What are the best ways to search for technosignatures?

April 9 2021, by Andy Tomaswick

Credit: NASA's Earth Observatory

The search for extraterrestrial intelligence (SETI) has long roots in human history. With the advent of modern technologies, scientists were finally able to start scanning the skies for any sign of life. When the search first started back in the 1960s, it focused almost exclusively on trying to detect radio signals. Over the decades, no irrefutable evidence of any artificial radio signals was ever found. Financial support started to drift away from the discipline, and where the money goes so do many scientists.

But more recently, the spike in interest in exoplanet research has breathed new life into the search for intelligent life, now commonly referred to as the search for "technosignatures." In 2018, NASA sponsored a conference where scientists who were involved with the field came to discuss its current state. That meeting was followed up by a meeting last year sponsored by the Blue Marble Institute, which NASA also helped to sponsor. Now a working paper has come out from the group of SETI scientists that attended the conference. Numerous potential mission ideas to find technosignatures are described in the paper. It's clear the search for extraterrestrial intelligence isn't limited just to radio astronomy anymore.

There are 12 different mission concepts discussed in the paper, but they can be broken down into two major categories—those that focus on exoplanets and those that focus on bodies in our own solar system.

The authors, led by Dr. Hector Socar-Navarro, a senior scientist at the Instituto de Astrofisica de Canarias and director of the Museum of Science and the Cosmos of Tenerife, introduce a novel parameterization that help understand the categorical breakdown. Called the "ichnoscale," it is defined as "the relative size scale of a given technogisnature in units of the same technosignature produced by current Earth technology."

So the ichnoscale uses the fact that most of the technosignatures the proposed missions are searching for would be visible on Earth given a powerful enough sensor. For example, if a alien civilization has a Dyson sphere (e.g. a type of advanced orbital structure that encompasses an entire star), then the ichnoscale of that Dyson sphere would be whatever the cross sectional size of the sphere is divided by the size of the largest orbital structure currently around Earth—the ISS.

The authors then introduce a graph that helps guide discussions about various technosignatures. On the graph, the y-axis is the ichnoscale, as described above, while the x-axis is the total number of objects that could be observed for that type of technosignature.

The types of technosignature sought by each mission vary widely in complexity and technology level of the civilization associated with it. One relatively straightforward mission concept is a mission to detect industrial pollutants in atmospheres of exoplanets. Dr. Socar-Navarro mentions that it is possible that the James Webb Space Telescope could detect NO_2, a common industrial pollutant emitted by combustion engines, in the atmospheres of exoplanets. Even more impressively, some more advanced mission concepts, such as LUVOIR, would be able to detect concentration levels similar to current Earth concentration levels on exoplanets up to 10 parsecs away. Other atmospheric pollutants, such as CFCs, widely known for having caused a hole in the ozone layer, could also point to a technological civilization on a planet whose atmosphere contains an abundance of them.

Atmospheric pollutants could be detected for a civilization which is at least as technologically advanced as humans. A few other missions could do the same. Though radio astronomy hasn't turned up much so far in the SETI effort, scientists have barely scratched its potential.

One suggested mission that could potentially find a human level civilization relatively nearby is a radio telescope on the far side of the moon. This isolated space would allow it to be affected by a minimal amount of radio interference—in fact it would be impacted by only a single satellite. Such isolation could allow for much more sensitive instrumentation, and a much higher signal to noise ratio of any data it collects.

Radio itself is a power intensive medium, and even on Earth it is being replaced by newer technologies such as laser pulses. Searching for those laser pulses is another proposed mission. Alien civilizations could use them either to communicate messages or even potentially as propulsion systems. Many of these beams are strong enough to be seen from very far away, and systems can be designed with modern technology to be able to capture them.

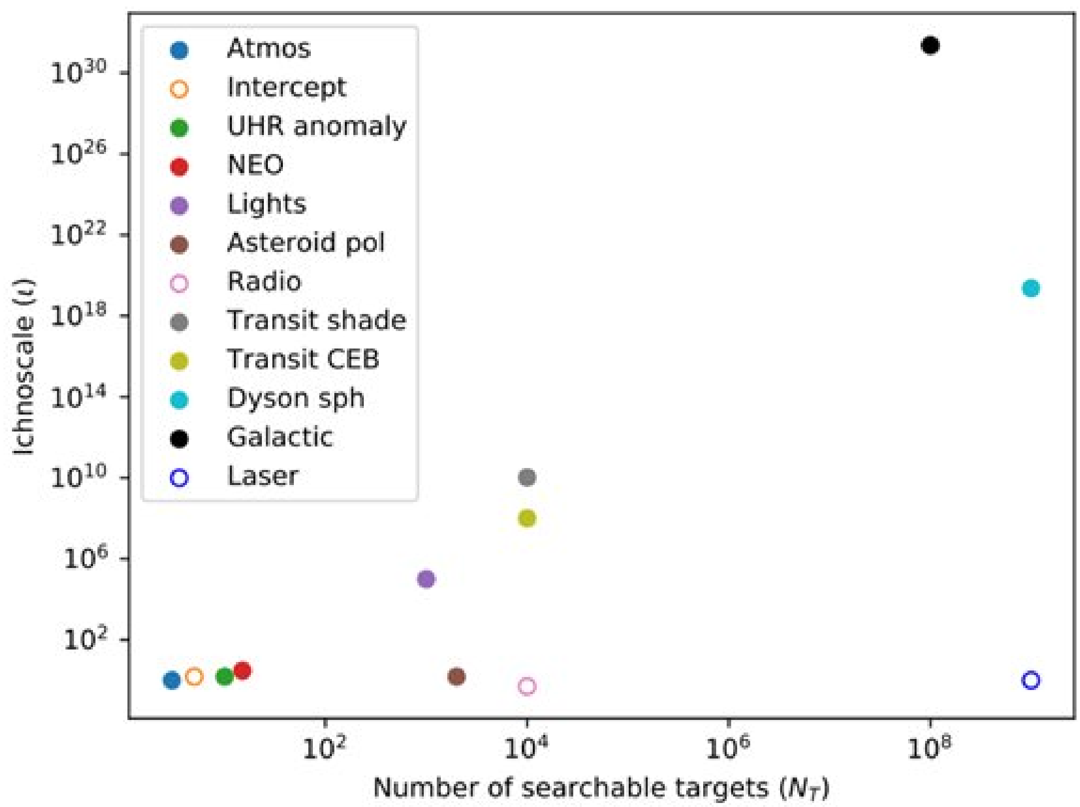
Another strategy to detect far away civilizations uses a technique similar to exoplanet hunters themselves—transiting. Transiting is when an object passes in front of a star that it is orbiting, and minutely lowers that star's brightness. These dips in brightness are not necessarily indicative of a planet, however, and could be caused by technosignatures themselves, such as a star shade or a satellite belt.

Smaller technosignatures aren't the only ones capable of blocking a star's light though. Larger structures, such the aforementioned Dyson sphere, or even a galaxy-spanning civilization producing anomalous waste heat, are a possibility for more advanced civilizations. These wouldn't be detectable via transiting as they completely block a star's light. However, they would be detectable via another modern technology—infrared imaging.

Such large structures would not be able to contain the huge amounts of energy put out by a star or galaxy. Therefore, it must be transmitted through the structure somehow. The most likely way it would be radiated is through waste heat, which can be monitored via a simple infrared camera. There are many infrared mission concepts, and one similar to the Herschel mission should be capable of detecting these large scale structures.

At this point it's pretty obvious that there are no such megastructures in our own backyard. But there might be smaller signs that we simply haven't been able to see because we never bothered to look. This concept of finding alien technology close to home was popularized by "2001: A Space Odyssey," and the missions suggested for searching closer to home would definitely have found the artifact made famous in the movie.

The Red Planet might not be the most likely place to look though. That title would most likely lie with a heavenly body without a lot of surface activity, and while Mars' environment might seem relatively stagnant, it actually isn't. There are much more geologically stable places in the solar system, such as Mercury, the moon, or even asteroids in the asteroid belt.



Graph of the Ichnoscale for the 12 different proposed projects in the paper. The y-axis is the calculated ichnoscale and the x-axis is the number of possible observation targets. Credit: Socas-Navarro et al

Dr. Socar-Navarro points out an important point about why this stability is important. Currently, the closest star to Earth (Proxima Centauri) is approximately four light-years away. However, stars are not stationary, and one approaches close enough to the Sun to breach the Oort cloud about once every 100,000 years. Since the Earth has formed, that means there have been approximately 45,000 stars that have passed by our planet.

If one of those stars contained a civilization as advanced as we currently are, they would probably have noticed the biomarkers of life in Earth's own atmosphere. They also might have been tempted to send a probe to observe the evolution of that life, similarly to how the Breakthrough Starshot initiative is attempting to send a probe to Proxima Centauri.

Any probe that was sent might have been caught up somewhere in the solar system. While the most likely places for a probe to end up, such as Jupiter and the Sun, might have destroyed any evidence, there is a chance it landed somewhere more stable. As such, close to home missions suggest focusing on trying to find a probe that might have been sent to our solar system in the past, with one exception.

Locations for this probe search range from the Moon to the Trojan asteroids that follow Jupiter around. For the moon mission, current observational techniques would be combined with AI algorithms to thoroughly search the entire surface of the moon, down to a few centimeters in diameter, for anything that might seem out of the ordinary. Transmitting all of that data back to a human on Earth who might be able to define what "out of the ordinary" is would be completely infeasible with the current bandwidth to lunar orbiters.

Instead, the paper suggests using a neural network AI system that was successfully trained to detect anomalies in data sent back by the Lunar Reconnaissance Orbiter. If that algorithm was uploaded to a newly designed orbiter, it could dramatically cut down on the number of images it would need to send, and therefore make such close observation feasible.

Pure data transfer wouldn't be as big of an issue for a few other missions suggested closer to home. One would be to send a polarimeter to the asteroid belt and the Trojan belt. The instrument could then conduct a survey of the objects in these two crowded areas of the solar system to see if any of them seem to be out of place when compared to similar objects. Human devices stick out very prominently in polarimetry because they are typically built with very flat, metallic surfaces, which tend to polarize light. Devices from alien origins would assumedly have the same sort of metallic sheen.

One of the most famous examples of where polarization would have been extremely useful was the very brief observation of 'Oumuamua as it zipped through our solar system. Unfortunately, scientists didn't get a chance to use the technique as the unique object was already on its way out of the solar system before observing platforms could be brought to bear on it. There has been some speculation that 'Oumuamua itself was actually an alien probe, but unfortunately we will never be able to tell as it is no longer in observational range of any of our platforms.

That sad fact informs the final close-to-home mission concept from the paper—the design and assembly of a rapid response intercept mission for any new interstellar visitors telescopes find. This mission could be based on the ground, set to launch when the time is right, or launch ahead of time with the expectation that it will complete a hard burn to catch up with whatever object might be transiting our solar system.

Even if the object such a mission would visit turns out not to be a probe, it would still provide invaluable data for other scientific efforts. Dr. Socar-Navarro points out that dual use scenario would be the norm rather than the exception. Every one of the proposed missions would collect data that would be useful to scientific disciplines other than SETI, making it more appealing to funding agencies.

SETI itself still has that special place in the human psyche though. Dr. Socar-Navarro praises the participants of the Blue Marble workshop and stresses the importance of this ongoing search.

"Technosignature research brings in people from the whole world—the interest in other civilizations is something that excites our imagination collectively." he says. The virtual workshop participation of 53 excited scientists from 13 countries lends credence to his assertion. With luck, these workshops will be a first step towards increasing interest in finding a definitive answer to one of the most fundamental questions of the human condition—are we alone?

More information: Concepts for future missions to search for technosignatures arXiv:2103.01536v2 [astro-ph.EP] arxiv.org/abs/2103.01536

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