

Observing the Earth as a Communicating Exoplanet

A WHITE PAPER FOR THE ASTRO2020 DECADAL REVIEW

PRIMARY AREA: *Planetary Systems including solar system bodies (other than the Sun), debris disks, and extrasolar planets; exobiology and the search for life beyond the solar system.*

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Abstract

This white paper highlights an observing project that aims to advance and refine our search for life in the Universe, measure the Earth's technosignature over time, and foster collaborations between radio astronomers and the wider astrobiology community for the next decade and beyond. This paper highlights the Moonbounce Project and prospective opportunities for project expansion. The Moonbounce Project is the pet name of a radioshine observation effort that attempts to measure Earth's radio leakage, reflected by the moon, through the Green Bank Telescope as a study of our technosignature. This project attempts to expand upon earlier radioshine observations conducted in the late 70s and once again 2012 and has implications for refining SETI searches. Plausible expansions of the Moonbounce project include with optical observations of our technosignature (i.e. anthropogenic emissions) from ground-based and space-based telescopes in the NIR/VIS/UV wavelengths. Corroboration of technosignature data across the electromagnetic spectrum can help inform future SETI searches and yield insight to how our own technosignature is changing over time (i.e. will CFCs be non-existent in our atmosphere in 50 years, or will we be radio quiet as we move toward fiber optic communications?).

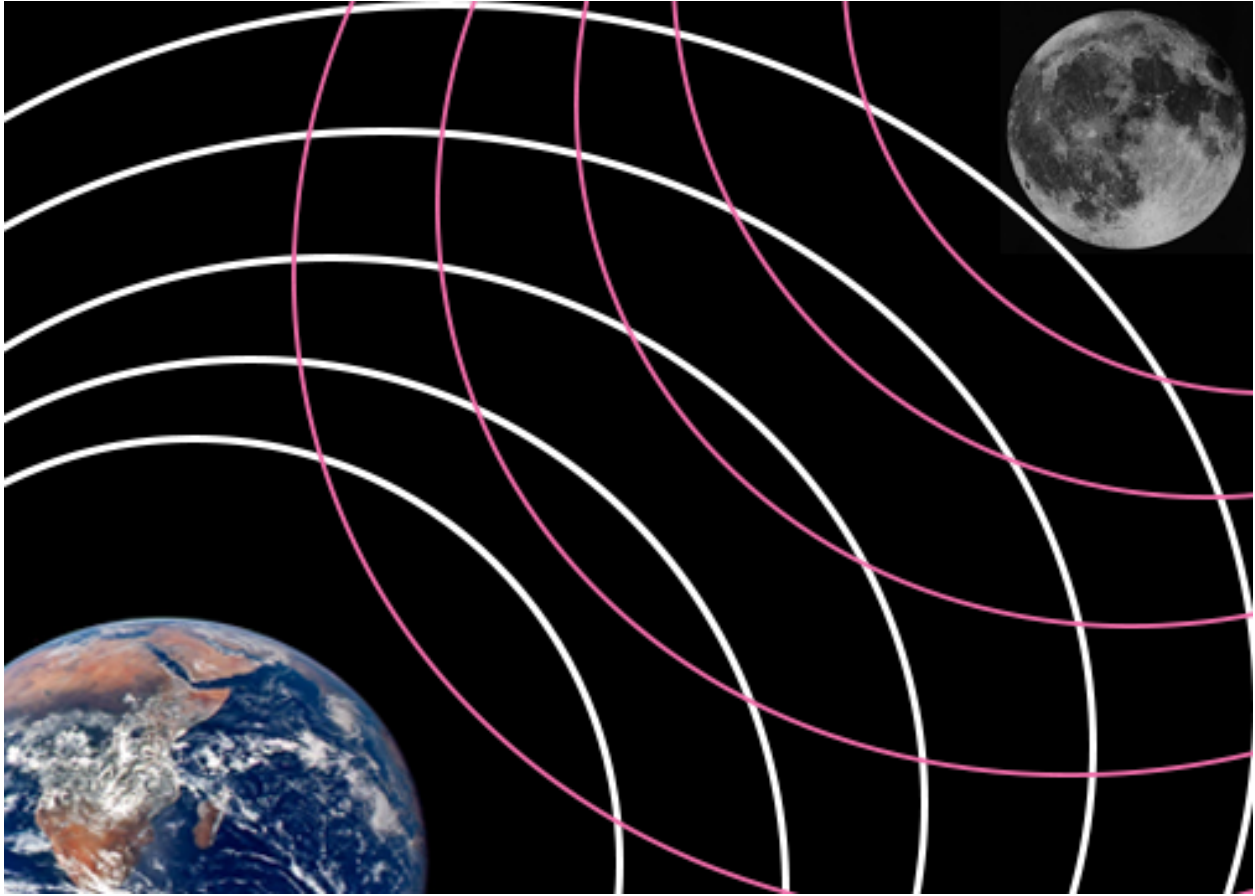


Figure 1: The Moonbounce Project: Observing Earth's Technosignature

1 Introduction

Earth as an Exoplanet:

Because of our data set of one, Earth has been used as a proxy for the search for life in the Universe. With several earthshine observations conducted to observe Earth's atmospheric biosignature spectral features from reflected by the moon (as if viewed by a distant observer), there have been relatively few radioshine observations (Palle, 2010). In other words, if a distant observer is monitoring the Earth in the visible or near infrared spectrum, they would be able to classify our planet as harboring life (or f^*l in the Drake Equation) due to the presence of known biosignatures. However, similar observations of Earth attempting to measure signs of intelligent, communicating life (or f^*i and f^*c in the Drake Equation), are few and far between. This begs the question, can we classify Earth's technosignature? In other words, what does our radio leakage look like to a distant observer?

*The Drake Equation $N=R \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$

Collaboration:

The Moonbounce Project is an effort driven by a collaboration between astrobiologists from the Blue Marble Space Institute of Science, a not-for-profit virtual research group, and SETI scientists from the Breakthrough Listen team, a SETI initiative based out of the UC

Berkeley SETI Research Center. The Breakthrough Listen initiative at the Berkeley SETI Research Center is the worlds most comprehensive SETI search to date and uses a number of large radio telescope and radio telescope arrays around the world. This unique collaboration is advantageous as it offers expertise and depth to research conducted by both groups.

We propose to use the Green Bank Telescope (GBT) to observe Earths radio leakage radiation as reflected from the moon in the 290-1230 MHz range yearly. These observations will give an indication of how the characteristics and detectability of Earths radio leakage, as seen by an external observer, have changed since a similar measurement was last performed in 2012 and before that in 1978 (McKinley et al. 2012., Sullivan and Knowles 1985a,b).

The Moonbounce project has previously been awarded observation time on the Green Bank Telescope in the fall of 2018 but observations did not come to fruition due to the priority level of the awarded time. The team has since resubmitted the proposal.

These observations will provide a follow up to the previous radioshine observations conducted in the late 70s (Sullivan and Knowles 1985a,b) and in 2012 (McKinley et al. 2012). These data play an important role in search for extraterrestrial intelligence by serving as an example of a planetary technosignature radiating from a technological civilization, which can be used to evaluate or calibrate signal processing algorithms that attempt to detect evidence of extraterrestrial intelligence (ETI) in SETI surveys.

Past Observations:

In the late 70's it was determined that television signals were the dominant source of radio leakage from Earth and would represent the most likely source of any potential radio leakage detected by a distant observer (Sullivan, Brown, and Wetherill 1978). In 1978 Sullivan and Knowles made the first observations of Earths radio leakage, as reflected by the moon, using the Arecibo antenna over several nights at various bands within the 181 to 445 MHz range. They confirmed that television signals and a few radars indeed dominated (Sullivan and Knowles 1985a,b).

2 Current Observations

Since the inaugural radioshine observation in 1978, human use of radio communication have changed significantly, thus transforming our radio leakage signature over the last 40 years. Advancements in technology include digitization, spread-spectrum modulation, and new types of antennas and services such as GPS and a plethora of satellite transmitters. Such technology, as our increased use of fiber optics, may cause the Earths leakage to diminish in its detectability. This trend that is happening on Earth may suggest that advanced extraterrestrial civilizations may inevitably evolve to a radio-quiet phase (Drake 2011). This possibility has been noted by scientists in the field and Sullivan and Knowles acknowledged this possibility, but also noted that as technology changes there will always be inefficiencies in any engineering system, leading to waste and often leakage. Since we have no confirmation of ETI transmissions it is uncertain whether or not ETI civilizations tend to remain radio quiet or emit detectable leakage (though this may be revealed with efforts like Breakthrough Listen). But we can at least answer the question for our own civilization on Earth.

Recent observations of Earths radio leakage as reflected off the moon were made with the Murchison Widefield Array (MWA) from 80 to 300 MHz (McKinley et al. 2012). Figure

2 shows the time-integrated spectrum from these MWA observations, mostly corresponding to FM radio transmissions. These observations with the MWA demonstrate the feasibility of detecting Earth's radio leakage still today, even with the advent of fiber optic technology. McKinley et al. (2012) conclude that Earth's FM radio band, as observed with 40 kHz resolution, would be a faint signal of about 19 nJy at the distance of Proxima Centauri.

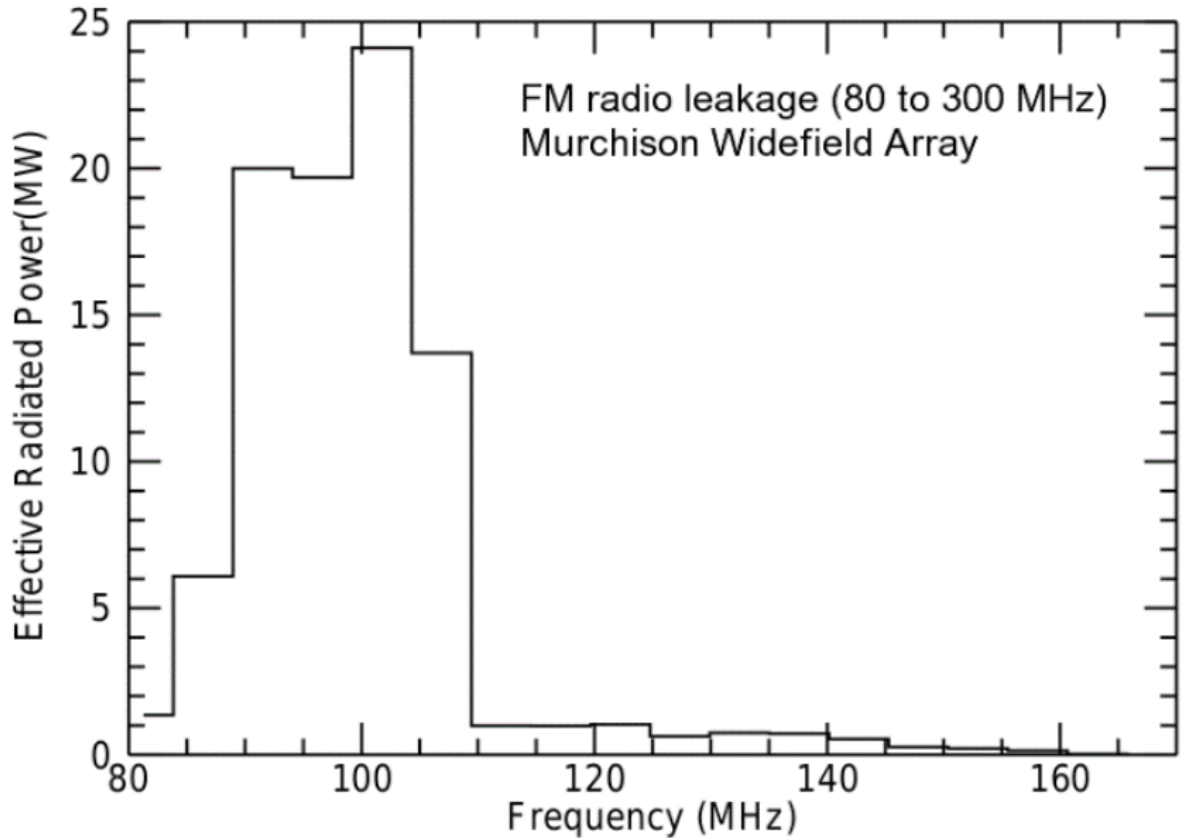


Figure 2: McKinley et al. 2012

PROPOSED OBSERVATIONS The following proposed observations are largely based on our previous observation proposal to the National Radio Astronomy Observatory in January of 2019 led by Principle Investigator, Dr. Jacob Haqq-Misra. (Proposal Code: GBT/19B-033 (Regular) Proposal Title: Observing Earth's Radio Leakage from Lunar Reflections, PI: Jacob Haqq-Misra)

An ideal allocation of observing time would be four 12-hour nights of lunar observations with the GBT to observe Earth's reflected radio leakage and repeated every year. Observations must be at night to minimize radio frequency interference (RFI) and must also be within 3-4 days near full moon, in order for the moon to be available for the full duration of the night. Our original request for time on the GBT did not come to fruition because these observations were not a high priority for the observation request at the GBT and may prove

to be difficult for overall GBT scheduling. If we cannot allocate our 12-hour nights near full moon, then we can still obtain valuable and useful data for much shorter periods.

We propose to use up to three prime focus (PF1) receivers to cover a broad frequency range, namely, PF1/342 (290-395 MHz), PF1/800 (680-920 MHz), and PF1/1070 (910-1230 MHz). These cover several television channels as well as an assortment of mobile, radio-navigation, and other telecommunication channels. [We have omitted the PF1/450 (385-520 MHz) and PF1/600 (510-690 MHz) bands, as RFI from local television transmissions usually overpowers these receivers.] We propose two nights of observations with PF1/342; the second night will be a repeat, which will be extremely valuable in the data analysis for sorting out whether candidate signals are local RFI or signals from the moon. Observing for two nights at this lowest frequency range will also aid in identifying any relevant temporal variations or Doppler effects that may be present in the data. In addition, we request one night each with the PF1/800 and PF1/1070 receivers to characterize the higher-frequency environment.

Using these three receivers will overlap with the frequency range observed by Sullivan and Knowles (1985a,b), and represent a portion of the spectrum used very actively worldwide and we will be poised to truly observe Earth as a communicating exoplanet. We will be processing the data through the Breakthrough Listen backend which offers flexibility because it records raw voltages for later processing.

Concerns: The primary challenge in making radio observations is the elimination of any local RFI. Spectra of the RFI environment in Green Bank posted online (from 2012) are undesirable for this reason we are excluding the worst range of 385-690 MHz. We will consult the latest local RFI surveys for guidance as to contaminated bands and other relevant features.

To demonstrate feasibility of the GBT for observing Earths radio leakage, we consider the detectability of a single typical television transmitter. We assume a transmitter power of 100 kW and a gain of 12 db. For a signal that originates from a transmitter on Earth and travels to the moon and back to the GBT, this gives the flux of the reflected signal observed at GBT as 10-13 W/m² (c.f., Shostak 2013). This is well above the 10-27 W/m² or lower sensitivity that should be achievable with the GBT. Prior measurements of radio leakage from 80 to 300 MHz with the MWA (McKinley et al. 2012) further indicate that we should be able to observe such signals with the GBT.

Sullivan and Knowles (1985a,b) accounted for RFI by taking "OFF-moon" integrations of "empty" positions to compare with their lunar spectra. Although this method is hardly foolproof in eliminating all local signals in todays high-RFI (and variable) environment, it still seems the best approach any frequency channel occupied in the OFF spectrum cannot be used for the ON-moon spectrum. We will likewise take alternating ON-moon and OFF-moon observations to eliminate, as best we can, local RFI. Each OFF position will be taken at the same declination and hour-angle range as the ON.

3 Observational Goals

We have the capacity to expand on our Moonbounce Project to include long term measurements of radioshine and to include the addition of high resolution VIS/NIR/UV Earthsine observations of technosignatures (such as NO_x emissions, CO₂, CH₄, and CFCs) to achieve

a robust dataset of our technosignature through various wavelengths. We propose to use the 2.4m Automated Planet Finder (APF) at Lick Observatory to measure Earthshine in visible wavelengths from 375nm - 980nm with high spectral resolution, similar to a 2014 observation of earthshine (Yan et al 2014). These data can be corroborated with our radioshine signal and can be used to evaluate ongoing and future exoplanet atmospheric surveys. Breakthrough Listen has allocated time on the APF at Lick Observatory.

Continuing Observations

We are living in a transitional time in the history of our planet as evidenced by human-caused climate, environmental, and species diversity change. This period of human-influenced global change is informally referred to as the Anthropocene (as it is not yet accepted by the international geological governing bodies).

A continued plan to observe both radioshine and earthshine over time will be an important study to see how our global technosignature is changing as more countries develop technology, reduce or increase use of fossil fuels. Essentially, it will be a measurement of how a technological civilization copes with the Anthropocene, or more simply, how our technosignature is changing through this 'technological adolescence.'

Biosignature detection on exoplanetary atmospheres are still in its nascent stages but future technologies, in development (such as the upcoming JWST, LUVOIR, and the UK-based Twinkle telescopes), will have the capabilities to resolve potential biosignature absorption features (Arney 2019). Biosignature research has also followed a similar trajectory to that of SETI searches. Initial research was focused on current atmospheric composition and has since expanded into research on potential detectable biosignatures in different situations such as on early-earth's atmosphere, atmospheric disequilibrium, hypothetical Earth-like exoplanetary atmospheres around different spectral classes of stars, etc

4 Recommendations

As humanity advances in technology and as countries continue to develop, our radio and atmospheric signatures are changing. This changing relationship with our planet is an interesting biosignature in itself. We recommend a higher priority for radioshine and earthshine observations in the upcoming decade and opportunities for multi-spectral collaborations between institutions and instruments (both ground-based and space-based) to occur frequently. These observations would create a novel and holistic study of Earth as an evolving, intelligent, communicating exoplanet and have the potential shape future technosignature searches.

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