Is Anybody Out There?

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For eons, humans have stared up at the night sky in awe, imagining what the vast region beyond Earth might be like. And as our place in the universe became more apparent to scientists studying the stars, a thought arose that has shaped the way we think about our own existence. Carl Sagan, a popular figure in science, eloquently explained this thought during the 1980s in his book Contact: “The universe is a pretty big place. If it's just us, seems like an awful waste of space.” (Sagan, 1985)

When you consider the vastness of the universe, it seems unlikely that Earth is the only place that harbors life (Sagan, 1985). This thought has trickled down into popular culture over the last several centuries and everyone seems to have their own opinion on if alien life could really exist or not, which has given rise to cultural trends and conspiracies like Area 51. But only in the past several decades has by the scientific community really considered it as an idea worth studying. As Sara Seager, a Canadian-American astronomer puts it (in reference to the relatively new emergence of ‘astrobiology’): “We stand on a great threshold in the human history of space exploration” (Seager, 2014).

From the search for life stems another idea that, until recently, would have been dismissed as science fiction: what if there is intelligent life in the universe? Intelligent forms of life are loosely defined as hypothetical organisms with technology similar to or greater than that of the human species. A species that has built a civilization, made complex scientific discoveries, and has turned its eyes towards the stars like us, searching for other life in the universe. It is a historically controversial idea, but a growing demo-

-graphic of scientists believe that with our rapid technological advancement, there may be ways to communicate with them.

This article will explore attempts to transmit messages to potential intelligent life forms, attempts to search for incoming alien signals, and analyze explanations for the silence that we have insofar encountered. However, before considering any form of communication, whether receiving or transmitting, we must first consider where to look.

Where is Life in the Universe?

Logically, a scientist that hopes to communicate with extraterrestrial beings must assume that: 1) extraterrestrial intelligent life exists in the universe, 2) it exists in high enough abundance that radio communication is possible, 3) a transmitted radio signal from Earth will be picked up by a receiver, and 4) the message will be translated successfully. Each assumption comes with challenges that make the process of creating a radio message appropriate for transmission extremely complicated.

Before we begin the search for intelligent life, it is important to recognize where life of any sort may exist in the universe. In general, scientists look for known precursors for life, like heavy elements (such as carbon, oxygen, or nitrogen), low radiation levels (since high UV radiation can be damaging to replication molecules like DNA), and liquid water. Water is especially important: all known life on Earth requires liquid water to survive. As such, within a solar system, the traditional 'habitable zone' is defined as the imaginary disc around the host star where water will remain in liquid form. A significant number of exoplanets have been discovered within this zone around their host star, but only a fraction of them are considered 'Earth-like', meaning that their surface conditions and sizes are similar to Earth's (Rekola, 2009).

> **"We stand on a great threshold in the human history of space exploration"** (Sara Seager, 2014)

Space telescopes such as Kepler (launched by NASA in 2009) have discovered just over 1000 exoplanets (as of 2015), a relatively small proportion of which can be seen in the green belt in Figure 1 (the image is biased as it excludes

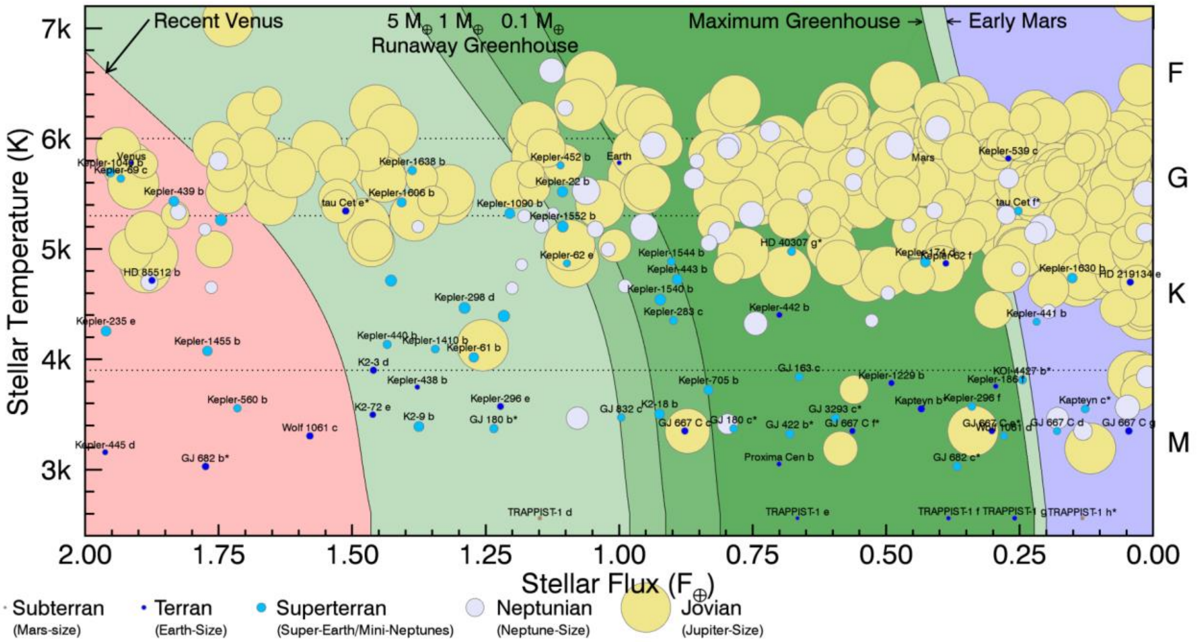


FIGURE 1: EXOPLANETS NEAR HABITABLE ZONES. This image shows the number of exoplanets found in habitable zone (green), and their relative sizes. Only the smaller, labelled planets have radii less than 2.5 times that of Earth (Méndez, 2017).

exoplanets that are not near the habitable zone). But being inside the habitable zone does not mean that we should immediately categorize them as a candidate for a planet with life. Pat Brennan, a science writer for NASA explains that if a planet is "too big, too uncertain, or circling the wrong kind of star…", even within the traditional habitable zone, we can usually ignore them as candidates for life in the catalogue of exoplanets (Brennan, 2016).

So what do scientists look for? Usually planets that look like the only planet we know to have life so far: Earth. Scientists determine if a planet is similar to Earth by using the Earth Similarity Index (ESI). This quantifies the similarities between the Earth and the planet of interest for certain parameters such as stellar flux, radius, density, escape velocity, and surface temperature. The output number for a planet's ESI (from 0 to 1, where 1 indicates a planet identical to Earth) can vary depending on how many parameters are considered in the ESI equation (Schulze-Makuch et al., 2011). Furthermore, the ESI at which planets are considered Earth-like is somewhat subjective. 'Earth-like' on the ESI can mean from 0.6 (tolerable for extremophile organisms) to 0.8 (acceptable for plants or animals as we know them). For reference, Mars has an ESI of 0.7 and the prospect of finding life there now is fairly unlikely. Kepler has discovered several planets that surpass the 0.8 threshold, notably Kepler-438b (0.88), and Kepler-296e (0.85) and exomoons that have reached an ESI of up to 0.96 (Denza & Denza, 2016).

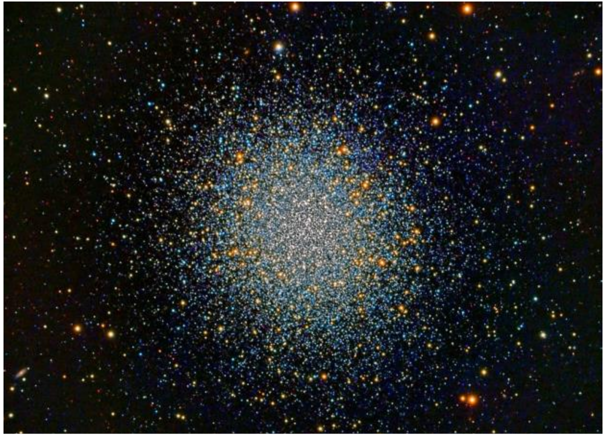


FIGURE 2: MESSIER 13. Messier 13 is a large star cluster in the Hercules constellation (KuriousGeorge, 2016).

However, the ESI often overlooks one of the most important aspects of determining an exoplanet's habitability: its atmosphere. Even small variations in a planet's orbital path can have huge impacts on terrestrial atmosphere, which shields the planet from solar radiation. A so called 'habitable' planet with an atmosphere that is too thick or non-existence is thought to have a much lower chance of sustaining life than a planet with an Earth-like atmosphere. Even climate cycles are also thought to impact habitability, which can be highly sensitive depending on the orbit of the exoplanet (Gómez-Leal et al., 2016). Another method for determining the habitability of exoplanets involves spectral analysis in order to determine chemical composition, which finds 'fingerprints' of carbon, oxygen, ozone, nitrogen, and other known organic molecules: prerequisites for life as a we know it (Kaltenegger & Selsis, 2009). Unfortunately, the fact remains that despite all of these efforts, we have yet to find any evidence of life existing anywhere but Earth in the universe.

Choosing Targets

With prospects like this, the likelihood that intelligent life exists seems even more bleak, but a famous equation created by Frank D. Drake in 1961 appears to demonstrate that perhaps our search is not as futile as it seems. The Drake Equation, as it is known today, estimates the number of extraterrestrial civilizations with the means to communicate with other intelligent life. In the Milky Way, this number has been estimated to be anywhere from 10 civilizations to 10 million. This large margin of error occurs because many of the probabilities used to calculate this number are impossible to determine, such as the percentage of planets with life on which intelligent life has evolved, or the percentage of planets on which the intelligent life is able to communicate with other intelligent life. Regardless, the Drake Equation is an interesting thought experiment that shows how common intelligence could potentially be, even within our own Galaxy (Maccone, 2011).

To choose a target destination for radio transmission with the hope of reaching intelligent life, a good strategy is to increase the chances of it reaching a large number of stars, by simply choosing a part of the sky where more stars are visible. The first radio transmission, known as the Arecibo message, was sent to a globular cluster of stars known as Messier 13 (M13) (Figure 2) in the

Hercules constellation in 1974, which contains at least 300,000 stars. The closest stars are approximately 25,000 light years away from Earth, but M13 itself is about 145 light years across in volume, meaning the the signal would continue to travel through the cluster well after having reached its destination. During the transit time, M13 is expected to move relative to our solar system, but only by about 25 light years (Fairbairn, 2008). Nevertheless the sheer distance between 'us' and 'them' is so astronomical that by the time the message arrives at M13 around 24,957 years in the future, our species may very well have forgotten about it.

Since the Arecibo message, targets for radio transmissions have become closer and more specific. "A Message From Earth" was sent to a red dwarf system called Gliese 158 in 2008, which is orbited by three 'super-Earths' (planets with mass between 1 and 10 times Earth's mass), one (Gliese 158g) located within the habitable zone of the star (Levenson 2011). The system exists within the constellation of Libra and due to its relatively close location, the outgoing message is expected to arrive in February of 2029 (Zaitsev 2012). If Gliese 158g has an atmosphere, it could be considered habitable, but assuming intelligent beings might roam its surface may be a long shot. Either way, we will not know for certain until after 2050, being the minimum amount of time it would take for us to receive a response, assuming the message is received and translated almost immediately, and assuming that the intelligent beings respond to our message (Zaitsev 2012).

As we discover more and more potentially habitable planets, scientists and researchers are pinpointing new locations in our universe for sending future radio messages in search of intelligent extraterrestrial life. Recently, radio transmissions into space have also been created for cultural, artistic or historical expression. For example, on October 10, 2016, The European Space Agency (ESA) sent the most recent radio message from Earth, called 'A Simple Response to an Elemental Message' (ASREM) to Polaris, the North Star, approximately 434 light years away (Scuka 2016). Though there is no evidence that Polaris hosts any exoplanet that would be considered habitable, there are obvious historical and cultural reasons for choosing the North Star as a destination (Evans et al. 2008).

There exist also many illegitimate messages sent out for humorous or celebratory reasons.

For example, a video advertisement for Doritos tortilla chips was transmitted to the Ursa major constellation in 2008. While it's interesting to ponder what aliens would think of our flat triangular snack foods, the actual possibility of this message making meaningful contact is slim to none. What criteria then must a transmission satisfy to be considered a "serious" or "scientifically relevant" effort to make contact?

Alexander Zaitsev, a prominent author in the field of interstellar transmission, argues there are three basic criteria that filter out most of what he calls 'pseudo-messages', such as the Doritos advertisement. These criteria are: (1) the choice of target star; (2) the energy required per bit of information; and (3) availability of a decoding 'key' inside the message. The first criterion considers whether we are transmitting to a plausible candidate for life, which is obviously necessary if there is to be any two-way communication. The second criterion is concerned with whether the message will reach the target. When sending radio messages through interstellar space, noise is added to the signal by the cosmic microwave background. This is the fundamental limitation on interstellar communication (Messerschmitt, 2015). The Shannon Limit, named after the famous communications scientist Claude Shannon, tells us the limit for reliable information transfer rate depends on the signal-to-noise ratio. An intuitive result from his equations is that the signal-to-noise ratio improves if our signal is sent with more energy per unit of information, and consequently less error on the receiver side when it is recovered from the noise. In other words, the more complex the message, the more energy required to send the message reliably. The third criterion is concerned with whether extraterrestrials could conceivably understand the contents of the message, considering they may have different languages and computing technologies.

After applying these criteria, we are left with only a handful of 'serious' attempts to transmit to extraterrestrial intelligence.

The Arecibo message is considered one these more serious attempts, since its message carefully written and encoded by Frank Drake and Carl Sagan. It included atomic numbers of the elements for life on Earth: hydrogen, carbon, oxygen, nitrogen, and phosphorus; chemical formulas for the sugars and bases in DNA; and graphics of humans, the Solar system, and the Arecibo station in Puerto Rico used to send the message -- all sent in binary by modulating the frequency of the signal (Atri et al., 2011).

Similarly, the Cosmic Call messages transmitted in 1999 and 2003 from the Evpatoria Planetary Radar, Ukraine sent a fairly complex series of messages, which included an alphabet of symbols to represent numbers, chemical elements, and mathematical operators (Dumas and Dutil, 2003). Each symbol was represented on 2D array of pixels, each represented by a bit, and were sent line-by-line in binary format: a 0 for an empty pixel or a 1 for a filled pixel. The message written in this 2D symbolic format was written to resist alteration by noise while travelling through space. A 1D message sent as a stream of bits, similar to Morse code is particularly susceptible to distortion. If, somewhere in the stream, a 0 is distorted to be a 1 instead, that part of the message no longer makes sense, similar to how changing a short dash to a long dash in Morse code might completely change the meaning of the message. If we use a 2D graphic instead, even if the symbol is reconstructed on the other side with some bits altered, the receiver could still conceivably recognize the symbol given that the distinct symbols are sufficiently different. This also means that as a whole, there is more information to be sent, which requires the signal to be sent with higher power, or to a closer target to minimize noise. The Cosmic Call messages were transmitted to several constellations all fewer than 100 light years away (see insert) (Zaitsev, 2012).

Other noteworthy projects include the Teen Age message and A Message from Earth, both also sent from Evpatoria, Ukraine in 2001 and 2008, respectively. The Teen Age message sent both analog and digital information, and included a musical melody, along with greetings in Russian and English (Zaitsev, 2012). Neither, however, would be considered ‘serious’ from the criterion of a legitimate attempt to communicate with extraterrestrial life. In fact, since Cosmic Call in the early 2000s, there has been a shift away from scientific based interstellar radio transmissions, to more crowd-supported public transmissions which are heavily based on popular culture and significance. At this time, it is not known if there will be a shift back towards the search for intelligent life in the universe that inspired Arecibo.

Efforts to Receive

Despite transmission efforts of messages into space no longer focusing as much on genuine attempts of communication with intelligent extraterrestrial beings, continuous efforts exist to detect such signals potentially coming from intelligent life. Because radio signals are not blocked by the Earth’s atmosphere, they are an appealing candidate for the search for extraterrestrial intelligence, commonly abbreviated SETI. Radio astronomy is therefore a good way to search for signs of intelligence life in the universe.

Radio astronomy

Radio astronomy uses dish-shaped telescopes that reflect radiation to a central point, where the antenna is situated. This induces a current in the antenna, which is then amplified by a radio receiver (Miller 1998). The radio signal is then filtered into specific frequencies or wavelengths (which are inversely proportional and therefore can be used interchangeably to describe radiation). The amount of radiation received at each frequency is plotted against the frequency, yielding a plot called a spectrum (Figure 3).

Though astronomical sources may produce spectra with peaks at specific frequencies, those peaks typically span a wide range of frequencies (Burke and Graham-Smith 2010). No natural source has yet been identified that can produce spectra with peaks narrower than 500 Hz. Therefore, because radio waves can penetrate the atmosphere, the search for alien life involves searching for radio waves with narrow-band emission peaks, less than 500 Hz. Narrow-band signals have only ever been

IS ANYBODY LISTENING?

INTERSTELLAR TRANSMISSIONS FROM EARTH

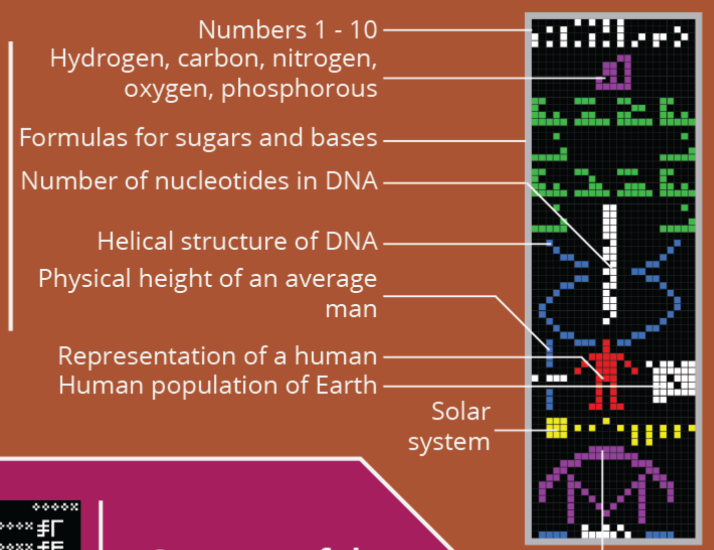
ARECIBO MESSAGE

1974

BINARY CODE

ARECIBO, PUERTO RICO

Designed by Frank Drake and Carl Sagan, this message was sent in binary by modulating the frequency of the signal. It was the first message of its kind.



Arecibo telescope

COSMIC CALL

1999, 2003

2D PIXEL ARRAY

EVPATORIA, UKRAINE

The 2D pixel array of the Cosmic Call message is resistant to alteration by noise as it travels through space due to its unique structure.

Contents of the message

- alphabet of symbols to represent numbers
- chemical elements
- mathematical operations

TEEN AGE MESSAGE

2003

DIGITAL TIME CAPSULE

EVPATORIA, UKRAINE

Contents of the message

- monochromatic probing signal
- theremin music (analog information)
- greetings in Russian and English

"Hello!
Привет!"

A MESSAGE FROM EARTH

2008

DIGITAL TIME CAPSULE

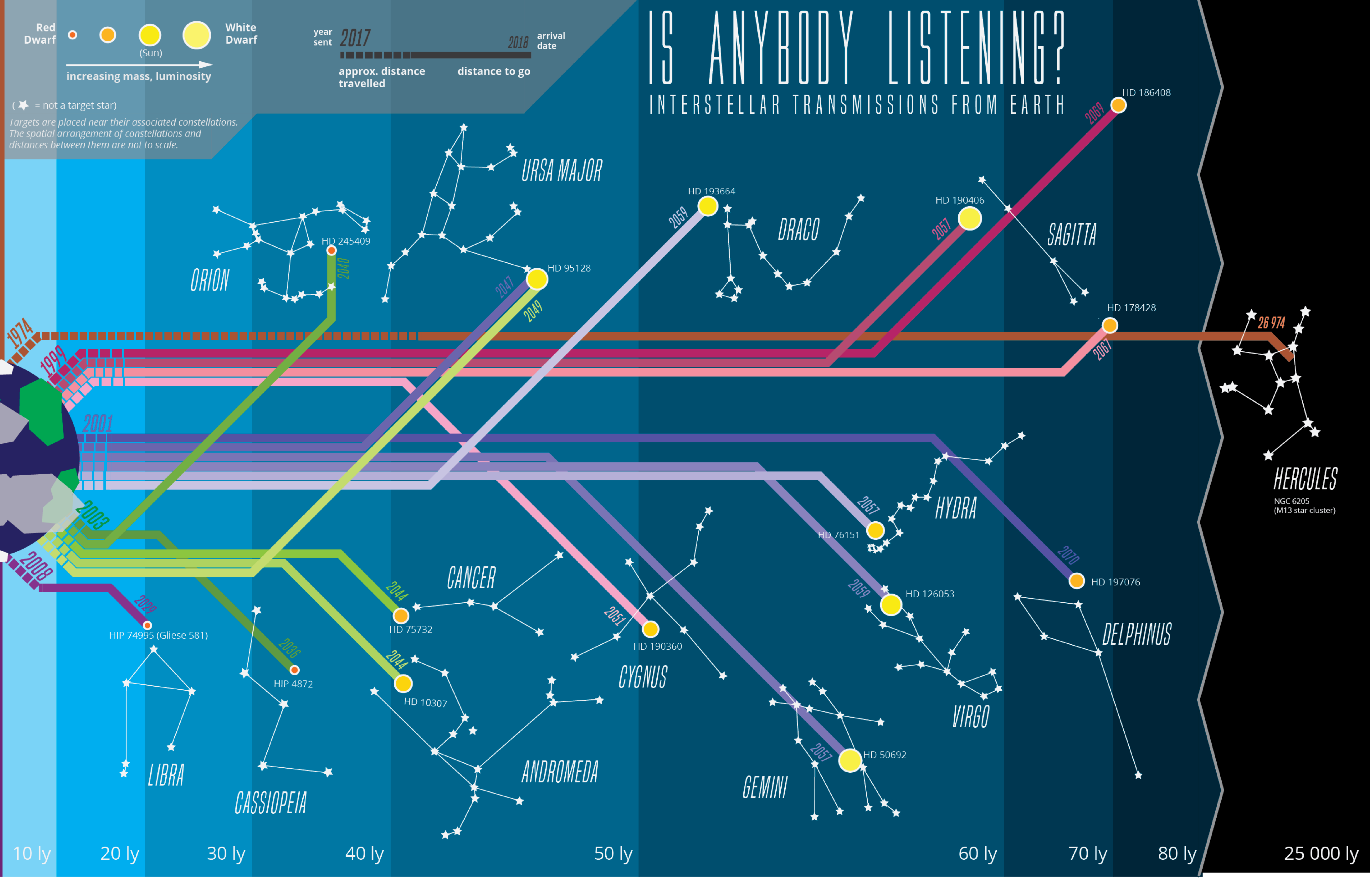
EVPATORIA, UKRAINE

The contents of this message were selected by members of Bebo, a social networking site. It serves as a sort of time capsule, containing images of contemporary and historical events, people, and landmarks. It also contains notes containing the thoughts and ambitions of its contributors.

The Scottish Edinburgh Castle was featured as an image in the message. Other images contained depictions of Hillary Clinton, George Bush. A note from a contributer ruefully stated they had been "born too early" for contact with aliens.

An image of U.S. President Obama was featured in the message.

An image of the world-famous London Eye was transmitted to the destination star.



produced artificially, and could therefore be attributed to an alien civilization (SETI Institute 2017b). Furthermore, it is thought that because hydrogen is the most abundant element in the universe, any civilization with advanced enough technology for radio transmission would also know of hydrogen's 21-cm wavelength emission line, equivalent to a frequency of 1420 MHz. As such, hydrogen's emission line might be selected as the wavelength for a deliberate radio transmission to Earth, and therefore a signal that we should be searching for (Ehman 2011).

SETI

Detecting such signals is an aim of the SETI (Search for ExtraTerrestrial Intelligence) Institute, founded in 1984, and based out of Mountain View, California (Wall 2012; Pierson 2010). SETI has several ongoing efforts in the search for alien-based radio signals, including the Allen Telescope Array, the SERENDIP project, SETI@home, and the new Breakthrough Listen initiative.

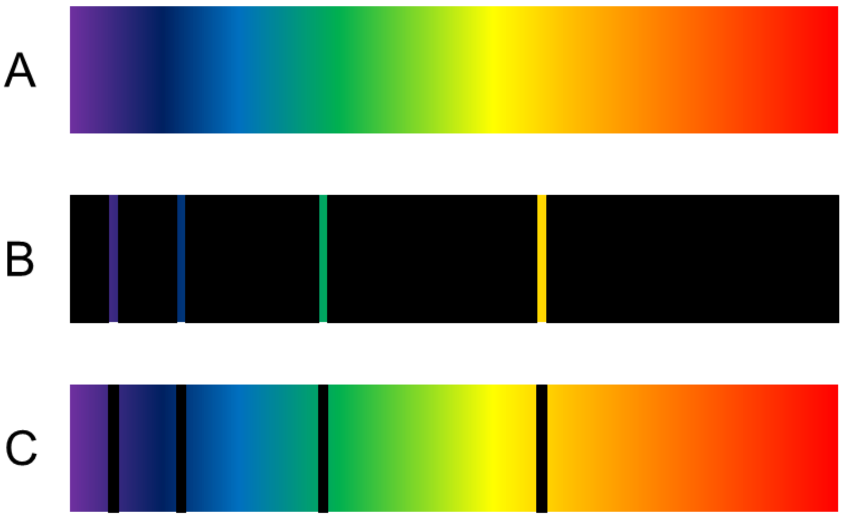


FIGURE 3: THE THREE TYPES OF SPECTRA. A) An astronomical source like a star will emit a continuous spectrum, radiating at all frequencies within a broad range. (C) However, if the continuous radiation from this star were to pass through a medium that absorbs only certain frequencies, such as a cloud of gas, a dark line or absorption spectrum would be observed. (B) Finally, a hydrogen atom, when its single electron is excited and then returns to rest, will emit radiation of specific frequencies with no radiation in between, giving a bright emission line spectrum.

The Allen Telescope Array (ATA) is an array of 42 radio telescopes located north of Lassen Peak, in California, and was constructed using donations from Paul Allen, co-founder of Microsoft, and Nathan Myhrvold, former chief technology officer at Microsoft (SETI Institute 2017a). An array of telescopes can simulate a large dish telescope, but is more flexible because the arrangement and number of disks involved is variable, and can be modified as needed to improve resolution (Figure 4A-D) (SETI Institute, 2017a). In fact, by replicating the cables and electronics attached to each element of the array, more than one virtual large telescope can be created, with variable curvature and beam (field of view) (Figure 4E). Therefore, the Allen Telescope Array can look at two or even three different astronomical locations at the same time (SETI Institute 2017a). The ATA is optimized to analyze signals from 500 to 10 000 MHz, making it possible to detect narrow-band 1420 MHz, potentially alien radio signals (SETI Institute 2017a).

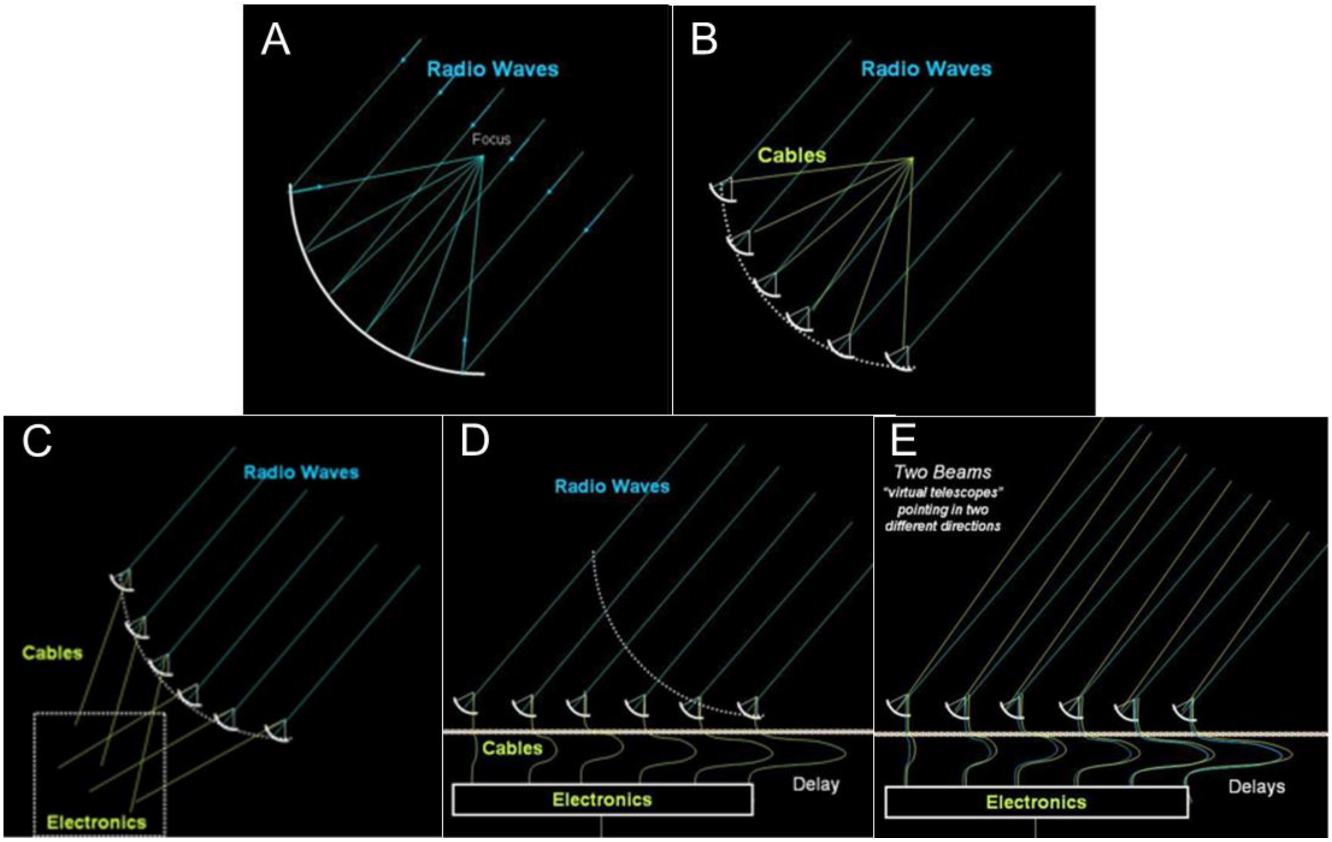


FIGURE 4: HOW THE ALLEN TELESCOPE ARRAY WORKS. A) pictures a large radio telescope dish and its focus, while B) shows how an array of telescopes can simulate a large telescope. C) shows that the cables from each element of the array do not need to connect to the focus, and can in fact D) be arranged flat on the ground, accounting for the concave shape of the virtual dish using different lengths of cables. E) demonstrates the capacity of the telescope array to look in two different locations at the same time (SETI Institute 2017a).

SERENDIP and SETI@home

Apart from operating their own telescope array, SETI also has several 'piggyback' initiatives, where the radio signals received by telescopes for other astronomical observation purposes are analyzed for signs of alien signals. One such initiative is the SERENDIP project, which looks for narrow-band signals in the data collected by the 300-foot U.S. National Astronomy and Ionospheric Center Arecibo telescope in Puerto Rico (Cobb et al. 2000; Lampton et al. 1992). A pattern detection algorithm, which looks for persistent narrow-band signals, is used to identify statistically interesting candidate signals for extraterrestrial intelligence (ETI) within Arecibo's data. A weighted sore is assigned to each candidate, based on the likelihood that the signal is alien, and high-scoring candidates are then re-observed (Cobb et al. 2000). However, most high-scoring candidates end up being terrestrial-based (Lampton et al. 1992).

SETI@home, another 'piggyback' SETI initiative, also analyzes Arecibo data, but uses the home or work computers of volunteers around the world to create a virtual supercomputer for high-volume radio signal analysis (Korpela et al. 2011). The SETI@home project has a smaller frequency coverage than SERENDIP, but is more sensitive. There are currently over 5 million participants in this project. During primary analysis, the virtual supercomputer searches for candidate signals, and then the project's own computers reject terrestrial-based radio frequency interference, and search the candidate signals for repeated events (Korpela et al. 2011).

Breakthrough Listen

Despite the importance of SETI's work, in recent years, the organization has been severely underfunded, relying on personal donations and government grants, with funding being the Institute's greatest challenge for progress (Pierson 2011; Merali 2015). In

April 2011, they were forced to put the Allen Telescope Array into hibernation for a few months due to lack of funds (Pierson 2011). Operations were resumed by December 2011 due to acquisition of funding, and the ATA was able to resume operations, even assisting NASA's Kepler mission (SETI Institute 2011).

A recent $100 million donation to the SETI Institute by Russian billionaire Yuri Milner has spearheaded a new SETI initiative, called project Breakthrough Listen, which will listen to messages from 1709 nearby stars, from 5-50 parsecs away, and 123 galaxies close to Earth (Wootten, 2015; Isaacson et al. 2017). The funding will be used to search for radio signals using the 100-metre-diameter Robert C. Byrd Green Bank Telescope in West Virginia, and the 64-metre-diameter Parkes Telescope in New South Wales, Australia, and the initiative will span 10 years, from 2015 to 2025 (Wootten 2015). The incredible sensitivity of these telescopes will allow SETI to detect transmissions with the power of common aircraft radar from civilizations based around the 1000 closest stars, and even from the center of the Milky Way, if the power of the transmission is 12 times that of interplanetary radars used to probe the Solar system (Wootten 2015). Thus far, the project has not found anything of interest, however, in contrast to SETI's past, there is now enough funding for the Institute to utilize a world-class radio telescope 365 days a year to search for signals from intelligent life. This will accelerate the work of the Institute tremendously, and there is a great amount of potential for this comprehensive search to potentially find signals from alien civilizations in the future (Isaacson et al. 2017).

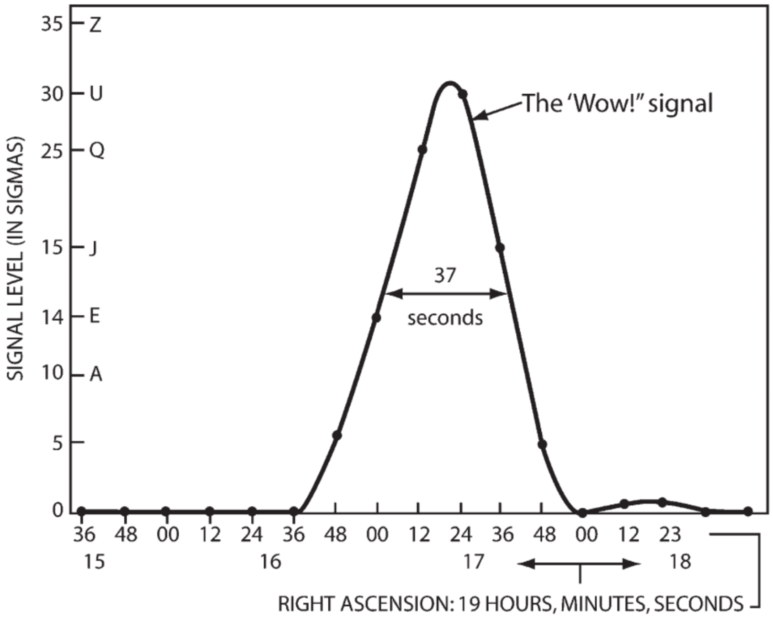


FIGURE 5: THE "WOW!" SIGNAL. Thus titled because the researcher that saw it drew a circle around it and labeled it "Wow!". Pictured here is its plot of signal intensity over time (Ehman 2011).

"Wow!" Signal

Despite these initiatives, no signals from alien life have yet been detected, though the most interesting potential candidate is the "Wow!" signal, detected by the "Big Ear" radio telescope at the Ohio State University Radio Observatory, analyzed on August 15, 1977 (Figure 5) (Ehman 2011). It is perhaps humanity's best candidate for extraterrestrial communications, as it was an intense, 37-second-long narrow-band signal, within the 21-centimetre wavelength (Figure x) (Ehman 2011). The 21-centimetre wavelength is thought to be the best candidate for deliberate alien transmission, as this is an emission line of hydrogen. It is thought that civilizations with technology sophisticated enough to emit radio signals would also know that hydrogen is the most abundant element in the universe, and thus that the 21-centimetre hydrogen emission wavelength would be known to all other civilizations, including humanity.

Though this signal is still the most compelling candidate for alien signals, recent findings have suggested that the source of the signal may have been two comets that had not yet been discovered in 1977 when the signal was observed, since the first observation of the comets was in 2006 (Paris and Davies 2015). The hydrogen clouds from these comets were potentially responsible for this signal, but further investigation is required to determine the source of the signal, making it still the most tantalizing candidate for the detection of alien life.

Explanations for Silence

When we account for the unfathomable size of the universe and our best understanding of conditions for life in the Drake equations, statistically speaking we are not alone in the universe. In fact, we should expect that life is reasonably common, which then raises the question: where are our neighbours in the sky, and why haven't we heard from them? This problem has been described as the Fermi paradox.

Imagine one day, a person wakes up in an empty city. All the buildings and streets are vacant without explanation. In the Fermi paradox we find ourselves in this situation with humankind as the person, and the universe as the city.

Hypotheses typically fall into three categories: solipsist solutions, rare Earth solutions, and catastrophic solutions.

Solipsist hypotheses reject the premise of the Fermi paradox, and are typically metaphysical solutions. For instance, the Zoo hypothesis proposed by Ball (1973) and Interdict hypothesis by Fogg (1987) states that there is an intergalactic 'club' of civilizations that have agreed to avoid contact with our civilization. This category also includes "brain in a vat"-type solutions: the premise that we are in a some sort of simulation and that nothing in our world is real. However, if we consider that the entire basis of modern science is empirical and based on the assumption that what we can observe is real, then by nature, these hypotheses hold little scientific value because they are difficult or impossible to test.

Is life less common than we think? Rare Earth hypotheses propose that the development of intelligent life can happen only under rare and extraordinary circumstances. For instance, the presence of a large moon to stabilize the rotation of the planet for climate stability, or the unlikely coincidence of certain chemical and geological conditions to enable rapid evolution and diversification of organisms as seen in the Cambrian explosion on Earth. These theories are more grounded in the physical world, but are still difficult to test. To say that intelligent life would not have evolved on Earth without the Moon is a self-defeating question because it makes the assumption that factors act independently, when in fact all these factors are interconnected. If the universe developed differently such that life did not arise on Earth, it may be the case that the right factors lined up to create life elsewhere. So even if it is true that the development of life on Earth is unique in the universe, given the practically infinite factors to consider, we may never be able to say exactly why this is the case.

But perhaps the advent of intelligent life is common in the Universe, and the Universe is more hostile towards life than we originally imagined. In the Cold War era, civilization self-destruction theories were popular (Cirkovic, 2009). These propose that it is inevitable for technologically advanced civilizations to wipe themselves out through means of nuclear holocaust or engineering gone awry. Catastrophic theories also include natural catastrophes. For instance, the Alvarez hypothesis -- the theory that the dinosaurs went extinct due to an asteroid impact falls into this category. Perhaps it is the case that extinction phenomena such as asteroid impact, super-volcanism, or supernovae occur more frequently than what our recent observations suggest. More recent thought on this topic suggests that Gamma ray bursts are a candidate for extinction events (Cirkovic, 2003). Catastrophic theories range in their approaches and some perhaps take some creative liberty, but are perhaps the most interesting to ponder because they would have direct implications on our future as a civilization.

Conclusion

Whether or not other intelligent life exist in the universe, we may never know. But what is exciting is that for the first time in history, we have been able to ask these difficulties questions through scientific endeavour, combining astronomy, biology, and philosophy. This fusion of disciplines has transformed the way we think about our place in the night sky. As for the radio messages… only time will tell.

REFERENCES

Atri, Dimitra, Julia DeMarines, and Jacob Haqq-Misra. 2011. "A Protocol for Messaging to Extraterrestrial Intelligence." *Space Policy* 27 (3): 165–69. doi:10.1016/j.spacepol.2011.01.001.

Ball, John A., and John A. 1973. "The Zoo Hypothesis." *Icarus* 19 (3): 347–49. doi:10.1016/0019-1035(73)90111-5.

Burke, Bernard F., and Francis Graham-Smith. 2010. *An Introduction to Radio Astronomy*. Cambridge University Press.

Brennan, P. 2016. "Finding Another Earth." *NASA*. https://www.nasa.gov/ames/kepler-finds-a-very-wobbly-planet.

Ćirković, Milan M. 2004. "The Temporal Aspect of the Drake Equation and SETI." *Astrobiology* 4 (2). Mary Ann Liebert, Inc. : 225–31. doi:10.1089/153110704323175160.

Cirković, Milan M. 2009. "Fermi's Paradox: The Last Challenge for Copernicanism?" *Serbian Astronomical Journal* 1 (178): 1–20. doi:10.2298/SAJ0978001C.

Clugston, M. J., and Rosalind. Flemming. 2000. *Advanced Chemistry*. Oxford University Press.

Cobb, J., M. Lebofsky, D. Werthimer, S. Bowyer, and M. Lampton. 2000. "SERENDIP IV: Data Acquisition, Reduction, and Analysis." In *Bioastronomy 99: A New Era in the Search for Life*, 213:485–90.

Scuka, Daniel. 2016. "A Simple Reponse". *European Space Agency*. http://blogs.esa.int/rocketscience/2016/07/28/a-simple-response/

Deza, Michel Marie, and Elena Deza. 2016. *Encyclopedia of Distances*. Springer.

Dumas, Stephane, and Yvan Dutil. 2003. "The Evpatoria Messages." *Activeseti.org*. http://www.plover.com/misc/Dumas-Dutil/evpatoria07.pdf.

Ehman, Jerry R. 2011. "'Wow!' - A Tantalizing Candidate." In *Searching for Extraterrestrial Intelligence: SETI Past, Present, and Future*, edited by H. Paul Shuch, 47–63. Berlin: Springer.

Evans, Nancy Remage, Gail H. Schaefer, Howard E. Bond, Giuseppe Bono, Margarita Karovska, Edmund Nelan, Dimitar Sasselov, and Brian D. Mason. 2008. "Direct Detection of the Close Companion of Polaris with the Hubble Space Telescope." *The Astronomical Journal* 136 (3): 1137. doi:10.1088/0004-6256/136/3/1137.

Fairbairn, Thomas Edward. 2008. *Universe's Intelligent Design Via Evolution (UIDE)©: The WIT Particle©*. Dorrance Publishing.

Fogg, Martyn J. 1987. "Temporal Aspects of the Interaction among the First Galactic Civilizations: The 'interdict Hypothesis.'" *Icarus* 69 (2): 370–84. doi:10.1016/0019-1035(87)90112-6.

Gómez-Leal, I., F. Codron, and F. Selsis. 2016. "Thermal Light Curves of Earth-like Planets: 1.

Varying Surface and Rotation on Planets in a Terrestrial Orbit." *Icarus* 269 (May): 98–110. doi:10.1016/j.icarus.2015.12.050.

Isaacson, Howard, Andrew P. Siemion, Geoffrey W. Marcy, Matt Lebofsky, Danny C. Price, David MacMahon, Steve Croft, et al. 2017. "The Breakthrough Listen Search for Intelligent Life: Target Selection of Nearby Stars and Galaxies." Advance publication in *Publications of the Astronomical Society of the Pacific*. https://arxiv.org/pdf/1701.06227.pdf.

Kaltenegger, L., and Selsis, F. 2009. "Characterizing Habitable Extrasolar Planets Using Spectral Fingerprints." *Comptes Rendus Palevol*, Traces de vie présente ou passé: quels indices, signatures ou marqueurs? Traces of past or present life: biosignatures and potential life indicators?, 8 (7): 679–91. doi:10.1016/j.crpv.2009.07.001.

Korpela, E J, D P Anderson, R Bankay, J Cobb, A Howard, M Lebofsky, A P V Siemion, J. von Korff, and D Werthimer. 2011. "Status of the UC-Berkeley SETI Efforts." *Instruments*. doi:10.1117/12.894066.

Eakins, T., O'Donovan, W. R. 1981, Black and white photographic print, 6 x 8 cm. Archives of American Art, Smithsonian Institution, Washington, DC. Available from: Flickr Commons, http://www.flickr.com/photos/smithsonian/2547841439 (accessed September 29, 2009).

KuriousGeorge. M13 from an 8. 2016, Wikimedia Commons. Available from: https://commons.wikimedia.org/wiki/File:M13_from_an_8%22_SCT.jpg

Kutner, M. L. 2003. *Astronomy: A Physical Perspective*. Cambridge University Press. https://books.google.ca/books?id=2QVmiMW0O0MC&dq=absorption+spectrum+astronomy&source=gbs_navlinks_s.

Lampton, M., S. Bowyer, D. Werthimer, C. Donnelly, and W. Herrick. 1992. "The SERENDIP Piggyback SETI Project." *Acta Astronautica* 26 (3–4): 189–92. doi:10.1016/0094-5765(92)90094-Y.

Levenson, Barton Paul. 2011. "Planet Temperatures with Surface Cooling Parameterized." *Advances in Space Research* 47 (11): 2044–48. doi:10.1016/j.asr.2011.01.031.

Maccone, Claudio. 2012. "Societal Statistics by Virtue of the Statistical Drake Equation." *Acta Astronautica*, Searching for Life Signatures, 78 (September): 3–15. doi:10.1016/j.actaastro.2011.09.014.

Méndez, A. 2016. "The Habitable Exoplanets Catalog - Planetary Habitability Laboratory @ UPR Arecibo." Accessed March 18. http://phl.upr.edu/projects/habitable-exoplanets-catalog.

Merali, Zeeya. 2015. "Hunt for Alien Life Gets Cash Bonanza." *Nature* 523: 392–93.

Messerschmitt, David G. 2015. "Design for Minimum Energy in Interstellar Communication." *Acta Astronautica* 107 (February): 20–39. doi:10.1016/j.actaastro.2014.11.007.

Miller, Diane Fisher. 1998. "Basics of Radio Astronomy for the Goldstone-Apple Valley Radio Telescope." Pasadena, California. http://www2.jpl.nasa.gov/radioastronomy/radioastronomy_all.pdf.

Paris, Antonio, and Evan Davies. 2015. "Hydrogen Clouds from Comets 266/P Christensen and P/2008 Y2 (Gibbs) Are Candidates for the Source of the 1977' WOW' Signal." *Journal of the Washington Academy of Sciences* 101 (4): 25–32. http://search.proquest.com/openview/e272880a0a2b27d1da24f8d9239aa4b9/1?pq-origsite=gscholar&cbl=1126338%5Cnpapers3://publication/uuid/D962EAC1-CD67-4457-8063-471BC71FB831.

Pierson, Tom. 2010. "The Birth of SETI Institute." *Seti.org*. http://www.seti.org/origin-of-the-institute.

———. 2011. "Subject: Status of the Allen Telescope Array." *SETI Institute*. http://archive.seti.org/pdfs/ATA-hibernation.pdf.

Rekola, Rami T. F. 2009. "Life and Habitable Zones in the Universe." *Planetary and Space Science*, Astrobiology: Study of Conditions related to Origin and Survival of Life on Earth and elsewhere. European Workshop on Astrobiology, 57 (4): 430–33. doi:10.1016/j.pss.2008.09.011.

Sagan, Carl. 1985. *Contact*. Pocket Books.

Schulze-Makuch, Dirk, Abel Méndez, Alberto G. Fairén, Philip von Paris, Carol Turse, Grayson Boyer, Alfonso F. Davila, Marina Resendes de Sousa António, David Catling, and Louis N. Irwin. 2011. "A Two-Tiered Approach to Assessing the Habitability of Exoplanets." *Astrobiology* 11 (10): 1041–52. doi:10.1089/ast.2010.0592.

Seager, S. 2014. "Exoplanets and the Search for Earth 2.0" *Earth Atmospheric and Planetary Sciences*. http://eaps-www-old.mit.edu/news/2014/exoplanets-and-search-earth-20/.

SETI Institute. 2017a. "ATA: How It Works." *Seti.org*. Accessed March 19. https://www.seti.org/seti-institute/project/details/general-overview.

———. 2017b. "FAQ (Frequently Asked Questions)." *Seti.org*. Accessed March 19. https://www.seti.org/faq#obs9.

———. 2011. "SETI Search Resumes at Allen Telescope Array, Targeting New Planets." *Seti.org*. http://www.seti.org/node/905.

Wall, Mike. 2012. "Searching for Intelligent Aliens: Q&;A with SETI Astronomer Jill Tarter." *Space.com*. http://www.space.com/15803-jill-tarter-seti-search-retirement-qanda.html.

Wootten, Janet. 2015. "Yuri Milner and Stephen Hawking Announce $100 Million Breakthrough Initiative to Dramatically Accelerate Search for Intelligent Life in the Universe." *Breakthrough Initiatives*. https://breakthroughinitiatives.org/News/1.

Zaitsev, Alexander. 2012. "Classification of Interstellar Radio Messages." *Acta Astronautica*, Searching for Life Signatures, 78 (September): 16–19. doi:10.1016/j.actaastro.2011.05.026.