Looking for potential radio technosignatures from extragalactic sources

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The Stephans Quintet captured by the James Webb Space Telescope (JWST). Credit: NASA/ESA/CSA

It has been more than sixty years since Dr. Frank Drake (father of the

Drake Equation) and his colleagues mounted the first Search for Extraterrestrial Intelligence (SETI) survey. This was known as Project Ozma, which relied on the "Big Ear" radio telescope at the National Radio Astronomy Observatory (NRAO) in Greenbank, West Virginia, to look for signs of radio transmissions in Tau Ceti and Epsilon Eridani. Despite the many surveys conducted since then, no definitive evidence of technological activity (i.e., "technosignatures") has been found.

This naturally raises the all-important question: are we going about the business of SETI wrong? Instead of looking for technosignatures within our galaxy, as all previous SETI surveys have done, should we look for activity beyond our galaxy (from possible Type II and Type III civilizations)? This premise was explored in a recent paper led by researchers from the National Chung Hsing University in Taiwan. Using data from the largest SETI project to date, Breakthrough Listen, the team looked for potential radio technosignatures from extragalactic sources.

The research team was led by Yuri Uno, a Ph.D. physics student at the National Chung Hsing University (NCHU) in Taichung, Taiwan. She was joined by an international team of astronomers and astrophysicists from the National Tsing Hua University (NTHU) in Hsinchu, Taiwan; The Australian National University (ANU), and the National Astronomical Observatory of Japan (NAOJ). The paper that describes their research and findings recently appeared in the *Monthly Notices of the Royal Astronomical Society*.

A key consideration for the team's study is the Kardashev Scale, the scheme for classifying extraterrestrial intelligence (ETI) proposed by Soviet astrophysicist Nikolai Kardashev in 1964. According to Kardashev, ETIs could be classified into three "types" based on the amount of energy they can harness.

- Type I—"Planetary civilizations" capable of harnessing and storing all of their home planet's energy (4×10^{19} erg/sec).
- Type II—"Stellar civilizations" capable of harnessing all the energy emitted by their star (4×10^{33} erg/sec)
- Type III—"Galactic civilizations" capable of harnessing the energy of an entire galaxy (4×10^{44} erg/sec).

To date, the majority of SETI studies were focused (implicitly or explicitly) on activities consistent with a Type I civilization. Aside from limited speculation about transiting megastructures, like the mysterious dimming of KIC 8462852 (aka Tabby's Star), attempts to look for possible Type II and Type III technosignatures has been very limited. According to the Taiwanese team, this leaves SETI surveys very limited in terms of the search area and overlooks potential technosignatures that would be very luminous. As Ono explained to Universe Today via email:

"Most SETI surveys have focused solely on stars within our galaxy and have primarily searched for radio signals, assuming that other civilizations are similar to ours and use radio communication. However, this approach is less efficient regarding the number of observable stars because observations are conducted one by one out of 100 billion stars in our galaxy. Also, this approach may not be comprehensive enough to detect more advanced hypothetical civilizations that could handle strong radio signals in other galaxies."

To address these limitations, Ono and her team focused on expanding the search beyond our galaxy and considered the possibility of highly advanced civilizations. These civilizations would be capable of sending several orders of magnitude more information over much greater distances, greatly increasing the odds of detection. According to Kardashev's original paper, a Type II civilization would be capable of transmitting 3×10^{9} bits/sec within a 100,000 light-year radius from their star system, 3×10^{5} bits/sec within a 1 million light-year radius, but nothing beyond that.

A Type III civilization would be capable of transmitting at a rate of 2.4×10^{15} to 2.4×10^{13} bits/sec within a 100,000 and 10 million light-year radius and 3×10^{10} bits/sec within a 10 billion light-years radius. For their study, Uno and her team examined data obtained by Breakthrough Listen (BL) since it began in 2016. Specifically, they conducted a statistical analysis of the non-detection results reported by BL. As Uno explained, the lack of detection allowed the BL team to establish upper limits on the existence of extraterrestrial civilizations based on the number of stars they observed:

"However, the radio telescopes' field of view was much larger than the apparent size of the target stars, allowing them to simultaneously observe other galaxies in the background. Therefore, we analyzed the number of stellar systems based on the background galaxies, assuming that advanced civilizations would have the capacity to send us signals from other galaxies. Our statistical analysis suggests that BL may have observed hundreds of trillions of stellar systems."

By taking into account background galaxies from previously-observed SETI fields, Uno and her colleagues found that the number of observed stars was much greater than previously reported. In fact, they found that the total number was about ten orders of magnitude (n10) greater than previous studies that focused on individual stars in our galaxy. However, as Uno explained, their results indicated that the number of civilizations in our local universe that we might have a shot of hearing from was staggeringly low:

"Our statistical method suggests that less than one in hundreds of trillions of extragalactic civilizations within 969 Mpc possess a radio transmitter above 7.7×10^{26} W of power, assuming one civilization per one-solar-mass stellar system. Additionally, we cross-matched the BL survey fields with the WISE SuperCOSMOS Photometric Redshift Catalog and compared [it] with the statistical method. Our result sets the strictest limits to date on the transmitter rate at such high power levels, emphasizing the high efficiency of searching for radio transmitters in galaxies and the rarity of technologically advanced civilizations in our universe."

Granted, this latest statistical analysis might sound like bad news. But it's important to note that research that establishes limits on the likelihood of finding extraterrestrial civilizations is essential to SETI research. This is what SETI forerunner Dr. Frank Drake attempted to capture with his famous Drake Equation, which established theoretical limits on the number of ETIs humanity could communicate within our galaxy. By extending those limits beyond the Milky Way, Uno and her colleagues have established theoretical constraints that are many orders of magnitude higher.

What's more, Uno stressed that this latest analysis only covers a fraction of the known universe and is subject to significant limitations in frequency and duration. What's more, she says, it presents new opportunities for SETI research:

"It is important to note that even though this was the largest SETI search ever conducted, it covered only a fraction of the sky (0.05%), a fraction of frequency (0.5%) and limited time duration (five minutes). Moreover, there are other parameters to consider, such as timing and direction, and we cannot immediately conclude that we are alone in the universe.

"Previous works are limited by the small number of observed stars. In this paper, we demonstrated how efficient the extragalactic SETI search is in terms of the number of observable stars. Therefore, I believe that extragalaxies are the frontier of SETI research, and we must continue our SETI search to understand the possibility of other civilizations better."

More information: Yuri Uno et al, Upper limits on transmitter rate of extragalactic civilizations placed by breakthrough listen observations, *Monthly Notices of the Royal Astronomical Society* (2023). DOI: 10.1093/mnras/stad993 arxiv.org/abs/2304.02756

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