Breakthrough Listen Follow-up of the Reported Transient Signal Observed at the Arecibo Telescope in the Direction of Ross 128

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1 Introduction.

Ross 128 is a low mass red dwarf star (M4V) and one of the nearest stars to the solar system at a distance of only 10.89 light-years (3.34 pc). It has been known as a flare star in the optical for more than four decades (Lee & Hoxie, 1972). Although we are aware of no claims of successful radio detections of Ross 128 in the literature (White et al., 1989, and others), non-thermal radio emission might be a possibility given observations of radio flares from other very active M-dwarfs such as AD Leo (Osten & Bastian, 2006) and the star's close proximity.

On May 12th 2017, Mendez (2017) observed a group of red dwarfs (including Ross 128) with the Arecibo Telescope, in a search for non-thermal emission possibly associated with exoplanets in these systems. We note that no exoplanets are known in the Ross 128 system. Mendez (2017) detected anomalous unpolarized radio emission during the observation of Ross 128 lasting for the full 10 min observation and spanning frequencies between 4.6 and 4.8 GHz. The observed emission has similar morphology and dispersive-like features to those presented by Osten & Bastian (2008) on AD Leo, but those emissions were between 1100 and 1600 MHz and were highly circularly polarized.

Mendez (2017) suggested that the emission was not likely to be local radio frequency interference (RFI) since it was not detected during observations of other stars preceding and following Ross 128. However, Mendez (2017) was unable to determine conclusively whether the emission seen during the observation of Ross 128 was associated with the star, due to another source along the line of sight or caused by RFI. The serendipitous potential detection of radio emission from this source encouraged re-observation by the Mendez group. New observations were carried out on July 16th with Arecibo.

In order to investigate the possible stellar nature of the Ross 128 emission, the Breakthrough Listen Team joined in this campaign and observed Ross 128 simultaneously with Arecibo using the Green Bank Telescope (GBT) and its C-band (4−8 GHz) receiver. Here, we briefly report on the observations carried out with the GBT during this campaign. We also present analysis of *Breakthrough Listen* archival data on this same source using the L-band receiver (1.1-1.9 GHz) of the GBT that has recently been submitted for publication (Enriquez et al., 2017).

2 BL observations

On 16 July 2017, the *Breakthrough Listen* Team conducted C-band (4–8 GHz) observations of Ross 128 using the GBT. The current *Breakthrough Listen* digital back-end (MacMahon et al., 2017) is capable of operating over the full 4 GHz span of the receiver simultaneously. The *Breakthrough Listen* back-end is unique in the sense that it can record time series voltage data across the full band, allowing arbitrary time and frequency resolution depending on science needs.

During the campaign we conducted 3x5-min observations of Ross 128 interleaved by 5-min observations of an OFF source star (Hipparcos 55848). This set of observations was followed by a 15-min on-source observation of Ross 128.

Currently three standard data products are produced from each observation (Lebofsky et al., 2017); one high frequency resolution product primarily for SETI analysis, one high time resolution product for broadband fast transient applications, and one mid frequency resolution for other astrophysical radio emission.

For this analysis we have used the mid frequency resolution product, which has a one second time resolution 3 kHz frequency resolution, both well matched to the phenomena under investigation. The bandpass of the C-band and polyphase filter applied to the raw data for channelization was removed by simply dividing by the median value of the of the time variations for a given frequency channel.

The current *Breakthrough Listen* SETI search pipeline, as described by Enriquez et al. (2017), is optimized for the detection of narrow-band Doppler-drifting signals. Since the emission reported by Mendez (2017) is broader and more complex in nature, we perform a by-eye comparison of the on and off observations, in a search for emission uniquely coming from the direction of Ross

128. No such emission is seen in our data.

Based on a conservative estimate of sensitivity from a typical C-band system equivalent flux density of 10 Jy, we calculate a 3σ upper limit of $\sim$500 mJy for impulsive emission at these time and frequency scales. The sensitivity of the GBT at C-band is comparable to that of AO. Mendez et al. (priv. comm.) reported a 1-σ sensitivity of 0.12 Jy for impulsive emission.

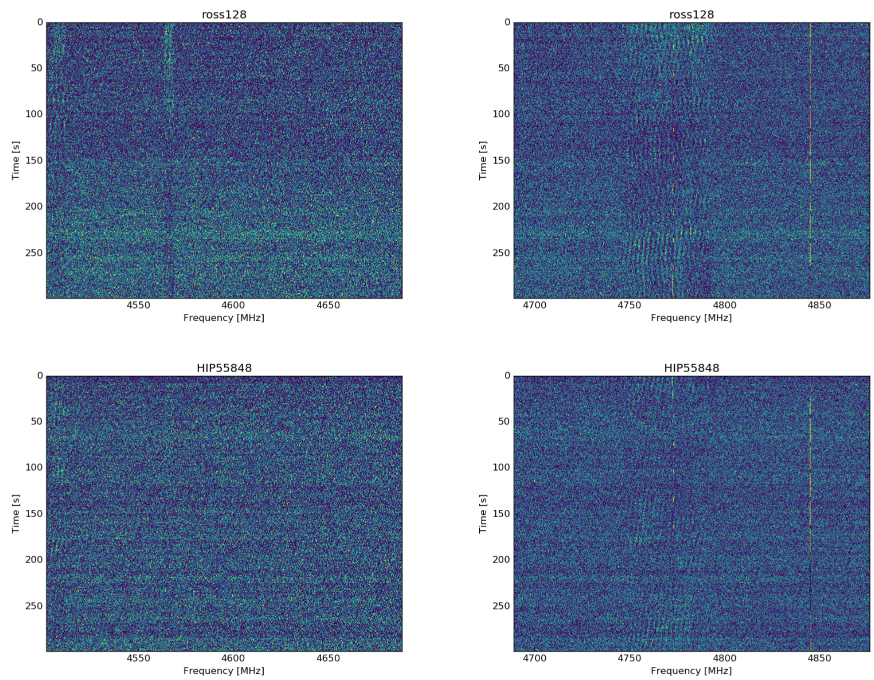

Figure 1: Waterfall (time/frequency, Stokes I) plots from exemplary 5 min observations of Ross 128 and HIP 55848 from the GBT campaign discussed herein. The two frequency ranges shown correspond to two 187.5 MHz subsets of the total 4 GHz band observed.

Figure 1 shows a representative example of our observations of Ross 128 and the off-source HIP 55848. We show here the frequency range between 4.5 to 4.9 GHz which corresponds to part of the region where Mendez et al. (priv. comm.) detected emission. Common spectral features between Ross 128 and HIP 55848 are examples of interference and instrumental effects. From our observations it is evident that there is no distinct presence of any emission isolated to Ross 128.

3 Archival data

Ross 128 was observed on 16 May 2016 with the L-band receiver on GBT as part of the regular *Breakthrough Listen* targeted search for extraterrestrial artificial radio emission (Isaacson et al., 2017; Enriquez et al., 2017). We have taken the available data at the optimal frequency resolution for this project and inspected these data for broadband emission as well. No such emission was found in our observations.

4 Discussion and Conclusion

During simultaneous targeted GBT C-band observations of Ross 128, as well as in a search of archival GBT L-band data on the source, we see no evidence for any non-thermal radio emission. However, our observations were of limited duration and we can not constrain the emission observed in the Mendez (2017) observations to be either astrophysical in nature or RFI. If Ross 128 does indeed produce detectable non-thermal radio emission it could well be intermittent and require substantial follow-up to confirm.

We note that one possible source for the emission detected by Mendez (2017) could be a broadband radio signal from an artificial satellite. Figure 2 shows the position of geosynchronous satellites around the direction of Ross 128. The satellite locations were derived from Two Line Element(TLE) [1] sources provided by the online space situational awareness (SSA) services, open to the public, provided by the U.S. Strategic Command (USSTRATCOM)[2]. The position of the Arecibo Observatory was used as observing reference. They were filtered by those specifically emitting in C-band frequencies.

We note that the presence of of RFI within the same band observed in the Mendez (2017) work shows that this band is contaminated by interference, and raises the likelihood that the Mendez emission is indeed due to RFI.

Readers who wish to independently examine the GBT data (in filterbank format) used in this analysis, along with plots of spectra across the full GBT bandwidth, may access the files at `http://blpd0.ssl.berkeley.edu/ross128/`.

References

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[1] Taking into account the different values one can accurately predict the RA and Declination of a Satellite.

[2] https://www.space-track.org/

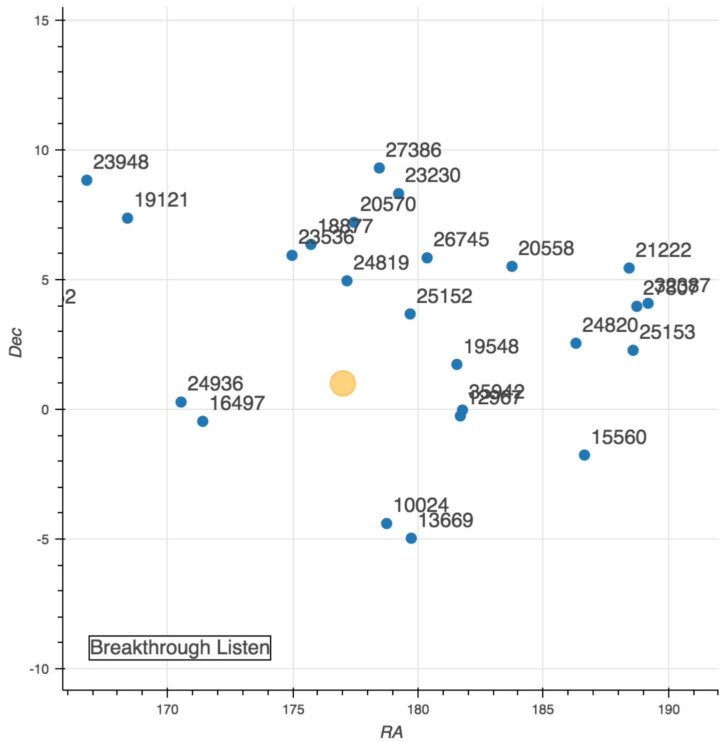

Figure 2: Position of known satellites with radio transmitters operating between 4-8 GHz. The location of Ross 128 is (ra, dec) $\sim$ (177^o, 1^o)

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