It will soon be possible to transmit wireless messages around the world so simply that any individual can carry and operate his own apparatus.

Nikola Tesla, 1909

How Many ETs are There?

Greetings Earthlings in AST 111! In this module we'll examine the question how many civilizations are out there?

We don't know.
But the Drake equation gives us a way to organize our thinking about the question. The image above shows Frank Drake with a version of his famous equation. Our version looks like this:

N = number of civilizations
N_{star} = number of stars in the Milky Way
f_{planet} = fraction of stars that have planets
$f_{habitable}$ = fraction of planets that are habitable
f_{life} = fraction of habitable planets with life
$f_{civilization}$ = fraction of life-bearing planets with civilizations
f_{now} = fraction of civilizations that exist now

$$N = N_{star} \times f_{planet} \times f_{habitable} \times f_{life} \times f_{civilization} \times f_{now}$$

N is the number of civilizations in the Milky Way with whom we could communicate. This is what we want to know. Our estimate begins with only one absolute number, the number of stars in the Milky Way. We know this number pretty well, certainly well enough for our estimation purposes. Its N_{star} = 100 billion.

All our numbers past this are fractions. For example, the next term is the fraction of those 100 billion stars that have planets. This a fraction we can now begin to answer with some degree of certainty from the Kepler mission. Its about f_{planet} = 0.2, so 20% with an uncertainty of about 10%. About one in every 5 stars has planets.

The next term is the fraction of planets that reside within the habitable zone, the temperature range where water is liquid. This number is more uncertain, but given the limited Kepler data of about 300 such exoplanets found to be in their habitable zone, the number is about 10%, so $f_{habitable}$ = 0.1.

The next term is the fraction of habitable worlds with life. Any kind of life, including single cell organisms or bacteria. This number is completely uncertain. Any value between f_{life} = 0 and f_{life} = 1 can be speculated upon. This term is the one will attempt to begin to answer with future missions such as TESS and beyond.

The next term is the fraction of life-bearing planets with civilizations. What is meant by the term “civilization” is the ability to send and receive radio communication. Its not an adjudication on the beauty of the architecture or anything like that. Just the ability to send and receive radio signals. Why radio? We’ll get to that. This term is also unknown, so any fraction between $f_{civilization}$ = 0 and $f_{civilization}$= 1 is fair game.

The last term is the fraction of civilizations that exist now. This is an interesting term. Maybe civilizations don’t last long because they destroy themselves or a large impactor hits their planet or their sun dies. Maybe civilizations decide at some point to stop broadcasting their radio signals out into space. We’re already starting to do this - witness the proliferation of internet and cable driven forms of communication. Any value between f_{now}=0 and f_{now}=1 is a valid estimate.

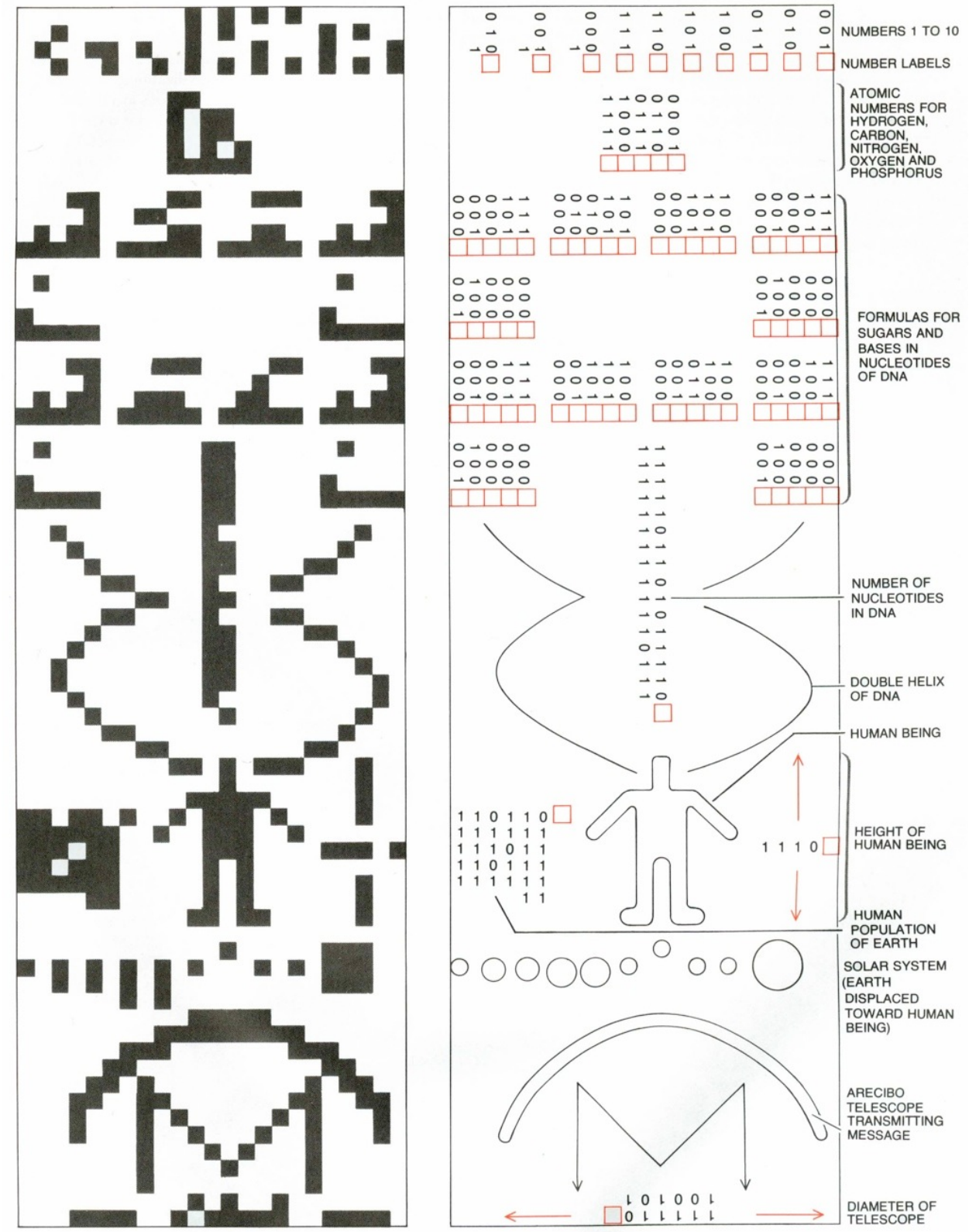
Credit: SETI Institute

Regarding the $f_{civilization}$ term. Substantial efforts have and are going into detecting other civilization's radio signals. The Search for Extraterrestrial Intelligence (SETI), generally refers to efforts to detect signals, such as radio communications, arriving from civilization on other worlds. The image above shows the Allen Telescope Array in Hat Creek, California. It is used, among other privately held telescopes, to search for radio signals coming from extraterrestrial civilizations. Of course, you're not expecting them to speak English! What you're looking for is a periodic signal that contains a pattern you can decompose into something meaningful.

For example, we've done the same. We've sent messages out. In 1974, a short message was broadcast to a star cluster that goes by the name of M13. The message was sent by the Arecibo radio telescope, shown below and a telescope we've covered before. One does not steer this telescope. You use the Earth's rotation to turn the telescope a for you. The telescope is also featured in a relatively famous movie, Contact, based on a novel written by Carl Sagan.

The message that was sent is shown and decoded below. The picture was encoded using two radio frequencies, so its binary system, like on, off, on, off. It counts to 10, it gives the atomic numbers for the most common elements in the universe, the biochemistry of our life forms, how tall e are, our solar system, and who the sender was. It's a relatively crude, pixelated picture. But if you were to pick up this radio broadcast, even if you couldn't decode it fully, it would be an unmistakable sign of a civilization trying to contact whoever's out there.

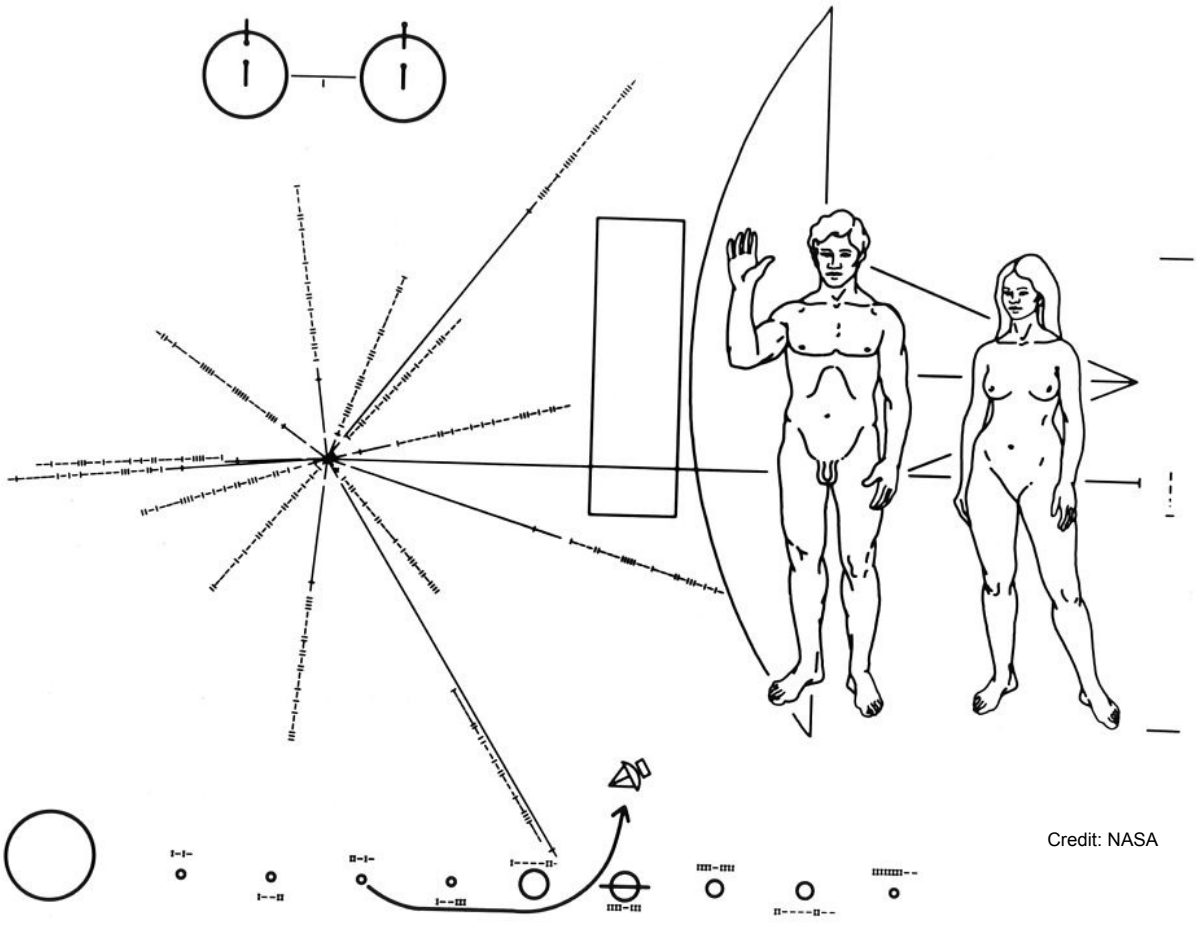
Credit: SETI Institute



Credit: SETI Institute

We have also sent out messages on our spacecraft, in particular the Pioneer and Voyager spacecraft, which are now the furthest spacecrafts man has ever sent out into space.

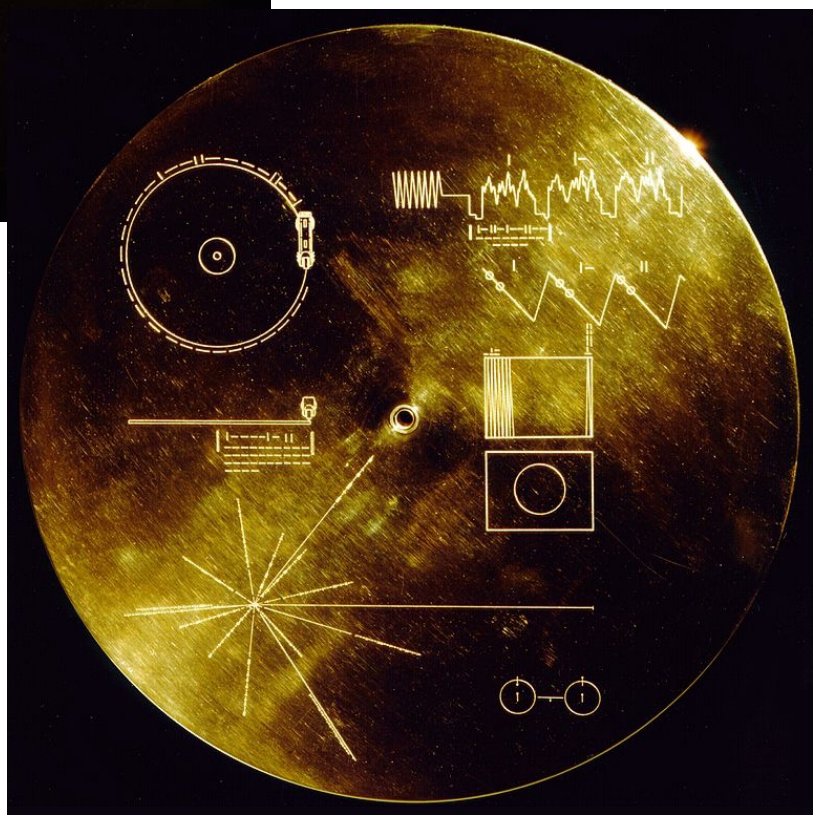
The Pioneer 10 and 11 gold-anodized aluminum plaques shown below are about the size of an license plate. A size scale set by the two circles with lines in the middle, signifying the a special 21 cm transition of hydrogen. So this is the ruler or meter stick. The spiky looking figure with 13 lines defines our solar system's by the distance to 13 pulsars. Pulsars are stars that pulse extremely regularly. There as or more accurate than atomic clocks. Because they're as accurate as atomic clocks, you can use them much like a GPS system. So we're using 13 pulsars, 13 GPS satellites, to locate our solar system. Underneath this GPS locator map is an image our solar system with an indication that it is the third planet from the sun where the message in a bottle was sent from. There is an rendition of what we look like. Of course, that created a whole bunch of hullabaloo, because yes, they are naked. But that's how we look. It took approval from the US Congress to send this image) The rendition of the Pioneer spacecraft shows we are as tall as the spacecraft that you have now found.



Credit: NASA

The Voyager 1 and 2 gold-plated copper disks, shown below, contains music and greetings in 50 languages, along with images of us on Earth. The electroplated aluminum backing gives some of the same information as on the Pioneer 10 and 11 plaques, namely setting the meter stick size scale, our location relative to 13 pulsars, 13 GPS satellites. The backing also contains instructions on how to play the phonograph record. Hmm, technology gone past - could we play our own record?!

Thanks! Bye Bye.



Credit: NASA