A GBT S Band Search of Low Latitude Fermi Sources for Highly Scattered Pulsars

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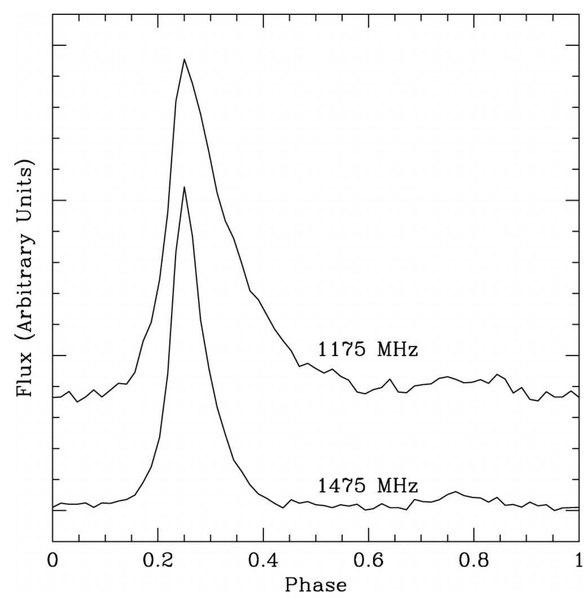
Abstract

We searched 20 unidentified Fermi sources at low Galactic latitudes for highly scattered young pulsars in the Northern sky. We performed ~2 hour observations of each source with the Green Bank Telescope using the S band receiver, choosing sources whose positional uncertainties in 4FGL-DR3 are well covered by the GBT Beam at 2GHz. Systematic uncertainties due to source confusion have previously prevented efficient searches at these higher frequencies. We discovered no new young pulsars in this survey. MSP searches are ongoing. We discuss the implications of this survey for the Galactic population of gamma-ray sources.

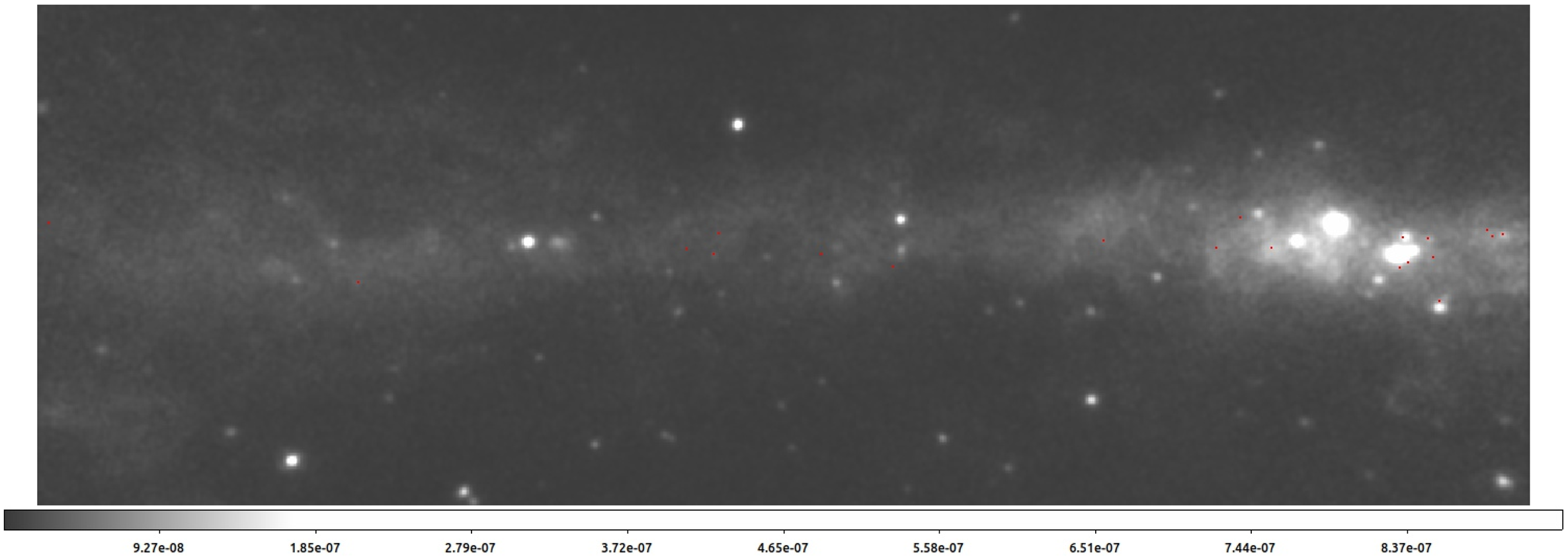
PSR J2021+3651



Hessels et al. 2004

Pulsar Scattering

The first GeV detected radio pulsar at $|b| < 0.2^o$ was PSR J2021+3651 in the Cygnus region. It has ~18ms of scattering at 1 GHz. (Hessels et al. 2004), about 4 times what Galactic models predict (NE2001,YMV16). Since scattering scattering time $\tau \propto \nu^{-4}$ (Bhat et al. 2004, Oswald et al. 2021), it would not have been discovered at frequencies below 1~GHz. A search of three EGRET sources near $l = 310^o$ at 6.3 GHz (O'Brien et al. 2008) discovered the energetic PSR J1410-6132 which was too highly scattered to be detectable at 1400 MHz. There is no observational way to reduce scatter save for observing at higher frequencies.



Pulsar Searches of Fermi Sources

Targeted radio searches of Fermi sources have been notoriously poor at finding new young pulsars, with only 8 of the around 110 pulsars reported in public lists from the Pulsar Search Consortium being young, with the rest being MSPs. The Green Bank Telescope (GBT) and Arecibo have searched mainly at low frequencies (< 1 GHz) so the beams would well cover Fermi source positional errors. The Parkes Galactic Plane Survey had searched low-latitudes with 35 minute L band pointings making difficult increased sensitivity with Parkes. MEERKAT greatly increases sensitivity towards sources in the South, but operates only up to L band. FAST also only operates up to L band and cannot access the sky North of 65º.

Table 1. Observed *Fermi* sources

4FGL-DR3 Name	R.A. J2000	Dec. J2000	l	b	Exposure	Max DM
	h:m:s	d:m:s	deg.	deg.	sec	pc cm^{-3}
4FGLJ0034.6+6438	00:34:38.9	+64:38:21	121.13	1.83	6468	357
4FGLJ0039.1+6257	00:39:08.7	+62:57:37	121.54	0.12	9271	333
4FGLJ0057.9+6326	00:57:58.9	+63:26:19	123.66	0.58	6935	336
4FGLJ0340.4+5302	03:40:26.4	+53:02:11	146.79	-1.82	6946	269
4FGLJ0501.7+4459	05:01:45.5	+44:59:30	161.84	1.86	6677	284
4FGLJ2004.3+3339	20:04:23.0	+33:39:19	70.68	1.20	6139	501
4FGLJ2004.9+3421	20:04:59.6	+34:21:02	71.33	1.46	6142	503
4FGLJ2005.8+3357	20:05:53.8	+33:57:22	71.10	1.09	6706	500
4FGLJ2013.5+3613	20:13:32.3	+36:13:31	73.85	1.02	7121	499
4FGLJ2016.2+3712	20:16:13.7	+37:12:47	74.97	1.12	7095	500
4FGLJ2017.3+3525	20:17:23.8	+35:25:21	73.62	-0.08	7201	455
4FGLJ2021.9+3609	20:21:56.7	+36:09:28	74.75	-0.43	7092	435
4FGLJ2024.2+3616	20:24:14.9	+36:16:09	75.11	-0.74	6755	416
4FGLJ2027.0+3343	20:27:04.9	+33:43:20	73.36	-2.69	6434	345
4FGLJ2035.6+4451	20:35:39.3	+44:51:03	83.32	2.55	6892	487
4FGLJ2038.4+4212	20:38:30.0	+42:12:31	81.53	0.54	6789	469
4FGLJ2049.3+4440c	20:49:22.2	+44:40:37	84.69	0.52	7084	458
4FGLJ2114.3+5023	21:14:21.5	+50:23:57	91.76	1.15	6107	451
4FGLJ2247.5+5812c	22:47:33.2	+58:12:10	107.20	-0.83	6952	342
4FGLJ2326.5+6122	23:26:34.8	+61:22:06	112.95	0.15	4879	354

NOTE—Observations were taken in November 2023 and January 2024, and generally covered the 95% confidence error contour within the GBT S band half power diameter. Maximum DMs for these directions were calculated using PYGEDM based on either the YMW16 or NE2001 free electron models, whichever gave a larger value.

A GBT Search for Scattered Pulsars

In November of 2023 and January of 2024 we observed 20 4FGL sources with the GBT S band receiver and VEGAS spectrometer at a central frequency of 2165 MHz with an effective bandwidth of ~800 MHz. The polarizations were summed and the data sampled with a time resolution of 87.38μs in 4096 0.366 Mhz wide channels. The data was analyzed with PRESTO (Ransom 2001). After RFI excision, we downsampled the data in time by a factor of 8, for an effective time resolution of ~0.7ms. We dedispersed the data into 980 time series corrected for dispersion measures (DMs) ranging from 20-999 pc cm^{-3} in steps of 1. These were searched using the program *accelsearch* between periods of 10 ms and 1 s, summing 16 harmonics and doing a very mild acceleration search (parameter zmax=4). Candidates were folded and examined manually.

Source Positions

Low frequency surveys are biased against highly scattered pulsars. Since radio beam sizes are inversely proportional to frequency, accurate pointing positions are needed. 95% confidence Fermi error boxes of low-latitude sources smaller than the GBT S Band beam (~6.3' @ 2GHz) have been available since 1FGL, but systematic errors due to source confusion and deficiencies in the diffuse Galactic emission models made these unreliable. In September 2010 we observed 15 1FGL sources whose errors were well matched to the GBT S Band but only 3 of those pointings have 4FGL-DR3 sources within their beams. With more than 12 years of data and improved background models, low-latitude 4FGL-DR3 source positions may be reliable enough for targeted high frequency surveys.

References and Acknowledgements

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This work was partially supported by NASA Award Number 80NSSC23K1493

This material is based upon work supported by the Green Bank Observatory which is a major facility funded by the National Science Foundation operated by Associated Universities, Inc.

Results

Unfortunately, no strong pulsar candidates have so far been discovered in these data.

Currently, ~1/2 of the Galactic Plane Fermi pulsars have only been detected in γ-rays despite deep searches in radio of many of these sources, presumably because their radio beams are pointed away from us. However, deep searches of PWN suggest that around 1/4-1/2 of the youngest, most energetic pulsars should be detectable. This survey should have been sensitive to young pulsars at a flux level similar to some of the faintest pulsars known (~20-25 μJy). However, it would have missed any pulsars scattered as highly as the recently discovered PSR J1813-1749 in the supernova remnant G12.82-0.02 (Camilo et al. 2021).

Full resolution acceleration searches for MSPs in these data are ongoing.