24 January 2022

Frontier Talk

Memo by Marina Sanchez Del Villar

The Search for Extraterrestrial Intelligence Hunting for Technosignatures in the Past, Present and Future

Speaker: Dr. Sofia Z. Sheikh (SETI Institute)[1] [2]

This event has been organised by the Technological Change and Society Interdisciplinary Research Cluster

Foundations of SETI: How do we search? Why do we search?

1. Are we alone?

SETI looks for beings outside of Earth that we can *relate to* and *talk to*, and have for example, technology, culture, or art. SETI, as a subdiscipline, is more focused on extraterrestrial technology than on extraterrestrial intelligence. The technology is a proxy for the existence of intelligence. SETI looks for technologies that are commensurate with our own, so it relies on a very narrow view of what constitutes technology. However, given what we understand of the universe, SETI uses the best choices grounded in Physics.

We can frame the more philosophical question of *Are we alone?* as a scientific question that we can provide an answer to. The Drake equation does precisely that; it estimates the number of civilizations in our galaxy with which we could communicate right now. The equation relates:

1. The number of stars with planets that may develop an ecosystem. The estimates suggest that there is a promising number of planets in our galaxy that could host ecosystems.
2. How often life develops in these ecosystems, how often this life is intelligent, and how often it can engage in interstellar communication. These elements are still quite unknown.
3. The average time that such civilizations survive. This point is very difficult to estimate.

[1] The recording of this talk is available at: https://www.youtube.com/watch?v=T58Qgy2hGVc

[2] Dr. Sheikh studied Physics and Astronomy at the University of California, Berkeley, for her undergraduate education and completed her dual Ph.D. in Astronomy and Astrobiology at Penn State. She worked with the Breakthrough Listen project at the Berkeley SETI Research Center throughout her academic studies, developing her interest in radio astronomy and the search for technosignatures. She is currently the recipient of a National Science Foundation MPS-Ascend Fellowship. In 2019, she was one of the authors of the Breakthrough paper on BLC1, published in Nature Astronomy.

The Drake equation is a conceptual aide that guides the way SETI researchers approach their work. In particular, SETI's role is to understand the fraction of stars that host technological civilizations.

Most phenomena observed in the universe are not unique. For example, we first identified a handful of pulsars or exoplanets, and now we have identified thousands; or we believed that Earth was special in that all stars and planets revolved around it, which was not true. Therefore, since Earth can host intelligence, it is possible that there are other celestial bodies that also host intelligent life.

2. Methods used in SETI

In this section, we outline how SETI looks for the fraction of stars that host technological civilizations.

<u>Communication SETI</u>

This method consists of listening for signals intentionally being sent our way. The researchers pursue two techniques in parallel.

1. Radio Communication SETI

Looking for radio transmissions intentionally sent by extraterrestrial civilizations. Radio communication's vast search space is expressed in frequencies, measured in gigahertz. The range under which SETI looks is narrowed down to focus on the area where researchers think they have the best chance of success.

- At low gigahertz values, the background noise from the galaxy is very *loud*. Although low frequencies are sometimes used for communication on Earth, if we tried to use them to listen towards the galaxy, we would capture the combined background noise of dust and gas.
- For high gigahertz values, the background noise comes from our own atmosphere (oxygen).

The region between low and high frequencies is called the **terrestrial microwave window**. In this region the atmosphere is transparent to radio waves from and to space. Any planet with an atmosphere like Earth's should have such a microwave through which it is possible to send and receive clear signals. SETI searches in the 60s and 70s focused on a particular range called the water hole, between the emission lines from hydrogen and hydroxyl.

Radio communication SETI can either use large single dishes or multiple larger dishes in coordination. An example of a large dish is the Green Bank telescope, the largest steerable structure on Earth, in the Green Bank observatory, where the Drake equation was invented.[3] Examples of telescopes that use multiple smaller dishes are the Allen telescope array, owned by the SETI institute, and the MeerKAT telescope in South Africa.

2. Optical Communication SETI

A challenge of optical communication SETI is that the targeted planets are close to stars. Stars are very bright at all optical wavelengths, so they would block an eventual signal coming out of a planet. As, in terms of frequencies stars are *silent*, radio SETI has been a more popular technique.

However, recent studies in optical SETI exploit the brightness of stars to look for optical signals. The idea is that if you use a laser that only transmits all the energy at one very specific wavelength, then you can be seen against your host star for brief periods of time. Optical SETI hence searches for laser flashes in the sky. [4]

Optical SETI is conducted using optical telescopes, like the James Webb optical and infrared space telescope, launched into space by NASA in December 2021.

Artifact SETI

The problem with communications SETI is that if no one is sending us a beacon, then we will never find SETI, but it does not mean that there is no other life in the galaxy. Artifact SETI tries to recognize the use of technology that alters the environment.

Researchers look for artifacts in the literal sense of the word by looking for **physical objects**. For example, humans have sent satellites into the solar system, so maybe other civilizations have too.

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[3] The work conducted in Green Bank also relies on observations from the Kepler or TESS telescopes. These telescopes keep catalogues of all the different stars that we know of that have planets, the planet size and distance from their stars. The largest single dish telescope in the world is the FAST telescope in China.

[4] An example is the PANOSETI project, led by Dr. Shelly Wright at UC San Diego. The idea of the project is to constantly scan the sky looking for flashes. It will rely on Fresnel lenses, usually used in lighthouses. The lenses and the ground detectors are currently in the testing phase.

Another avenue is to exploit that technology makes **detectable changes to the environment** (detectable if you are close enough or have a good enough instrument). For example, lights on Earth have changed the way our atmosphere looks at night; or polluting molecules leave their spectral fingerprints on the atmosphere, so that we can compare the atmosphere of a planet in two points in time and conclude that there is a likelihood that there is some sort of industrial technology.

Finally, researchers also look for **leakage radiation**. Sometimes, signals sent on Earth leak past their intended targets and travel out into space. These signals, which are not strong as they were not intended to be sent into space, could be captured with a sensitive enough telescope. These transmissions travel at the speed of light, which is finite: the further away we are from the transmitters, the further into the past we would be looking.

Problems with communications and optical SETI

1. How do we distinguish between technology and nature?

Sometimes scientist find interesting phenomena in the sky that turn out to be behaviours of the universe never documented before. A well-known example is that of Dr. Jocelyn Bell and pulsars.

While a PhD student in the UK during the 60s, Dr. Jocelyn Bell Burner was studying the night sky when she noticed points on the sky that seemed to be flashing regularly. Jokingly, her advisor and her called these bright pulses of radio emission LGM, for little green men. After discussions with theoretical astrophysicists, they realised that what she had discovered were pulsars: neutron stars emitting radio of leftover energy from the supernova that created them.[5]

Recently, the interstellar comet Oumuamua captured a lot of attention in the media. Although some astronomers initially suggested that it was an alien probe intentionally sent to Earth, recent evidence points towards it being a part of a planet ejected during a collision.

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5 There are two possible results after a dead star experiences a supernova: neutron stars and black holes. Neutron stars arise if the core of the dead star is too small to become a black hole. Neutron stars are small, dense and spin quickly. They have a lot of energy left over from the supernova, which they shoot out in a jet from the poles of the neutron star. Planets just along the line of the jet will see a flash as the jet passes over. Pulsars are used for celestial navigation across the universe as markers, akin to lighthouses for ships.

These comets are very useful for SETI, as our understanding of the universe beyond our solar system is very limited.

2. How do we distinguish between human an extraterrestrial technology?

Sometimes Earth technology masquerades as signals from space. This is a problem that will worsen over time as the interference environment gets more crowded. The following examples illustrate this problem.

For roughly five years, the Parkes telescope in Australia detected very bright and fading signals in the terrestrial microwave window, at seemingly random parts of the sky. Eventually, the astronomers realized that the signals were left over radiation of the microwaves that the staff living onsite used to heat up their meals. Today, microwaves in observatories tend to be multiple boxes deep to make sure this does not happen.

The BLC1 signal detected in 2019 is another example. The signal seemed to have all the promising characteristics: it changed frequency over time; it only appeared when pointing at Proxima Centauri, our nearest stellar neighbour; and it was narrow and persistent. After exhaustive verification, researchers found many signals that had exactly the same shape at the same frequency, but at different times and when pointing at different places, which indicated the signals were coming from Earth.

METI

Messaging ETI consists of sending signals and messages to the universe. There are two ways in which METI is conducted:

1. Sending physical fingerprints of our existence out into space. Examples of this practice are the golden record in Voyager, an international project to portray humanity as a whole; or the Pioneer satellite with the Pioneer plaque, which included a pulsar map with the information of how to find our planet. These satellites are barely getting out of our solar system.
2. Sending electromagnetic signals into space stating our existence in the universe.

3. The institutions funding SETI in the United States

The funding environment in the United States is very dynamic.[6] For the most part, SETI funding is private. The latest Astronomy and Astrophysics Decadal Survey, which guides the government's priorities of astronomy for the next ten years, barely mentions SETI research.

Nowadays, some organizations involved in SETI are:

1. The SETI Institute, a non-profit located in Silicon Valley.
2. The Berkeley SETI research centre, a long-standing institution currently hosting the *Breakthrough Listen* project, which is the most well-funded study project in SETI history.
3. The National Science Foundation (NSF), which had not been active in funding SETI research for decades, is now participating through fellowships and other projects.
4. NASA recently awarded technosignature grants, which they had not since the early 1990s.

SETI researchers face a challenge when submitting funding proposals: their science has long time scale, lots of space to search and a lot of negative results are guaranteed. However, the researchers stress that SETI is at the forefront of technological development: advancements in instrumentation, data science and algorithms arising from SETI research spill over to other fields.

Ethical and policy implications

This section provides a broad overview of the connections between SETI and other fields, and the issues that SETI researchers run into. Social science work on many of these topics is sparse, as funding is difficult to obtain. More engagement is needed between hard and social scientists and policy makers to advance some of these open questions.

1. The space industry and megaconstellations

The more we develop technology that relies on radio communications, the more interference there will be with space related research. The increasing number of satellites are especially difficult to filter out because they can mimic sources that come from the sky.

Astronomers are particularly worried about the rise of megaconstellations, such as Starlink. These satellites contaminate the images that optical researchers use and jeopardize the sensitivity of radio astronomers. The Square Kilometre Array (SKA) telescope, for example, uses for some of its exploratory tasks the same downlink bands as Starlink. The challenges need to be weighed against the potential benefit that these megaconstellations could bring.

[6] There is SETI research being conducted outside of the United States: For example, in China with the FAST telescope, and in Europe with strong network of SETI scientists, such as SETI Italia.

There are policy solutions that one could envision to solve this issue. Alternatively, there are other technical solutions, such as machine learning algorithms to eliminate the contamination or launching the telescopes into space so that they are above the satellite bubble. Additionally, there is the questions whether access to dark skies is a human right.

2. METI

METI is a controversial practice, and is gaining importance as technology is now cheaper and hence it is easier to book time on a transmitter. Individual interest groups can pay for access to a transmitter and unilaterally decide what to send.[7] There are no treaties in place that govern METI, which means that there are no punitive measures for wrongdoing.

Regulating METI transmissions would be an international effort, as transmission sent by one person could affect all of humanity. Additionally, METI and SETI are connected, as METI might follow a reception of alien signals. In this case, who speaks on behalf of Earth? Furthermore, there are questions on whose responsibility it is to contain the METI activity.

3. The complicated colonial legacy of astronomy and physics

Sometimes, the perspectives of astronomy and indigenous people do not align. For example, the sites where telescopes are located need to be elevated, in cold and dry conditions, and far away from cities. With these considerations, the best sites for telescope construction are also sites that are guarded by indigenous communities, and not necessarily in the countries that are the primary stakeholders in the science.

For example, Hawaii recently approved a permit to start building a 30-meter optical telescope in Mauna Kea, one of the most sacred sites in Hawaii. The indigenous community fiercely opposed the construction of the telescope. The MeerKAT telescope, located in the Kuru dessert, is also surrounded by controversy, as there are issues regarding the ownership of the land.[8]

Additionally, western scientific practice might bias our ability to imagine alien life. For example, pop- culture portraits aliens as creatures looking to colonize Earth. If we are aware of those biases and we try to actively mitigate them, we may come up with new search strategies. An example of a non- western view is Cinxin Liu's book *The Dark Forest Theory*.

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[7] An example is METI International.

4. Artifact SETI

In case artifact SETI succeeds, who owns the alien artifact? Who has the rights to it? And do these rights depend on whether it is found on Earth, in the Moon, or simply floating into space? How can we regulate access to that artifact by all the groups that might be interested in it? How do the astrobiology planetary protection protocols apply to alien artifacts?[9]

5. What if SETI succeeds?

There have been instances of false alarms when for a time the public thought that ETI had been found. These times, the impact of the announcements was low. But what would a successful SETI detection say about the place of humanity in the universe? Could we predict what alien life would do? This is connected to our own anthropocentrism and the way we approach other cultures.

The International Astronautical Association and the International Astronautical Congress provide some guidelines for what to do in case of a detection. The guidelines' first step is to confirm that the detection by multiple groups at multiple sites. They also provide guidance about engaging with the media and providing open access to the data. These guidelines, however, are more than a decade old and not enforceable. Given that news now travels fast, and that social media plays a prominent role, they would need to be updated.

Bonus section: Dr. Sheikh's recommendations of Sci-Fi reading

1. *Roadside Picnic* by the Strugatsky brothers
2. Any of Becky Chambers' books.

[8] For more information: Davide Chinigo and the SKA case.

[9] Planetary protection is also a concern in space industry's *colonization* initiatives of Mars and the Moon.