

Breakthrough Listen Follow-up of a Transient Signal from the RATAN-600 Telescope in the Direction of HD 164595

Steve Croft, Andrew Siemion, David MacMahon, Matt Lebofsky, Howard Isaacson, Jack Hickish, Danny Price, Dan Werthimer, Vishal Gajjar, and David DeBoer

Berkeley SETI Research Center¹, Astronomy Department, 501 Campbell Hall, University of California, Berkeley

1 Introduction

HD 164595 (also known as HIP 88194) is a Sunlike (G2V) star at a distance of 28.9 pc from Earth, with one confirmed ($16M_{\oplus}$) planet (Courcol et al. 2015) orbiting with a 40 day period. Recently, a SETI² search using the RATAN-600 telescope is reported (Bursov et al. 2016) to have detected a strong (~ 750 mJy) signal in the direction of HD 164595. Slides from a presentation scheduled to be delivered on 2016 September 27 at the International Academy of Astronautics (IAA) SETI Permanent Committee meeting, were forwarded to the UC Berkeley *Breakthrough Listen* team by one of the RATAN study's co-authors. A plot showing the scan at 11.1 GHz across the source where the transient signal was detected is shown in Fig. 1. While we await with interest a formal write-up of the RATAN-600 result, the claim that the detection could be a signal from an extraterrestrial civilization has attracted much media interest. In this memo, we briefly report on our own follow-up observations, undertaken using the new *Breakthrough Listen* back-end instrument at the Green Bank Telescope (GBT). This preliminary analysis will be followed up in time with a more formal refereed publication of the initial scientific results from *Breakthrough Listen*.

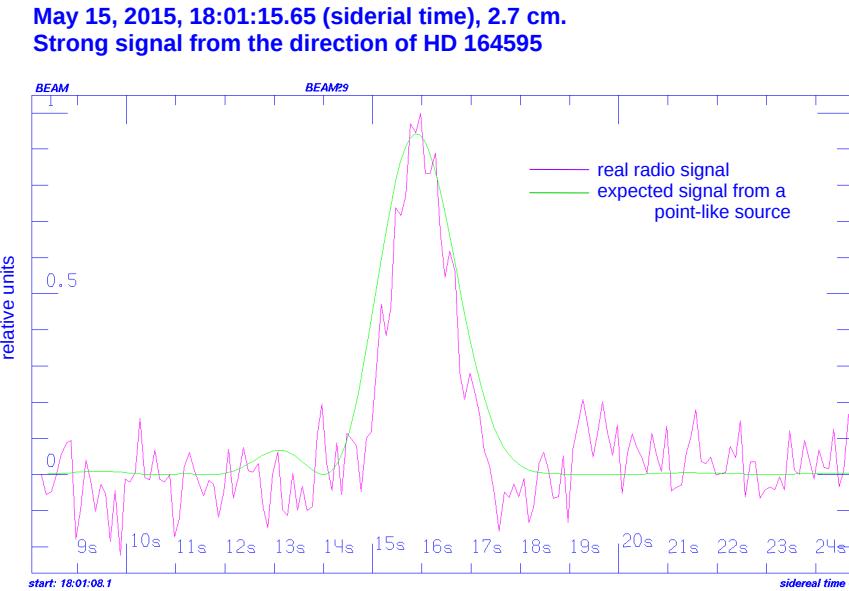


Figure 1: Figure from Bursov et al. (2016) showing the RATAN drift scan in which the transient was detected.

2 Archival Data

We searched the NVSS catalog (Condon et al. 1998) for possible quiescent counterparts to the RATAN transient. The NVSS observing frequency (1.4 GHz) is significantly different from the frequency (11.1 GHz) at which the RATAN transient was detected. However, the sensitivity of NVSS (completeness limit ~ 2.5 mJy) is such that any astrophysical source with a plausible spectral index that is detected at 750 mJy at 11.1 GHz would also be easily detected at 1.4 GHz, even if it had varied by factors of 100 or more.

No NVSS counterpart is seen at the position of the claimed RATAN transient (Fig. 2). The closest NVSS source to the position is a 3.5 mJy source at a distance of 5''. The positional uncertainty of the RATAN transient is not reported in the presentation by Bursov et al. (2016); however, typically the beam of RATAN-600 is a few tens of arcseconds at these frequencies (Tokhchukova et al. 2014) and so positional uncertainties for a bright point source

¹<http://seti.berkeley.edu>

²Here "SETI" refers to the search for extraterrestrial intelligence as a field of scientific research, rather than a specific research institution such as the SETI Institute or Berkeley SETI Research Center

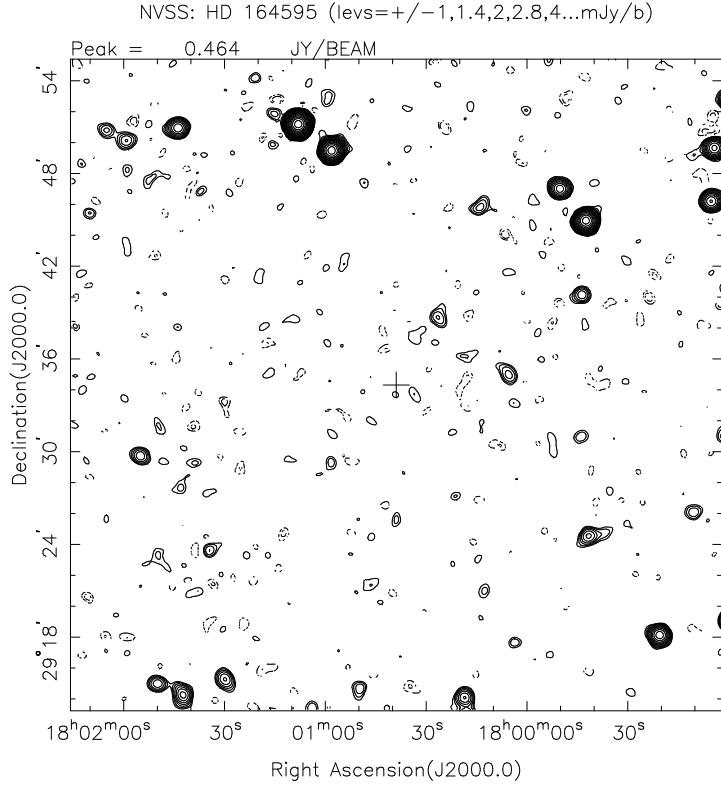


Figure 2: $0.^{\circ}7 \times 0.^{\circ}7$ contour plot from NVSS at 1.4 GHz showing the region surrounding the transient candidate.

should be around a few arcseconds.

A number of authors have surveyed the sky at GHz frequencies in search of transient radio sources. Note that such continuum imaging surveys do not distinguish *a priori* between different categories of transients (including scintillating active galactic nuclei, gamma ray bursts, tidal disruption events, stellar flares, and transient emission from extraterrestrial intelligence). In other words, we can compare the inferred rate of transients extrapolating from transient reported by Bursov et al. (2016) to the limits from the literature.

Although precise comparisons of rates from different surveys are difficult due to different survey parameters (frequency, cadence, area surveyed, Galactic latitude, etc.), the limits obtained by various authors are broadly consistent. A recent compilation at 1.4 and 5 GHz frequencies is shown in Fig. 3. Transient snapshot rates (also referred to as surface densities) at a few hundred mJy are $\lesssim 10^{-4} \text{ deg}^{-2}$. In other words, the entire sky would have to be surveyed in order to detect approximately one transient at such flux densities.

Even if the RATAN transient candidate is not due to natural astrophysical processes, but is instead artificial emission from a civilization in the vicinity of HD 164595, its detection can be used to infer a rate for such continuum transients. The overall parameters (area surveyed, sensitivity, etc.) of the RATAN search are not reported by Bursov et al. (2016), but they note that only one transient was seen out of 510 transits of 31 stars on their target list, with each transit lasting 2 seconds (corresponding to $\lesssim 0.5'$ in right ascension, i.e. consistent with the beam size, as expected). If we assume that the total area covered as part of the SETI search is 510 targets multiplied by the beam area ($0.5' \times 0.5'$), this yields a transient snapshot rate of $\gtrsim 10 \text{ deg}^{-2}$, inconsistent with rates from the literature by 5 orders of magnitude.

If instead we assume a stellar density of around 0.1 pc^{-3} , we find ~ 10000 stars in the solar neighborhood at least as close as HD 164595. Assuming the transients do not vary in luminosity, and extrapolating from one source seen by RATAN in 510 snapshots, we obtain a snapshot rate of ~ 20 events at least this bright across the whole sky. This is a snapshot rate of $\sim 10^{-3} \text{ deg}^{-2}$, still inconsistent with the literature rates by an order of magnitude.

In other words, if the RATAN transient is real, such events ought to have been seen by previous surveys. It appears therefore that Bursov et al. (2016) were either extremely lucky to detect this source in their observations, or that the transient is due to local interference or other calibration issues. Nevertheless, as a candidate SETI signal we judged

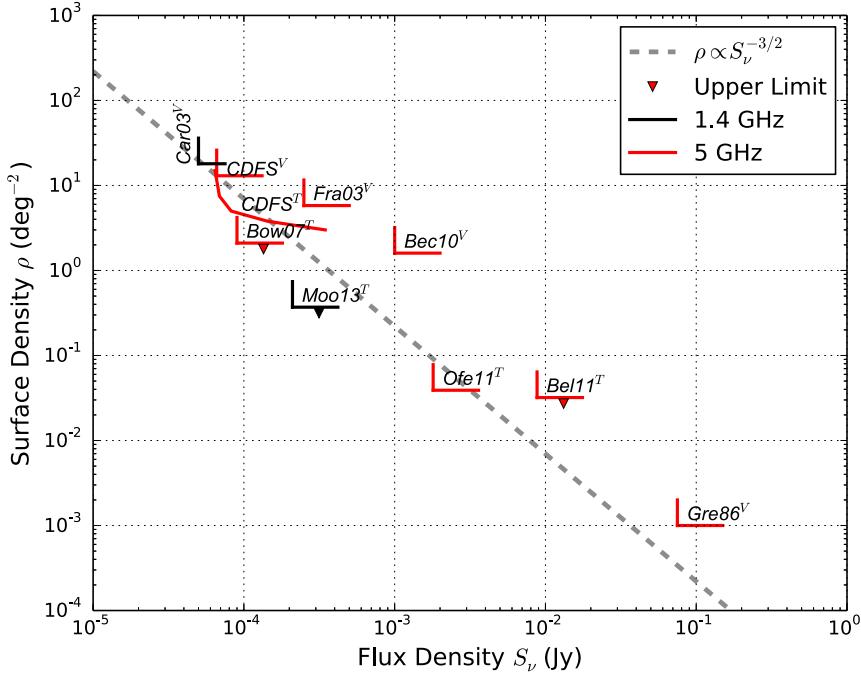


Figure 3: Rate–sensitivity plot (Bell et al. 2015) showing upper limits on the surface density of transient and variable sources as a function of flux density for a selection of surveys at 1.4 and 5 GHz. The dashed grey line represents a fit normalized to the results of Bell et al. (2015) with $\rho \propto S_\nu^{-3/2}$.

this source worthy of follow-up observations using the GBT.

3 GBT Followup

The GBT, situated in Green Bank, WV, is the world’s largest fully-steerable radio telescope. *Breakthrough Listen* (part of the Breakthrough Initiatives sponsored by the Breakthrough Prize Foundation) is the world’s largest search for intelligent civilizations beyond Earth³. The science program for *Breakthrough Listen* is headquartered at the University of California, Berkeley. Since 2016 January, *Breakthrough Listen* has been observing using a dedicated hardware backend for 20% of the time on GBT. Data from the project are being uploaded to a public data archive.

On Sunday 2016 August 28 05:30 UTC the *Breakthrough Listen* Team conducted brief X-band observations of HD 164595 using the *Breakthrough Listen* Digital Backend (BLDB, MacMahon et al in prep). The *Breakthrough Listen* Digital Backend is still undergoing deployment, and currently consists of a 16-node compute cluster interfaced to the VEGAS system (Anish Roshi et al. 2012) capable of recording raw baseband voltage data across a 3 GHz bandwidth in dual polarizations at 8 bits / sample. The *Breakthrough Listen* Digital Backend will eventually grow to a 12 GHz dual polarization capability. For these observations, baseband voltage data were processed using a GPU-accelerated software spectrometer to produce Stokes-I (total power) integrated spectra with 12288 channels across 2.25 GHz with an integration time of 22 ms. RA scans were performed over both the bright quasar 3C 48 and HD 164595 (Fig. 4), covering 0.5° in 30 s (1 s beam^{-1}). Both scans were conducted using the X-band receiver observing a total bandwidth of 2250 MHz centered at 2.8 cm (10.5 GHz). Although these data have not been rigorously calibrated, we can place a conservative 10σ limit on the presence of a continuum source at the position of HD 164595 of 10 mJy.

4 Conclusions

If the transient claimed by Bursov et al. (2016) originates from beyond the Earth, then, given what we currently know of the parameters of the RATAN search, such events ought to be common. The fact that they are not frequently seen in continuum imaging surveys suggests that the RATAN transient is likely due to instrumental interference or to some other artifact of human technology. While absence of evidence for extraterrestrial intelligence is by no means evidence of absence, our GBT observations did not detect ongoing emission from the direction of HD 164595 between

³<https://breakthroughinitiatives.org/News/1>

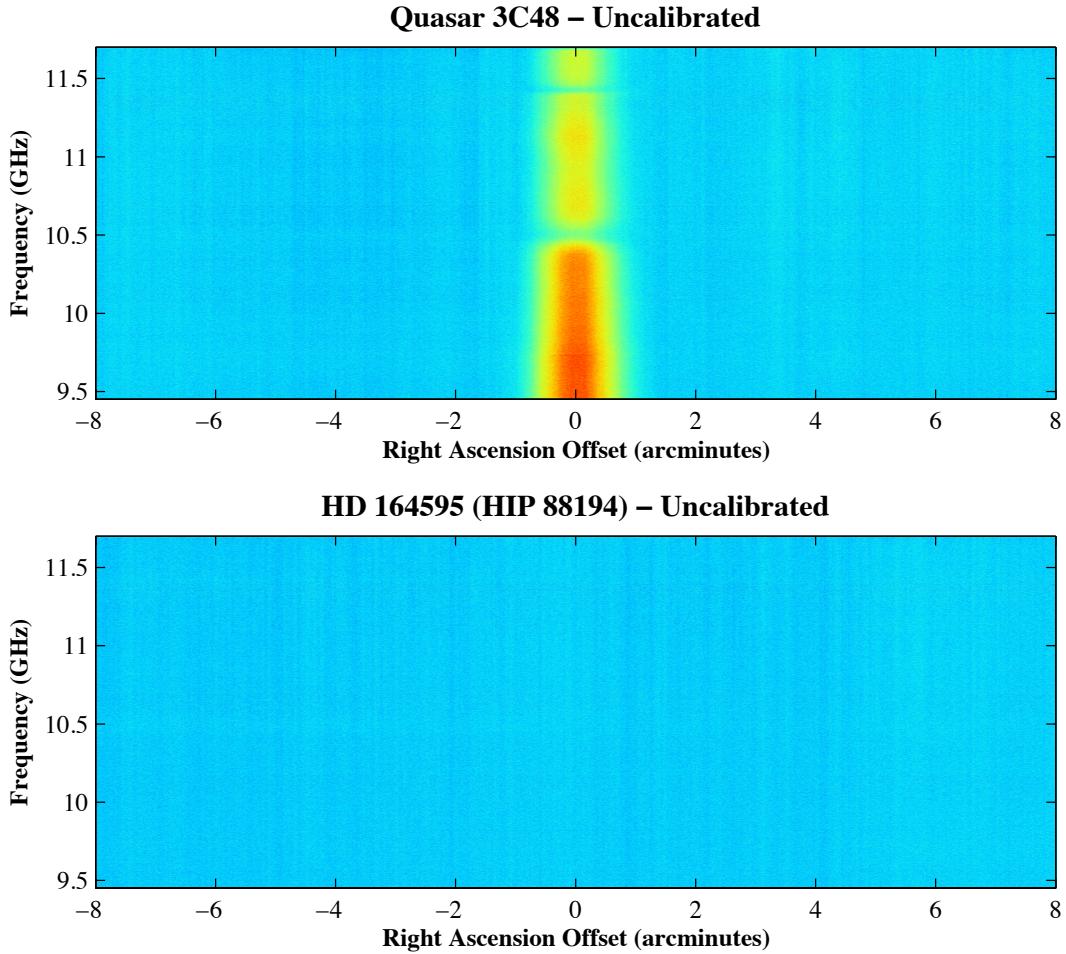


Figure 4: Scans in right ascension (RA) across the bright quasar 3C 48 and HD 164595 conducted using the Green Bank Telescope and the Breakthrough Listen Digital Backend (MacMahon et al in prep) on Sunday 2016 August 28 05:30 UTC. Both scans were conducted using the X-band receiver observing a total bandwidth of 2250 MHz centered at 2.8 cm (10.5 GHz) with a scan duration of 1 s beam^{-1} . Although these data have not been rigorously calibrated, we can place a conservative 10σ limit on the presence of a continuum source at the position of HD 164595 of 10 mJy. Note: 3C 48 is a variable continuum source with a flux density of $\sim 2.5 \text{ Jy}$ at these frequencies (Perley & Butler 2013). Gaps in the 3C 48 spectrum are due to known receiver resonances at 10.504 and 11.415 GHz.

9.1 and 11.6 GHz to a sensitivity of ~ 10 mJy (10σ). Single-epoch transients are by their nature hard to confirm or deny, illustrating the need for confirming followup, either at a later time, or as part of the observing strategy (whether triggered follow-up of interesting sources, or some form of on-off observing). We intend to reobserve HD 164595 as part of the *Breakthrough Listen* target list, along with ongoing observations of targets selected using a range of criteria.

Breakthrough Listen at UC Berkeley is always open to coordinated efforts and follow-ups of interesting signals. The program seeks to further coordination with telescopes and SETI groups across the world. We welcome opportunities for partnership in order to quickly validate and analyze candidate signals, to continue to develop tools and techniques, and to share our excitement with those who, like us, seek to answer the question, “Are we alone?”.

Acknowledgments

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