# Hycean Exoplanets as Targets for Technosignature Detection: A Case Study of K2-18 b in the 3–10 GHz Band

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## ABSTRACT

Recently the James Webb Space Telescope performed near-infrared spectroscopic observations of the atmosphere of a potential Hycean exoplanet, K2-18 b. These spectra provided evidence of methane and carbon dioxide in its atmosphere, along with **a possible line attributed** to biomarker dimethyl sulfide. In this work, we present triggered narrow-band radio observations of K2-18 b conducted using the Allen Telescope Array over 3–10 GHz, in search of signs of artificially produced radio emissions (technosignatures). We do not find any spatially isolated signals in the direction of K2-18 b, establishing lower and upper limits on the equivalent isotropic radiated power ($\sim 10^{13}$ W - $10^{16}$ W) of potential extraterrestrial transmitters between 3–10 GHz. This study emphasizes the importance of ongoing observations to further explore K2-18 b's potential as a candidate for the detection of technosignatures.

*Keywords:* Hycean exoplanet - Extraterrestrial Intelligence - K2-18 b

## INTRODUCTION

Introduced by Madhusudhan et al. (2021), *Hycean* exoplanets are distinguished by their extensive oceans under hydrogen-dense atmospheres. With expected radii between $1-2.6\,R_\oplus$ and masses between $1-10\,M_\oplus$, falling within the sub-Neptune range, Hycean planets allow for a vast diversity of atmospheric and internal structures. These features may result in a broader habitable zone than traditional terrestrial planets. Using space-based telescopes such as the James Webb Space Telescope (JWST), Hycean planet candidates are now accessible for atmospheric characterization, including biosignature searches (Madhusudhan et al. 2023).

Madhusudhan et al. (2023) recently reported a transmission spectrum of a Hycean planet candidate, K2-18 b, which was obtained using the JWST Near-Infrared Imager and Slitless Spectrograph (NIRISS) and Near-Infrared Spectrograph (NIRSpec) instruments in the 0.9–5.2 $\mu$m range. The spectrum revealed methane ($CH_4$) and carbon dioxide ($CO_2$) at $5\sigma$ and $3\sigma$ confidence, respectively, with high volume mixing ratios of $\sim 1\%$ each in a hydrogen rich atmosphere. The abundant $CH_4$ and $CO_2$ along with the non-detection of ammonia ($NH_3$) are consistent with chemical predictions for an ocean under a temperate $H_2$-rich atmosphere on K2-18 b. The spectrum also suggests potential signs of dimethyl sulfide (DMS), which has been predicted to be an observable biomarker in Hycean worlds. These detections motivate further characterization of K2-18 b, with a focus on searches for biosignatures on the planet (Madhusudhan et al. 2023).

Given these new insights, K2-18 b emerges as an ideal target to search for techosignatures in the radio domain. Here, we report on primary observations and analysis of K2-18 b conducted by the Allen Telescope Array (ATA), in which we searched for localized, Doppler-drifting, narrow-band signals (e.g., Enriquez et al. 2017).

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## OBSERVATIONS

The ATA is a 42-element radio interferometer, specifically designed for the Search for Extraterrestrial Intelligence (SETI). The ATA has a maximum baseline of 300 m, is sensitive between 1 and 11 GHz, and hosts a flexible Digital Signal Processing back-end that allows the digitization of 4 tunings of ∼700 MHz each anywhere in the sensitivity window. The ATA system enables sensitive multi-beam observations within a relatively large primary beam enabled by the small aperture 6.1 m-diameter dishes.

On the 13$^{\text{th}}$ of September 2023, we used 20 antennas to observe K2-18 b in the bands listed in Table 1, spending 905 seconds in each band. To evaluate signal localization, we synthesized one beam on the target of interest (K2-18 b), and another on empty sky at the edge of the telescope's primary beam, to function as a spatial filter against radio frequency interference. Prior to conducting these observations, the calibrator source 3c286 was observed using the software correlator to calculate phase, delay, and amplitude solutions which were later applied to the beamformer.

## RESULTS AND DISCUSSION

To search for narrowband drifting signals, we deployed the `turboSETI` software package (Enriquez et al. 2017) over a Doppler drift rate range of $\pm 30\,\mathrm{Hz\ s^{-1}}$ and a signal-to-noise (S/N) threshold of 10 on the $\sim 1\,\mathrm{Hz}$ / $\sim 18.25\,\mathrm{s}$ data product, broadly following the steps described by Price et al. (2020) and Sheikh et al. (2020). Any narrowband signals associated with pointings toward K2-18 b would appear in the ON-beam and appear attenuated by at least a factor of 4 in the OFF-beam, due to the synthesized beam shape and sidelobe structure. In total, `turboSETI` returned 8930 hits. The majority of the hits were detected at C-band, between 4–8 GHz, which is consistent with the dominant band of satellite downlinks — however, all potential candidates appear at near-identical S/N in the OFF-beam, which rules out any spatially isolated signals in the direction of K2-18 b.

Using K2-18 b's distance of ∼38 pc (Montet et al. 2015), Equations 3–4 of Enriquez et al. (2017), and our calibrated system equivalent flux density (SEFD; see Table 1), we calculate the lower and upper[1] minimum detectable flux for a 905 s observation, with 1 Hz resolution. Using these values and Enriquez et al. (2017) Equations 5–7, we derived the lower and upper (per Gajjar et al. (2021) Equation 4–5) limit for the effective isotropic radiative power (EIRP) of a hypothetical transmitter. These values, calculated for each observing frequency, are also shown in Table 1.

Given the ATA's flexibility and optimization for SETI searches, we will conduct weekly follow-up of K2-18 b to continue to search for radio technosignatures. Future observations of K2-18 b with JWST or other future missions, like PLATO, **the Nancy Grace Roman Space Telescope or the Atmospheric Remote-sensing Infrared Exoplanet Large-survey** (Rauer et al. 2014; Kasdin et al. 2020; Pascale et al. 2022), may provide new insights which reaffirm its potential as a candidate for subsequent radio observations.

**Table 1.** The observing frequency, derived SEFD, and estimated EIRP for the observation of K2-18b

| Frequency (MHz) | 3350 | 4050 | 4750 | 5450 | 6150 | 6850 | 7550 | 8250 | 8950 | 9650 |
|---|---|---|---|---|---|---|---|---|---|---|
| SEFD (Jy) | 361 | 427 | 426 | 467 | 546 | 608 | 690 | 829 | 950 | 1114 |
| EIRP Lower bound($10^{13}$ W) | 2.074 | 2.456 | 2.45 | 2.682 | 3.136 | 3.494 | 3.966 | 4.764 | 5.460 | 6.406 |
| EIRP Upper bound($10^{16}$ W) | 1.135 | 1.345 | 1.341 | 1.468 | 1.717 | 1.913 | 2.171 | 2.608 | 2.99 | 3.507 |

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[1] EIRP lower limits primarily apply to lower drift-rates, while EIRP upper limits apply to higher drift-rates since sensitivity is compromised due to interaspect smearing.

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