This paper found that the periodicity can be characterized with more than 50% certainty despite the limited samples given that the waiting time is bimodally distributed.

I. INTRODUCTION

Fast Radio Burst (FRB) is a class of transients first discovered by Lorimer et al. (2007) with currently unknown origin. It is characterized as a radio pulse with durations in the order of milliseconds and a relatively high dispersion measure. Its high dispersion measure suggests an extragalactic origin consistent with observation of identified hosts such as in Bannister et al. (2019), Chatterjee et al. (2017), and Ravi et al. (2019).

With increasing interests in FRBs, progress have been made in detections (especially with the commisioning of the CHIME/FRB telescope (The CHIME/FRB Collaboration et al. 2018) and in the future, BURSTT (Lin et al. 2022)), theoretical models (a list of theories can be found in Platts et al. (2019)), and analyses (especially on regularly repeating bursts such as FRB20121102A and FRB20180916B). For an in-depth review of the growth of FRB research, readers are suggested to read Petroff, Hessels, and Lorimer (2019) and their follow-up review Petroff, Hessels, and Lorimer (2022).

Currently, FRBs can be categorized as repeating or non-repeating. The population seem to favor non-repeating FRBs over repeating FRBs as The CHIME/FRB Collaboration et al. (2018) reports on 18 (3.7%) repeating sources are among 492 FRB sources detected [1]. A recent paper (Andersen et al. 2023) estimates that repeating sources constitutes about 2.6%

[1] https://www.chime-frb.ca/catalog

of known FRBs. However, it is important to note that there is no guarantee that one-off FRBs will not repeat. Following this assumption, the term 'apparently non-repeating FRB' have been used in various papers, such as in Cui, Zhang, Wang, Zhang, Li, Peng, Zhu, Wang, et al. (2021), Cui, Zhang, Wang, Zhang, Li, Peng, Zhu, Strom, et al. (2021), and Katz (2022).

Multiple statistical analyses seem to support the idea that they are truly two different population of FRBs with consistent differences between repeating and non-repeating FRB in various properties (Cui, Zhang, Wang, Zhang, Li, Peng, Zhu, Wang, et al. 2021; Chen et al. 2022; Zhang et al. 2022). This consistency does not prevent some authors in assuming that a small part of the non-repeating FRBs might repeat in the future dubbed as 'potentially repeating' or 'repeater candidates', as was done by Bo Han Chen et al. (2021), Luo, Zhu-Ge, and Zhang (2022), Zhu-Ge, Luo, and Zhang (2022), and Pleunis et al. (2021).

Regularly repeating FRBs such as FRB20121102A and FRB20180916B are rare. Most of the repeaters currently identified has a limited sample which makes it hard to study its individual property. As such, many repeaters are understudied as its low number of samples provide limited certainty. This paper tries to study the property of individual sources with limited samples.

Since periodicity generally requires many data points, this paper examines whether it is possible to determine the periodicity of a source with at least 50% confidence using samples with more than 3 and less than 20 event counts. If so, what are the criteria to differentiate between determinable and non-determinable periodicity? Having this criteria can help anticipate new detections.

II. METHODOLOGY

This paper will examine the periodicity of FRB20190915D (10 detections) and FRB20191106C (7 detections) from the CHIME/FRB Catalog 2023[2] (Andersen et al. 2023). This paper will also include FRB20180916B (77 detections) from CHIME/FRB Catalog 1 [3] (The CHIME/FRB Collaboration et al. 2021) to compare the validity of meth-

[2] https://www.chime-frb.ca/repeater_catalog

[3] https://www.chime-frb.ca/catalog

ods since its periodicity value is well quantified to be around 16 days (The CHIME/FRB Collaboration et al. 2020; Sand et al. 2023).

A. Periodogram

A periodogram is a function of cost versus periods which quantifies the strength of the fit between the given period and the time series data. The cost function depends on the method of choice. The best period is chosen based on the period with the maximum or minimum cost. While most periodogram methods choose the best period via the maximum cost, the phase dispersion minimization method chooses the minimum cost. VanderPlas (2018) includes four types of periodograms: (1) Fourier Method, based on Fourier transforms; (2) Phase-Folding Method, which calculates cost by trying to fold phases at multiple trial periods; (3) Least-Square Method, which fits a model time series; and (4) Bayesian Approaches, which applies Bayesian probability to the problem.

1. Method: Lomb–Scargle Periodogram

The Lomb–Scargle periodogram Scargle (1982) is the most commonly used in astronomy. The cost function for this periodogram is the Fourier power which is to be maximized. As such, it is a periodogram based on Fourier transform but it can also be approached as a least square optimization (VanderPlas 2018). The widespread use of this method warrants its place in the `astropy` package[4], an astronomy package for the Python programming language.

2. Method: Duty Cycle

The Duty Cycle method is a phase–folding periodogram which measures the trial period with the longest continuous inactivity per cycle of a given FRB. This method was introduced by Rajwade et al. (2020) to measure the periodicity of FRB20121102A because of the nature

[4] https://docs.astropy.org/en/stable/api/astropy.timeseries.LombScargle.html

of repeaters to be active within a certain period per cycle. A duty cycle of 56% means that there is a continuous inactivity for 44% of the cycle.

3. Method: Phase Dispersion Minimization

Phase Dispersion Minimization (PDM) is a phase–folding method to determine the periodicity of non–sinusoidal time variation introduced by Stellingwerf (1978). This method computes the variances, `theta`, of the data with respect to mean light curve at each trial periods and minimizes it. It is suitable for small dataset with irregularly sampled observations, such as the repeaters sampled in the CHIME/FRB 2023 Catalog. This paper will use the Python wrapper of this algorithm written in C using the `py-pdm`[5] package.

4. Parameter: Frequency Grid

For this study, we chose a frequency grid of $f_{\mathrm{max}} = (3\ \mathrm{days})^{-1}$ to $f_{\mathrm{min}} = 0.5 * (T_{\mathrm{obs}}\,\mathrm{days})^{-1}$, where T_{obs} is the length of observation (1,007 days). The maximum frequency is chosen such that if the period of FRBs is less than 3 days, we would see it much more often at a daily or bidaily rate. On the other hand, the minimum frequency is chosen such that to minimize the windowing effect near the length of observation. Following the advice of VanderPlas (2018), the frequency grid is chosen such that $N_{\mathrm{eval}} = n_0 T_{\mathrm{obs}} f_{\mathrm{max}}$ where n_0 is chosen to be 7.

B. Uncertainty Estimation

Periodograms do not usually have an associated uncertainty, especially non-Bayesian periodograms. As such, the Lomb–Scargle periodogram is equipped with a False Alarm Probability (FAP) associated at each power level to avoid false positives. However, the same cannot be said about other periodograms. It is treated with a case by case basis. For example, Rajwade et al. (2020) approached the problem by calculating the full width at half maximum of the peak.

[5] https://github.com/ckm3/Py-PDM