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A Fast Folding Algorithm Search for Long-Period Pulsars in Unidentified Bright Radio Sources

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ABSTRACT

We have used a fast folding algorithm to search for radio pulsations at long periods (1 to 30 s) from 75 unidentified radio sources. These sources were originally identified in the NRAO VLA Sky Survey as radio bright, unresolved, and highly linearly polarized, suggesting that they could be previously undetected pulsars. These targets had been observed with the Green Bank 43-m radio telescope and searched for repeating pulses using standard Fourier techniques as well as for dispersed single pulses. This new search of the data is more sensitive to large periods and small duty cycles than the previous Fourier search. We found no promising signals and extend the flux density limit of the original search of ~ 3 mJy to this larger spin period range.

Keywords: Pulsars (1036) — Surveys (1671)

1. BACKGROUND

A pulsar search was conducted by D. Schmidt et al. (2013) which targeted 75 unidentified and unresolved sources from the NRAO VLA Sky Survey (J. J. Condon et al. 1998). These sources were bright (> 15 mJy at 1400 MHz) and had significant linear polarization ($> 5\%$), suggesting that they might be undetected pulsars (perhaps sub-millisecond pulsars) that escaped detection in previous large-scale pulsar surveys. The search observations of these targets were made with the Green Bank 43-m radio telescope at 1200 MHz with observing parameters outlined in D. Schmidt et al. (2013). The data were searched for radio pulsations, including sub-millisecond signals, at dispersion measures (DMs) up to 100 pc cm^{-3}. The full target list is given in Table 1 of D. Schmidt et al. (2013). No convincing periodic signals were detected in this search. A subsequent analysis by F. Crawford et al. (2021) extended the search to higher DMs and a larger range of possible binary accelerations. This latter search also included a single-pulse search that was sensitive to fast transient sources such as rotating radio transients (M. A. McLaughlin et al. 2006) and fast radio bursts (D. R. Lorimer et al. 2007). No astrophysical signals were found in this second search.

We have conducted a third search of these data for long-period pulsars using a Fast Folding Algorithm (FFA), motivated by the recent discoveries of ultra-long-period pulsars and long-period transients with periods ranging from tens of seconds to hours (e.g, N. Hurley-Walker et al. 2022, 2023; M. Caleb et al. 2022, 2024; Y. W. J. Lee et al. 2025). This includes 10 radio pulsars currently

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listed in the ATNF Pulsar Catalog (R. N. Manchester et al. 2005)[3] having spin periods between 10 and 30 s (six of these are recent discoveries from the FAST 500-m radio telescope; J. L. Han et al. 2025), plus the 76-s ultra-long-period pulsar PSR J0901−4046 (M. Caleb et al. 2022). These discoveries have extended the observed period range well beyond the 8.51 s period of PSR J2144−3933 (M. D. Young et al. 1999), the first pulsar observed to lie beyond the so-called pulsar "death line" in the period/surface magnetic field plane (see Fig. 2 of M. D. Young et al. 1999).

Apart from rotating neutron stars, another possibility mentioned by D. Schmidt et al. (2013) is that the radio emission could be produced by rotating white dwarfs (WDs) having strong magnetic fields. WD systems that are tidally locked (polars), such as AM Her (G. Chanmugam & G. A. Dulk 1982) and AR UMa (P. A. Mason & C. L. Gray 2007) have spin/orbital periods of hours, and so would not be detectable in our search. However, a faster-spinning WD, similar to AE Aqr (J. A. Bookbinder & D. Q. Lamb 1987), which has a spin period 33 s (J. Patterson 1979), might be detectable.

The FFA is well-suited for detecting long-period pulsars compared to the Fast Fourier Transform (FFT). It does not suffer from the same degradation in sensitivity from spectral "red noise" at low spin frequencies (long periods). Also, long-period pulsars more commonly have narrow duty cycles (S. Johnston & A. Karastergiou 2019), and this produces many harmonics of the fundamental frequency. In an FFT search, some of these higher-order harmonics might be excluded in the harmonic summing process if their frequencies extend beyond the maximum frequency of the spectrum. The FFA does not have this limitation. A comparison of these two approaches and their relative sensitivities is presented by G. Grover et al. (2024).

2. ANALYSIS AND RESULTS

All 75 targets were processed with the RIPTIDE FFA software package (V. Morello et al. 2020)[4]. The raw filterbank files were first masked for radio frequency interference (RFI) with PRESTO tools(S. M. Ransom 2001; S. M. Ransom et al. 2002) and dedispersed at DM trials between 0 and 100 pc cm^{-3} in steps of 0.03 pc cm^{-3}. This DM range encompassed the expected maximum Galactic DMs along the line of sight for most of the 75 targets (as determined by the NE2001 Galactic electron model of J. M. Cordes & T. J. W. Lazio 2002). Each dedispersed time series was searched with RIPTIDE at trial periods between 1 and 30 s. All candidates with a signal-to-noise ratio greater than 7 were retained and inspected visually.

There were seven instances of promising broadband signals with periods near 11.74 s and with narrow duty cycles. However, several factors indicated they were RFI. All had DMs at or near zero, suggesting a terrestrial origin. Their periods varied slightly (from between 11.741 and 11.749 s), implying millisecond-level differences. Finally, the signals appeared in widely separated telescope pointings, making a single astrophysical source unlikely. The flux density limit from this FFA search for the period range searched ($1 < P < 30$ s) is ~ 3 mJy at 1200 MHz, similar to the limit determined from the Fourier search for canonical pulsar periods (D. Schmidt et al. 2013). Our results extend this flux density limit to larger periods where the sensitivity from the prior Fourier search is degraded relative to the FFA, as discussed above.

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[3] https://www.atnf.csiro.au/research/pulsar/psrcat/

[4] https://github.com/v-morello/riptide