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Breakthrough Listen Observations of 3I/ATLAS with the Green Bank Telescope at 1–12 GHz

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ABSTRACT

3I/ATLAS, an interstellar object, made its closest approach to Earth, at ∼1.8 AU, on 2025 December 19. On 2025 December 18, the Breakthrough Listen program conducted a technosignature search toward 3I/ATLAS using the 100 m Robert C. Byrd Green Bank Telescope at 1–12 GHz. We report a nondetection of candidate signals down to the 100 mW level.

Keywords: interstellar objects — technosignatures — search for extraterrestrial intelligence

1. INTRODUCTION

3I/ATLAS (also designated C/2025 N1 (ATLAS) and, formerly, A11pl3Z) is the third interstellar object (ISO), following 1I/'Oumuamua and 2I/Borisov, to be discovered during a passage through the Solar System. The Asteroid Terrestrial-impact Last Alert System (ATLAS) reported its discovery on 2025 July 1 (S. Deen et al. 2025).

Unlike 1I/'Oumuamua, 3I/ATLAS exhibits mostly typical cometary characteristics (S. Deen et al. 2025), including a coma and no evidence for an elongated nucleus. There is currently no evidence to suggest that ISOs are anything other than natural astrophysical objects. However, given the small number of such objects known (only three to date), and the plausibility of interstellar probes as a technosignature (e.g, R. A. Freitas & F. Valdes 1985), thorough study is warranted (see J. R. A. Davenport et al. 2025). Putative nonanthropogenic interstellar probes are likely to communicate via narrowband radio signals for transmission efficiency and for the low extinction of such signals across interstellar space; all of humanity's spacecraft, including the now-interstellar craft *Voyager 1* and *Voyager 2*, communicate via such signals.

The Breakthrough Listen (BL) program observed 3I/ATLAS using the 100-m Robert C. Byrd Green Bank Telescope (GBT) on UT 2025 December 18, ∼1 day before the ISO's closest approach to Earth. Similar technosignature searches have recently been undertaken by S. Z. Sheikh et al. (2025) and D. J. Pisano et al. (2025) over different frequency ranges and with different sensitivities. Like those searches, we find no credible detections of narrowband radio technosignatures originating from 3I/ATLAS.

2. OBSERVATIONS

Our GBT observations cover four bands of the radio spectrum, each with a different receiver: L (1.1–1.9 GHz), S (1.8–2.7 GHz), C (4.0–7.8 GHz) and X (7.6–11.7 GHz). With each receiver, we observed a 30-min cadence: three 5-min on-target pointings interspersed with three 5-min off-target pointings in an ABACAD arrangement. All observations were conducted between UT 04:15 and 09:15 on 2025 December 18. Our observations and analysis used an ephemeris from the Jet Propulsion Laboratory's `Horizons` tool.[8]

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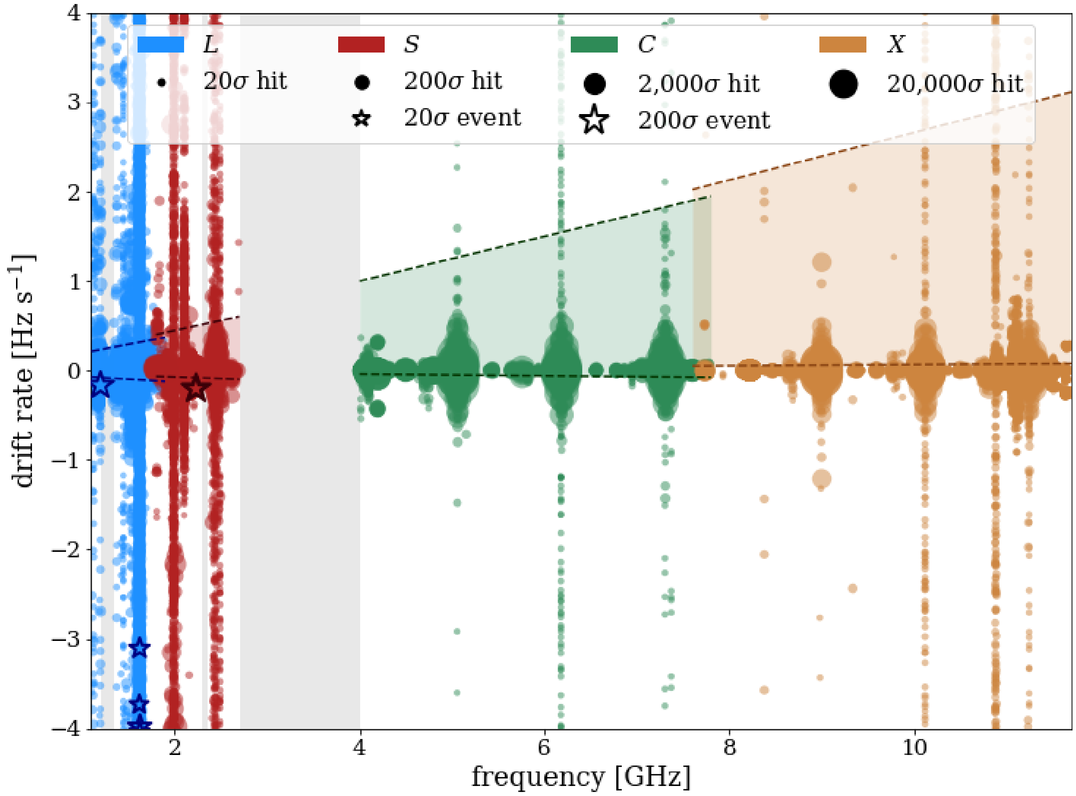

Figure 1. Distribution of hits (circles) and events (stars) over frequency and drift rate. The marker size gives the S/N. The gray-shaded regions show ranges not sampled, including narrow notch filter regions in the *L* and *S* bands. The color-shaded regions give the range of drift rates expected from Earth's orbital motion and rotational motion and 3I/ATLAS's rotation at each of the four observing bands. These regions do not perfectly align between bands due to 3I/ATLAS's radial acceleration changing during overhead time between observations. No events lie in the expected drift rate regions.

We used the BL back end (D. H. E. MacMahon et al. 2018; M. Lebofsky et al. 2019) to digitize the data and the software `turboSETI` (E. Enriquez & D. Price 2019) to conduct our signal search. We refer the reader to M. Lebofsky et al. (2019) for an overview of our observing strategy and to J. E. Enriquez et al. (2017) and C. Choza et al. (2024) for further details on `turboSETI`.

3. RESULTS

The BL back end channelizes our observation data to 2.8 Hz resolution. Using `turboSETI`, we search for signals above a $\sim 16\sigma$ threshold (corresponding to a software input threshold of 5σ; see C. Choza et al. 2024) in a drift rate range of $\pm 4\,\mathrm{Hz\,s^{-1}}$. We use a lower threshold, 10σ (software input 3σ), for off-target scans to discourage the "detection" of candidates with slightly less power in those scans. We find 471,198 "hits," or drifting signals above 16σ (for on-target scans) or 10σ (for off-target scans). After applying the sky localization filter on the full ABACAD cadences, which removes all candidates that appear in one or more off-target scans, we are left with nine "events."

Figure 1 shows the distribution of hits and events over frequency and drift rate, with marker size encoding signal-to-noise ratio (S/N). The shaded regions give the range of drift rates expected due to Earth's rotational and orbital motion and 3I/ATLAS's rotation (R. de la Fuente Marcos et al. 2025), assuming an unmodulated transmission. Overdensities in frequency correspond to known bands of high radio-frequency interference (RFI) contamination. We visually inspect the nine events and, due to their appearance in the off-target scans and/or congruence to known contaminants, classify all of them as RFI, ruling out any potential extraterrestrial technosignatures.

[8] https://ssd.jpl.nasa.gov/horizons/

We place new constraints on the existence of radio transmitters at the location of 3I/ATLAS. The minimum flux density detectable using our survey, assuming an unresolved signal, is (V. Gajjar et al. 2021)

$$S_{\rm min} = \frac{({\rm S/N})_0}{\beta} \frac{\rm SEFD}{\delta\nu_t} \sqrt{\frac{\delta\nu}{n_{\rm pol}\,\tau_{\rm obs}}}, \tag{1}$$

where $({\rm S/N})_0$ is the S/N threshold of the survey (16); SEFD is the system equivalent flux density of the receiver (10–15 Jy); $\delta\nu_t$ is the transmitted signal width (assumed to be $\sim$1 Hz); $\delta\nu$ is the survey frequency resolution (2.8 Hz); $n_{\rm pol}$ is the number of polarizations (2); $\tau_{\rm obs}$ is the length of an observation (300 s); and β is a dedrifting efficiency parameter that accounts for loss due to signal smearing at high drift rates. The effective isotropic radiated power (EIRP) corresponding to a flux density S is

$$\text{EIRP} = 4\pi d^2 S\,\delta\nu_t, \tag{2}$$

where d is the distance of the transmitter ($\sim$1.8 AU for 3I/ATLAS during our observations; only $\sim$0.0005 AU off from closest approach). Our survey concludes that there are no isotropic continuous-wave transmitters above 0.1 W at the location of 3I/ATLAS. For comparison, a cell phone is an approximately isotropic continuous-wave transmitter at a level of $\sim$1 W.

All data collected by BL will be publicly available. The observations described here can be downloaded from the Breakthrough Listen Data Portal.

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