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Breakthrough Listen Search for the WOW! Signal*

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Abstract

Caballero identified the star 2MASS19281982-2640123 as a potential Sun-like star from which the WOW! signal could have originated. We conducted a search for artificial narrowband (2.79Hz/1.91Hz), drifting ($\pm 4\text{Hz s}^{-1}$) technosignatures from this source using the TURBOSETI pipeline, from 1–2GHz, using simultaneous multi-telescope observations with both the Robert C. Byrd Green Bank Telescope and the newly refurbished Allen Telescope Array on 2022 May 21. Both telescope observations had an overlap of 580s. While blind searches using radio telescopes have been conducted in the general field of view in which the WOW! signal was first detected, this is the first time a targeted search has been done. No technosignature candidates were detected.

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1. Introduction

The WOW! Signal was a bright anomaly detected in the radio spectrum on 1977 August 15 by the Ohio State University's Big Ear radio telescope (Kraus 1979). It was observed near the 21 cm hydrogen line at 1420.4556 ± 0.005 MHz (Ehman 1998), lasted for 72 s, and has not been redetected in subsequent observing campaigns (e.g., Gray 1994; Harp et al. 2020). The telescope's two feed horn design introduces a degeneracy, such that it is not known in which horn the signal was detected.

Using data from the Gaia archive, Caballero (2022) identified a Sun-like star within the WOW! Signal region. The author used effective temperature ($4450 \text{ K} < T_{\text{eff}} < 6000 \text{ K}$), radius ($0.83 < R_{\odot} < 1.15$), and luminosity ($0.34 < L_{\odot} < 1.5$) thresholds on the thousands of Gaia objects located inside the horns' span and found 38 and 28 K- and G-type stars for the positive and negative horns, respectively. Only one of these is Sun-like: 2MASS19281982-2640123. According to Gaia DR2, this star has an estimated temperature of $T_{\text{eff}} = 5783 \text{ K}$, a radius of $0.9965662 R_{\odot}$, and a luminosity of $1.0007366 L_{\odot}$ (Gaia Collaboration et al. 2016, 2018).

We describe observations and analysis of 2MASS19281982-2640123 using both the Green Bank Telescope (GBT) and the Allen Telescope Array (ATA) as part of the Breakthrough Listen (BL) search for technosignatures (Isaacson et al. 2017; Worden et al. 2017; Gajjar et al. 2019). Following the signal verification framework developed from BL's first signal-of-interest (Sheikh et al. 2020; Smith et al. 2021), these simultaneous observations represent an attempt to prepare for verification in the case that future candidate technosignatures are identified by either telescope individually.

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2. Observations

2.1. GBT

We observed 2MASS19281982-2640123 with the GBT beginning on UT 2022 May 21 10:29:44. We observed two consecutive ABACAD cadences, where the "A" or "ON" observation was centered on the target's J2000.0 ephemeris ($19^{\text{h}}28^{\text{m}}19.^{\text{s}}8$, $26^{\circ}40'12''.6$), and the "B," "C," and "D," or "OFF" observations picked secondary sources at least 5 beam widths away from the primary target. Observations were recorded using the BL backend (MacMahon et al. 2018). Raw voltage data were reduced using the standard BL data reduction pipeline (Lebofsky et al. 2019).

2.2. ATA

We observed 2MASS19281982-2640123 with the ATA for six 5 minutes pointings, beginning on UT 2022 May 21 10:40:57. We used 20 antennas and a newly deployed beamformer backend (Farah et al. 2022, in preparation) to synthesize 2 coherent beams, one centered on the target, and another placed $0^{\circ}8$ ($\sim 13\times$ full-width half-maximum of the synthesized beam) away in both R.A. and decl.

All data are available online.¹⁰ Table 1 shows the observational parameters for both telescopes. The mean system temperature is determined from observations of 3C295 for the GBT and 3C286 for the ATA.

Table 1. Observational Parameters and Calculated Values for Both Telescopes at L-band

Sensitivity Limits							
Telescope	Frequency	Start Time	End Time	Measured	SEFD	10σ Detectable Flux	10σ EIRP limit
	Range (GHz)	(UTC)	(UTC)	T_{sys} (K)	(Jy)	Density Limit (Jy)	(10^{12} W)
GBT	0.94–2.06	10:29:44	11:32:01	16.9	8.2	5.6–146.3 ^a	201–5261 ^a
ATA	1.064–1.736	10:40:57	13:29:51	51	335.1 ^b	189.1–415.7 ^a	6800–14848 ^a

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^a The span of our limit, dependent on our dechirping efficiency due to signals at high drift rates spreading across multiple channels, which reduces our sensitivity. The lower bound applies to all drift rates $|\dot{\nu}| \leq 0.15 \text{ Hz s}^{-1}$ and $|\dot{\nu}| \leq 1.82 \text{ Hz s}^{-1}$ for the GBT and ATA, respectively, while the high bound applies to our maximum drift rate $|\dot{\nu}| = 4 \text{ Hz s}^{-1}$. ^b Computed for the output of the coherent beamformer with 20 ATA antennas.

3. Results and Discussion

To test our recording pipeline and sensitivity, we simultaneously observed, and detected, PSR1932+1059 with both telescopes (figures on website). The detection signal-to-noise (S/N) ratio of the pulse profiles follows expectations based on sensitivity estimations of both telescopes, and the pulsar's flux density.

We used TURBOSETI to search for narrowband signals over a Doppler drift rate range of $\pm 4 \text{ Hz s}^{-1}$ and a S/N threshold of 10 with the high spectral resolution data products (GBT: $\sim 2.79 \text{ Hz} / \sim 18.25 \text{ s}$, ATA: $\sim 1.91 \text{ Hz} / \sim 1.05 \text{ s}$), broadly following the steps described by Price et al. (2020) and Sheikh et al. (2020). For the GBT, a continuous, celestially localized signal associated with pointings toward 2MASS19281982-2640123 would appear in all 3 of the ON observations and in none of the OFF observations. We do not see any signals with this behavior: all of our 507 potential candidates appear in at least one OFF observation, which rules out spatially isolated signals in the direction of 2MASS19281982-2640123. For the ATA, the second beam was placed sufficiently far from the on-source ($1^\circ 13'$) that it can be treated as an "OFF" observation; thus any potential signal from the direction of 2MASS19281982-2640123 should only appear in the first beam. All of the ~ 9000 events detected appeared in both beams, suggesting that they are due to local RFI.

Using 2MASS19281982-2640123's distance of 1788^{+19}_{-19} light years from Gaia's DR3 (Gaia Collaboration et al. 2016, 2021), Equations (3)–(4) of Enriquez et al. (2017), and our calibrated system equivalent flux density (SEFD), we calculated the minimum detectable flux density for a 300s observation using a 10σ threshold. Using Enriquez et al. Equations (5)–(7), we derived an upper limit for the EIRP (Equivalent Isotropic Radiated Power) of a hypothetical transmitter with an intrinsically narrow spectral width of 1 Hz (see Table 1).

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After visual inspection of our candidates, we find no trace of the WOW! signal. Using Caballero (2022)'s filtering criteria from earlier, with their more stringent temperature of $5730\text{K} < T_{\text{eff}} < 5830\text{K}$ for Sun-like stars, there are actually a total of 8 Sun-like stars within the WOW! signal uncertainty region. Additionally, using effective temperature as the only criteria ($3500\text{K} < T_{\text{eff}} < 6000\text{K}$), we find as many as 602 sources (262 for which radius and luminosity are known). F- and M-type stars have also been suggested as having the potential to host habitable environments (Tarter et al. 2007; Sato et al. 2014; Shields et al. 2016), so these cannot be ruled out. There remain a significant number of sources that are either Sun-like and/or pass the criteria for having a habitable zone, and future observations could target these in followup of the WOW! Signal.

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Footnotes

* Dedicated to the memory of Bart S. Wlodarczyk-Sroka.

10 <https://seti.berkeley.edu/wow>

11 <http://breakthroughinitiatives.org>

