Are we alone? If not, why hasn’t anyone dropped by Earth for a visit?

In the media, questions about astrobiology always devolve into a single issue: *Are we alone?* Are humans the only technological civilization that exists currently in the cosmos, or are we one of many? Are other worlds home to civilizations of intelligent life forms, or intelligent machines with biological ancestors?

The discovery of thousands of planets around nearby stars in recent years has led astronomers to calculate a presence of 15 billion to 30 billion Earth-like planets in our galaxy alone, yet we haven’t encountered any extraterrestrials (ETs).

Those hard realities shine a spotlight on an old problem known as the Fermi Paradox, for Enrico Fermi, the Nobel Prize winning physicist who came up with it back in the 1950s. Fermi helped figure out how to get energy out of the atom not long after Albert Einstein had suggested such a project would be a waste of time. Yes, Einstein is remembered for writing to President Franklin Roosevelt that harnessing the atom was achievable, but that was late in the game — 1939, after Fermi and another physicist, Leó Szilárd, convinced Einstein that, in fact, nuclear technology was practically at hand.

Being a nuclear physicist focused on technological applications of the science, Fermi must have realized the potential of nuclear energy to propel a spaceship over enormous distances. And so, in 1950, after hearing a lot of speculation on the likelihood of sentient life forms existing on other worlds, he calculated that they ought to have arrived long ago. Numerous ET species from various worlds should have arrived on Earth. But they weren’t here and that was the paradox.

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Enrico Fermi

Over the last 65 years, the Fermi Paradox has always been on the minds of people interested in the search for extraterrestrial intelligence (SETI), but the awareness of the enormous number of planets in our galaxy puts the debate in a new context. In Fermi’s time, astronomers knew that our galaxy, the Milky Way, contains hundreds of billions of stars, and that itself is one of hundreds of billions of galaxies in the cosmos. But as for planets around stars other than the Sun, that was purely hypothetical. Until the very late 20th century, the only known planets were the handful in our own Solar System.

Over the last two decades, new instruments and techniques and new spacecraft, particularly NASA’s *Kepler* probe, have led to the discovery of thousands of planets orbiting stars in our corner of the galaxy. Temperatures of the extrasolar planets, and whether liquid water is possible in their environments, can be estimated, and the sizes of the planets can be measured as well. Based on all of this, a certain fraction of the newly discovered planets are considered “Earth-like”, likely to have environments that are life-friendly. Enough of them are confirmed for astronomers to do a planet census to estimate numbers of different types of planets within the entire galaxy, and this is what has led to the calculation of 15 billion to 30 billion worlds similar to Earth. That’s just Earth-like planets in our galaxy, and if we add the possibility of moons with Earth-like environments orbiting Jupiter-like planets the number grows still more.

Adam Frank meets Enrico Fermi

The huge amount of potential homeworlds for ET civilizations brings the Fermi Paradox to center stage. University of Rochester astrophysicist Adam Frank is now unpacking the question of "why aren't the ETs here yet?" in a series of short articles for NPR and his own site, the *13.7 blog*. In the first installment, he considered one possible answer, that we're simply alone. It's the most geocentric answer, of course, which should be a clue that it's probably wrong, but the consequences of that scenario would be profound:

> On the one hand, it's possible that no other species has ever reached our state of development. Our galaxy with its 300 billion stars — meaning 300 billion chances for self-consciousness — has never awakened anywhere else. We would be the only ones looking into the night sky and asking questions. How impossibly lonely that would be. On the other hand, it's also possible that other species have made it to where we stand today. But no one has made it much farther. Say that like a "great filter". Something like war or environmental collapse keeps anyone, anywhere, from reaching beyond our stage of technological development. If that's true then we, like all who have come before us, are doomed.

Drake equation and planets with ETs

It's rather extreme to imagine that "NO ONE has made it much farther". It may be that a certain fraction has. In fact, everything in astrobiology and the search for extraterrestrial intelligence (SETI) has been a matter of fractions ever since astrobiology got started in the middle of the last century. Back in the 1960s, astronomer Frank Drake wrote up what came to be known as the Drake Equation.

$$N = R^* f_p n_e f_l f_i f_c L$$

It's a series of variables that get multiplied by one another, starting with the rate of star formation in the galaxy (R*), which represents the number of stars. That's multiplied by the fraction of stars that have planets (f_p) and by a factor representing the number of planets with environments that could support life per star that has planets (n_e). This produces a number of Earth-like planets in the galaxy. That was hypothetical when Drake came up with the equation, because the only fractions that could be plugged in for f_p and n_e were mere guesses.

Today, though, because of new planet discoveries, the first three variables of the Drake Equation are hard numbers. They'll probably be tweaked in the years to come with new planet search instruments in space, but that census result of 15 billion to 30 billion Earth-like planets makes the whole thing a lot less hypothetical than it used to be. The rest of variables represent the fraction of Earthlike worlds that actually develop life, the fraction of those worlds that develop intelligent, sentient life forms, the fraction of worlds with intelligent life whose intelligent beings develop technology and finally the longevity factor "L", how long that technology-bearing species endures.

Plugging in conservative numbers for the remaining variables we can estimate that about 1.5 million to 3 million worlds in our galaxy have likely produced at least one intelligent species with hands or an ability to manipulate the environment. Next comes technology, f_c, which Drake equated with the ability to communicate by radio across space, the space communication method that an advancing civilization would discover first. No doubt, there are a wealth of factors accounting for whether an intelligent species ends up building radio technology, spaceflight technology, and everything else that's needed to communicate and travel through space, but they're all variations on the f_c variable. The more you proceed through the Drake variables the more difficult it gets to estimate, so let's assume the f_c is 0.01, which means 15,000-30,000 worlds developing a civilization at any point over the last several billion years when the galaxy had planets ripe for life.

Surviving 'technological adolescence'

That's where the longevity factor, L, comes in. If we use 30,000 as the number of worlds that harbored a civilization at any point over the last 10 billion years, and if we guess that a typical civilization lasts 10 million years before it collapses into a dark age or its species goes extinct, that would mean that we Earthlings are 1 of about 30 civilizations in our galaxy. We'd be the most primitive one, of course, since we literally just acquired the earliest technology for communicating over space.

There's no good reason for making L 10 million years, except that it makes the math really easy, but you can raise the number from 10 million or drop it and see what it does to the odds of finding some other civilization. If we stay with the 10 million year value, it means that the home planet of the closest ET civilization is really far away, but over millions of years a species could colonize star system after star system in short hops. That should have brought somebody here by now, just as Fermi guessed, and a continuous colonization wave would very likely raise the life expectancy of the species far beyond 10 million years to the lifetime of the galaxy, or beyond.

This consideration revives Frank's suggestion that civilizations might not last long enough to colonize star system after star system, meaning that L is a very small number. But it doesn't make sense that every civilization would not last. A certain number–a fraction that we have no way of knowing right now — must make it through the critical period that we're living in right now. The late astronomer Carl Sagan called it "technological adolescence". Either we'll go extinct — by succumbing to a natural disaster that our technology is not advanced enough to stop (like an immense volcanic eruption), or by destroying ourselves with technology that we're using irresponsibly (like making nuclear weapons) because our social development is too far behind our technology– or we'll survive into an age of more advanced technology and greater wisdom.

If only a fraction of civilizations survive technological adolescence, the Fermi Paradox still holds. This, in turn, raises another possibility, one that is just as simple as the "we are alone" solution, but it's a lot more appealing. ETs could be aware of us and avoiding us on purpose. Perhaps, they are waiting to initiate a first contact until they think we are ready.

If ETs exist, why have they not made contact with us?

Surely, you can think of many possible reasons why we are not ready, but if our behavior is shameful perhaps the ETs recall a time in their own history when they were just as bad and their existence hung in the balance. They could be waiting for us to end war and religion and create a planetary government, or they might prefer to avoid interacting with us until that they have to, because we're about to discover something that will lead us to them.

star trek

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On the TV series *Star Trek*, that worthiness for first contact — at least by responsible, space faring beings — always depended upon a civilization crossing the technological threshold for "warp propulsion". Enabling a species to travel rapidly between star systems, newly acquired warp capability made it inevitable that a species would soon discover that it was not alone in the universe. That, in turn, put the home world of that species on the radar screens of the older, more established civilizations of our galaxy.

"As long as we're confined to our solar system, we're probably not so interesting to other spacefaring civilizations (assuming any exist)," Carl Sagan's son, Nick Sagan, noted recently. Being a science writer and a science fiction author who wrote for two *Star Trek* series (*ST The Next Generation* and *ST Voyager*), the younger Sagan has a unique perspective that's spiced by imagination, yet grounded in an awareness of hard core science realities. Thus, he added, "Once we demonstrate that we might soon travel from star to star, perhaps we'll start receiving messages from whatever's out there."

Whether they await ethical or political developments, or a technological threshold, or both, the idea of patient ETs suggests it could be a long time before humanity experiences its first contact. On the other hand, particularly if it depends on a technological threshold, the first contact with another civilization could be right around the corner. Either way, it seems like a much more reasonable resolution to the Fermi Paradox than the idea that we're truly, completely alone.

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For more background on the Genetic Literacy Project, read GLP on Wikipedia.