Are we Alone? Simultaneous dual-site SETI with LOFAR

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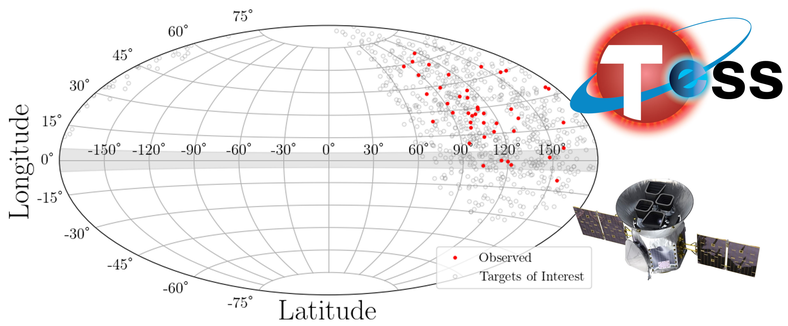
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Abstract

The Search for Extraterrestrial Intelligence (SETI) aims to search for evidence of technosignatures which can point towards the possible existence of technologically advanced extraterrestrial life. Radio signals similar to engineered signals on Earth might be transmitted by other civilizations and such searches should be conducted across the entire radio spectrum. However, the lower-frequency part of the radio spectrum has largely remained unexplored as a large number of searches were primarily conducted near 1.4 GHz. Here, we report simultaneous dedicated-time observations of 225 deg^2 of the northern sky using I-LOFAR and LOFAR-SE with the HBA array. The survey is searching for three different types of signals which include; narrowband signals with Doppler drift, signals with periodic spectral modulations, and signals with artificial dispersion. The survey is also able to reject the presence of any transmitter with the output power equivalent of Kardashev Type-I societies towards all our targets for the three signal types. This is done with use of simultaneous observations, along with being among the very first low-frequency SETI searches, also allowed for the first time the excellent opportunity of rejecting anthropogenic signals with the help of coincidence matching.

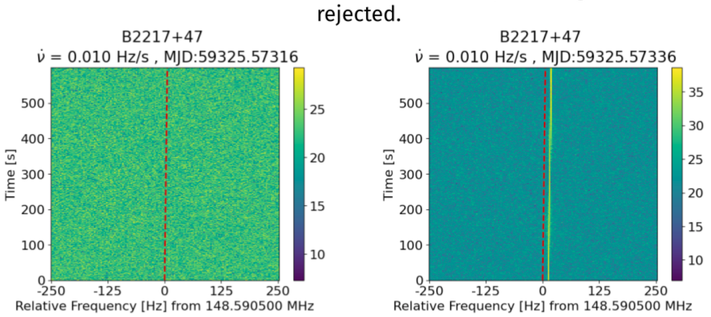
The Targets



Pointing's for this survey were taken from targets of interest from TESS (Ricker u.a., 2015) entries in the NASA Exoplanet Archive. All pointings have been observed at both Irish and Swedish LOFAR (van Haarlem u.a., 2013) stations.

Narrow-band Signals

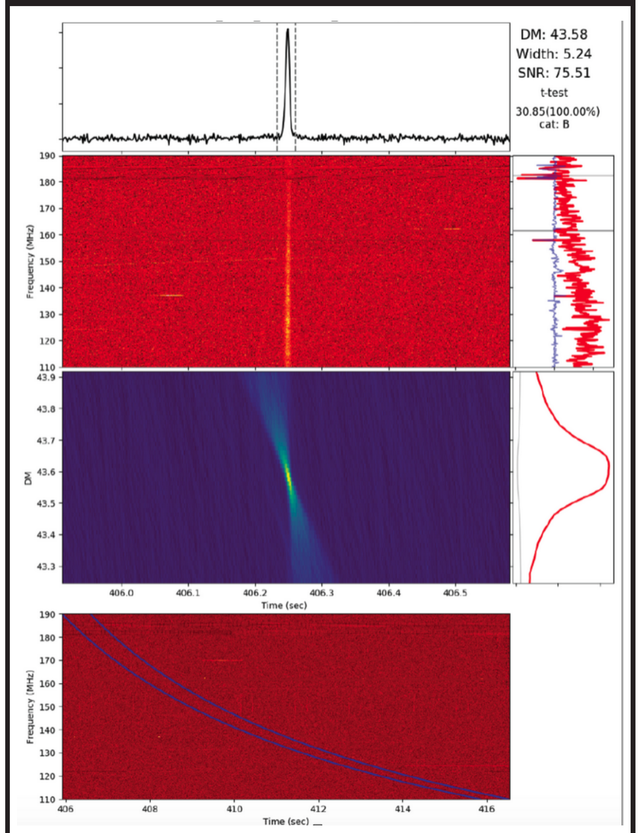
Hit which was detected in Ireland but not Sweden, allowing for hit to be rejected.



TURBOSETI[a] is used to search for narrow-band signals emanating from radio communications from intelligent life.

[a] https://github.com/UCBerkeleySETI/turbo_seti

Artificially & Naturally Dispersed Signals



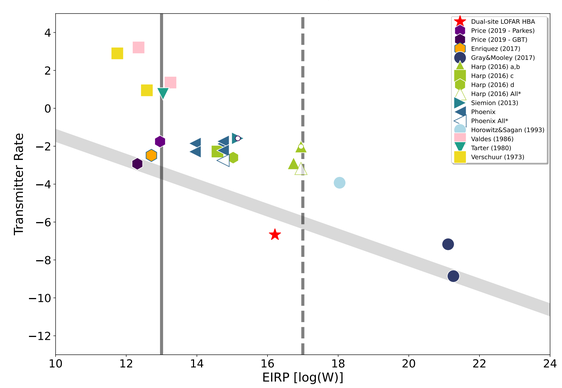
SPANDAK[a] (Gajjar u.a., 2021) to look for single pulses from pulsars, FRBs, and aDM transient signals.

[a] https://github.com/gajjarv/PulsarSearch

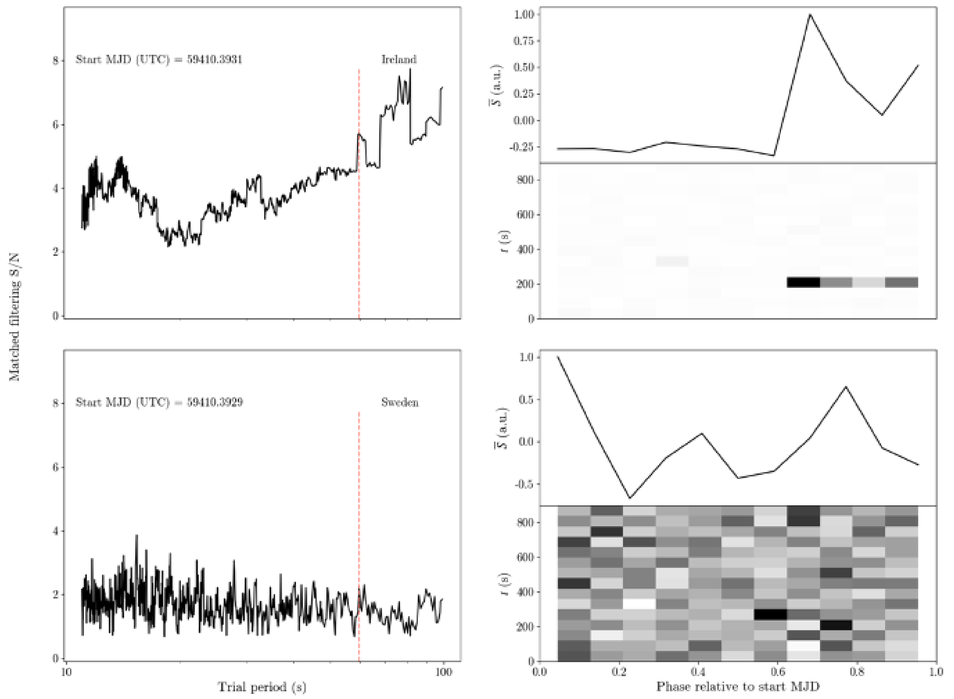
Survey Sensitivity

The power required for an ETI transmitter to be detected depends on its directional and other characteristics. This can be quantified for each of the signal types using in terms of the effective isotropic radiated power (Enriquez u.a., 2017).

$$\mathrm{EIRP} = \sigma \times 4\pi d_\star^2 \frac{\mathrm{SEFD}_{\mathrm{HBA}}}{\delta\nu_t}\sqrt{\frac{\delta\nu}{n_p t_{obs}\omega}}\ W/Hz, \qquad (1)$$



Periodic Spectral Signals



The Breakthrough Listen Investigation for Periodic Spectral Signals (BLIPSS[a]) (Suresh u a. 2023, in prep) searches data for periodic modulated signals emanating from life residing in the universe.

[a] https://github.com/UCBerkeleySETI/blipss

Conclusions & Future Research

- Continued observations of targets of interest from TESS & Gaia targets
- Tri-site observations with France's LOFAR station (FR606)
- Real-time transient detection.
- Further inquiry into the sensitivity of in-beam targets.

References

Haarlem, M. P. van u.a.(2013): *LOFAR: The LOw-Frequency ARray*A2.
Ricker, George R. u.a.(2015): *Transiting Exoplanet Survey Satellite (TESS)*014003.
Enriquez, J. Emilio u.a.(2017): *The Breakthrough Listen Search for Intelligent Life: 1.1-1.9 GHz Observations of 692 Nearby Stars*, 2: 104.
Gajjar, Vishal u.a.(2021): *The Breakthrough Listen Search For Intelligent Life Near the Galactic Center. I.*, 1: 33.

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