Draft version October 18, 2021
Typeset using LaTeX **RNAAS** style in AASTeX63

No Redetections of blc1 in 39 Hours of Reobservation Campaigns of Proxima Centauri

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ABSTRACT

In April 2019, radio observations of Proxima Centauri were performed with the UWL Receiver on the Parkes Telescope. A narrowband radio search of these data revealed a technosignature signal-of-interest reported as 'blc1' at 982.002 MHz. After the initial discovery of blc1 in the data in October 2020, we performed a series of reobservations over the next 6 months, totalling 39 hours of on-sky time. We do not redetect blc1, or find any other signals-of-interest, within ± 1 MHz of 982.002 MHz in this dataset. Taken in context, this null result implies that blc1 was transient radio frequency interference, makes it less consistent with a periodic transmission, and makes it less consistent with interstellar scintillation.

Keywords: SETI — technosignatures — RFI

INTRODUCTION

From 2019 April 29 to May 4, the Breakthrough Listen (BL) project performed observations of Proxima Centauri (ProxCen) with the CSIRO Parkes "Murriyang" telecope using the Ultra-Wideband Low (UWL) receiver (0.704–4.032 GHz), as part of an international multi-wavelength campaign to monitor ProxCen for stellar flares (Zic et al. 2020). In parallel with the stellar flare analysis, the Breakthrough Listen team analyzed the data with the narrowband technosignature search pipeline `turboSETI` (Enriquez et al. 2017) to place limits on the prevalence of radio technosignatures, remotely-detectable radio emissions produced by extraterrestrial intelligences (ETIs), in the direction of ProxCen (Smith et al. 2021). This pipeline returned a narrowband signal-of-interest now known as "blc1", whose discovery and characterization are detailed in Sheikh et al. (2021). Based on the characteristics of the signal's drift rate, the occurrence of similar radio frequency interference (RFI) in the days prior to and following the detection, and the presence of RFI intermodulation products with identical morphologies across the band, Sheikh et al. (2021) concluded that blc1 was most likely human-generated RFI and not a technosignature from ETI. The BL project also performed a series of reobservations of ProxCen using the same instrument and receiver (Murriyang, UWL) to attempt to redetect blc1.

OBSERVATIONS

All data from the initial campaign and the reobservations are available at seti.berkeley.edu/blc1. In Table 1, we list all observations of ProxCen taken by BL with Murriyang UWL. There is one additional archival observation on UTC 2018-10-06, prior to the installation of the UWL on Murriyang, but this observation did not cover the 982 MHz region and is thus not included.

The observational choices made in the original flare campaign were made to optimize flare detections, with a majority of time pointed toward ProxCen (30 minutes/pointing), with 5-minute off-source pointings toward flux calibrator

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Context	UTC Date	$T_{integration}$	Δt	$\Delta \nu$	$T_{total,PC}$
Flare campaign during which blc1 was detected	**2019-04-29** 2019-04-30* 2019-05-01* 2019-05-02* 2019-05-03 2019-05-04*	30 min	16.8 s	3.81 Hz	24 hr
November 2020 re-observations of opportunity	2020-11-19 2020-11-25 2020-11-30	15 min	15 s	2 Hz	3 hr
January 2021 re-observations of opportunity	2021-01-04 2021-01-05 2021-01-07 2021-01-13	15 min	15 s	2 Hz	5 hr
April 2021 two-year anniversary reobservation campaign	2021-04-29 2021-04-30 2021-05-01 2021-05-02 2021-05-03	30 min	15 s	2 Hz	21 hr

Table 1. All observations of ProxCen taken with the Parkes telescope as part of BL, with $T_{integration}$ as the on-source (ProxCen) integration time per scan, Δt as the time resolution of the observation, $\Delta \nu$ as the frequency resolution of the observation, and $T_{total,PC}$ as the total amount of time spent on ProxCen. Bandwidth for all observations was 704–4032 MHz. The bolded date indicates the appearance of blc1, while the dates with * indicate reappearances of a similar, though not provably identical, signal.

sources. The higher $T_{\rm sys}$ for calibrator pointings, and uneven split between on and off-source pointings, are non-ideal for standard radio interference detection techniques employed in single-dish SETI observations.

We thus changed the observing cadence and parameters in the November 2020 and January 2021 reobservations (NOV20 and JAN21) to account for some of these choices, including making the on-source and off-source scans the same length; using off-source positions devoid of strong discrete sources; and using off-sources nearer to the target. For NOV20 and JAN21, we used a 15-minute ABACAD observing cadence; ProxCen (the A target) was observed for 15 minutes, then a nearby off-source star was observed for 15 minutes, then this cycle was repeated twice, with a different off-source star chosen each time.

For the April 2021 reobservation campaign (APR21), we chose instead to replicate the exact same observing script as the original 2019 observations, to maximize the chances of redetection with the same interference and/or astronomical environment. At the end of each day of observing, we visually-inspected the 982 MHz region of the ProxCen scans; in the event of something resembling a redetection, we would switch to the more technosignature-optimized ABACAD cadence described above. This did not occur, and we used the replicated cadence for all five days of APR21.

In APR21, we enabled the UWL noise-adding radiometry (NAR) system, which periodically injects a signal from a calibrated noise source. This slightly increases the receiver temperature ($\sim$10%), but the signal can be used to better calibrate the gain stability of the receiver over long timescales. For the narrowband search presented here, NAR calibration was not required.

As described in the table, all of the reobservations had a slightly higher frequency resolution (2 Hz) and slightly better time resolution (15s) than the original flare campaign.

DATA ANALYSIS

To evaluate whether we redetected a similar signal to blc1, we used the same software, `turboSETI`, to search for narrowband signals near 982.002 MHz. We ran the software on all ProxCen scans from NOV20–APR21, searching for signals with a minimum drift of 0 Hz/s, a maximum absolute drift of 0.1 Hz/s (blc1's maximum drift was 0.03 Hz/s), and a signal-to-noise ratio (SNR) of at least 10, commensurate with the original search.

We inspected the full-cadence dynamic spectrum plots of the 2196 hits that were returned by the `turboSETI` pipeline. All of these hits were RFI, and none resembled blc1 in drift morphology or variability. Only 3 of these hits were within ±1 kHz of blc1's original detection frequency; all three were triggers on broadband RFI that was present in APR21 and were clearly caused by a different phenomenon than blc1. Thus, there were no redetections of blc1 in the 39 hours of BL ProxCen reobservations.

UPPER LIMITS

We can calculate the minimum detectable flux densities for a narrowband radio technosignature search using Equation 4 from Gajjar et al. (2021):

$$S_{\mathrm{min,narrow}} = \frac{SNR_{\mathrm{min}}}{\beta} \frac{S_{\mathrm{sys}}}{\delta\nu_t} \sqrt{\frac{\delta\nu}{n_p \tau_{\mathrm{obs}}}} \tag{1}$$

Our search had the following characteristics:

- $SNR_{\mathrm{min}} = 10$ (detection threshold)
- $\beta = 1$ (dechirping efficiency with all drift rates below the one-to-one point, from Sheikh et al. 2019)
- $S_{\mathrm{sys}} = 40$ Jy (system equivalent flux density for UWL)
- $\delta\nu_t = 1$ Hz (fiducial narrowband transmission frequency < 3 Hz, from blc1's measured width)
- $\delta\nu = 2$ Hz (frequency resolution)
- $n_p = 1$ (number of polarizations)
- $\tau_{obs} = [15, 30]$ minutes (on-source observation time for [NOV20/JAN21, APR21] respectively)

This leads to a minimum detectable flux density $S_{\mathrm{min}} = 32$Jy for NOV20 and JAN21 and $S_{\mathrm{min}} = 13.34$Jy for APR21, corresponding to EIRPs ($EIRP = S_{\mathrm{min}} \times 4\pi d^2$, where d is 4.221 ly, the distance to ProxCen) of 6.4 GW and 2.6 GW respectively. APR21 was therefore more sensitive than the original observations due to its equivalent τ_{obs} and better $\delta\nu$.

The distribution of our observing hours was not uniform throughout the year, but instead in clumped sessions. The original observing campaign showed a signal present for at least 5 hours on a single day, with no definitive redetections on any of the other 5 days of the campaign, ruling out a continuous or daily periodicity.[1] APR21 rules out exactly annual or biennial periodicities for blc1. NOV20 and JAN21 make repetitions seem unlikely on the scales of weeks–months. We thus find no evidence that blc1 is a repeating signal on yearly timescales or shorter, but did not cover the entire periodicity space.

We can use the additional observations to even further constrain the likelihood that the signal was interstellar, using expectations from diffractive interstellar scintillation (DISS) calculations. Narrowband radio signals of interstellar origin will vary from DISS if they are more distant than $\sim$ 100 pc. While they are not relevant to a source at ProxCen's distance, they would be significant for background sources and could cause a weak source to be raised above threshold or a strong source below (Cordes et al. 1997). DISS of an orbiting transmitter will correlate for an hour or more but less than a day and thus would be statistically independent between epochs given in Table 1. It is highly improbable for an intrinsically steady source be detected in one to six initial observations followed by 12 non-detections. It should be noted that plasma lensing from a discrete cloud could produce highly episodic signal modulations, which makes DISS a highly improbable effect for these data, but not an impossible one.

ACKNOWLEDGEMENTS

Breakthrough Listen is managed by the Breakthrough Initiatives, sponsored by the Breakthrough Prize Foundation. Shane Smith and Steve Croft were supported by the National Science Foundation under the Berkeley SETI Research Center REU Site Grant No. 1950897.

[1] There were occurrences of very similar RFI to blc1 on four days during the original campaign as described in Sheikh et al. (2021). If these are considered the same signal, as we think is likely, then blc1 was continuous or daily for about a week before it was never seen to repeat again.

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