# Rationally Speaking #203: Stephen Webb on "Where is Everybody? Solutions to the Fermi Paradox."

Julia Galef: Welcome to Rationally Speaking, the podcast where we explore the borderlands between reason and nonsense. I'm your host, Julia Galef, and I'm here with today's guest, Stephen Webb. Stephen is a physicist. He's at the University of Portsmouth and he's the author of several books on cosmology, science fiction, and other topics, including *Where is Everybody? 75 Solutions to the Fermi Paradox and the Problem of Extraterrestrial Life*. That's what we're going to talk about today. Stephen, welcome to Rationally Speaking.

Stephen Webb: Hi Julia, thank you for inviting me.

Julia Galef: I just want to say one of the many things that I really appreciated about your book is its structure of laying out a taxonomy of different approaches, or solutions.

I wish that more books out there presented taxonomies. I just find it incredibly instructive to have this juxtaposition of different ways that people have thought about a problem. Even sort of the basic structure of that list, the basic categories that you grouped those solutions into, was super helpful in organizing my thinking.

I don't want to get too ahead of myself in talking about those categories, but I just wanted to put a plug in there for the idea of "taxonomy" books, it was pretty great.

Stephen Webb: Well, thank you very much. A tip for authors, it's a good way of writing. You can focus on one solution, or one topic, forget it for a while, go and do something else.

Julia Galef: Yeah, I can imagine.

To begin at the beginning, could you tell our listeners the basics of what is the Fermi Paradox, and maybe tell the story of how it arose, or how it was first proposed?

Stephen Webb: Well, back in 1950, Enrico Fermi — he was one of the great physicists of the last century — he was based at Los Alamos during the summer of 1950, and there was a cultural sociological thing happening. You might know more than I do. There was a spate of UFO sightings in America and it was in all of the newspapers, lots of discussion going on.

And Fermi, in a Los Alamos lunch, was discussing these UFO sightings, and he asked out of the blue, "Where is everybody?" It's a question, rather than a paradox — but there are paradoxical elements to the question, and we know pretty much, I think, what Fermi, what his thought processes were in asking that question. Because he was a wizard at mental calculation.

This was before everyone had calculators on their smartphones. He could come up with order-of-magnitude answers to questions in his head. Pretty much what he'll have done is come up with a form of the Drake Equation, which I'm sure your listeners will have heard of. To paraphrase it, we know there are a trillion planets in the galaxy, maybe more. Actually, Fermi wouldn't have known that, but we do now. We want to know how many civilizations, advanced technological civilizations are on those planets. You run that trillion planets through a series of barriers, if you like.

So, habitability is the first barrier. What fraction of those planets are in that Goldilocks zone where water flows as a liquid? If a planet is too close to a star, it's going to fry. If it's too far away from the star, it's going to freeze. What's that fraction of habitable planets?

Abiogenesis is the next barrier. In what fraction of those habitable planets does life start from non-life? Then once you have life, what fraction of those planets go onto develop a technological civilization?

Incidentally, not all planets with life presumably would go on to have a technological civilization. We have alien intelligences here on Earth — elephants can collaborate with other elephants to solve problems. Octopuses, or octupi, they can recognize individual humans and act differently. Ravens and parrots, these are clever creatures, but they're not going to build a technological civilization.

Finally, what fraction of those civilizations actually want or choose to communicate? We need them to disturb the universe in some way that we can then detect.

You make estimates. And your guess is as good as mine, and it's as good as Fermi's, but he'd done it in his head, and typically when I run this by physical scientists, they come up with a number in the thousands. Frank Drake himself came up with 10,000. Some people go even more. Possibly 10,000, maybe more, civilizations out there in the galaxy.

The paradoxical element comes up when you realize that the universe is 13.8 billion years old, and some of those civilizations could've come into being billions of years ago. If they follow the technological path that we seem to be on, and Fermi himself would've experienced — he was born into a world that didn't have airplanes. We were literally a terrestrial species. Before he died, he saw humankind just reach space.

If a technological civilization lasts just for a few thousand years, maybe a bit longer, just think of what abilities they would have. They could build self-replicating probes to visit every planetary system in the galaxy, or they could build Dyson spheres to collect all that free sunlight, or they could build antimatter rockets, or hyper-relativistic aircraft, or whatever. Something that we would see. Or maybe to just shout out to the universe, "Here we are."

Julia Galef: And… nothing.

Stephen Webb: We see nothing. That's the paradoxical element. We expect to see them, and Fermi I think himself would've expected to see life, but so far we don't. Where is everybody?

Julia Galef: Could you ... I imagine for many listeners, the point that their mind is going to is, "Well, maybe it's just not feasible to traverse the immense distances in space, even if you have spacefaring technology. We shouldn't be surprised. Even if aliens exist, and are spacefaring, we shouldn't be surprised that we haven't seen them, because space is just so vast."

Could you talk a little about that?

Stephen Webb: That's a possibility. Although, Stuart Armstrong and Anders Sandberg recently came up with a proposal for how with technology that is based on known physics — I'm not talking wormholes, or warp drives, anything like that, nothing magical — even with that sort of technology that is imaginable, the sort of technology we might be able to achieve in a few hundreds years time, they came up with a scheme. Whereby a civilization could send out tiny, tiny probes, self-replicating probes, acting if you like as some sort of virus, to colonize not just our galaxy, but potentially millions of galaxies in the neighborhood.

And the Fermi Paradox isn't just, why aren't they here? They, being intelligences from our galaxy, but intelligences actually from other galaxies. It's not any more difficult under their scheme, it just takes a lot longer.

Now you might say, "Okay. That's pie in the sky science fiction stuff. Space is vast. They're never going to be able to travel or traverse that distance." Fair enough, but it doesn't address this question why don't we hear from them, why don't we see signs of them?

Julia Galef: What would signs look like, potentially?

Stephen Webb: It depends. I think we have to adopt a Stapledonian viewpoint, after Olaf Stapledon. He was a philosopher and a science fiction author. I think we just have to try and take the constraints off our imagination and just think, "What might be possible for an extremely advanced civilization to do?"

Possibly, build Dyson spheres to capture all of the sunlight around a star. That would leave a signal in terms of infrared radiation we could pick up. If they wanted to deliberately draw attention to themselves, they could, for instance, alter the spectrum of their star. They could dump material into the star that would create stellar lines, spectral lines that we would clearly understand were not natural. Or they could put swarms of particles up there to make a star flash on and off.

Or the holy grail, if you like, is to look for a deliberately broadcast signal. They could send a signal by radio, by a laser towards us, or towards the galaxy in general. There's all sorts of things you could imagine them doing. We haven't yet seen any of that.

The question is, in my mind, is that silence telling us anything yet? I think many of my colleagues would simply say we have to listen a bit longer, we have to listen a bit smarter. There's a huge phase space that we haven't yet investigated and it's a matter of time-

Julia Galef: When you say phase space, what do you mean?

Stephen Webb: In the sense that we need to scan a variety of wavelengths. We need to ensure that our telescope is pointing in the right direction. It's got to be pointing in the right direction at the right time. Are we looking for narrow band or broadband signals, and so on? There's lots and lots of different possibilities that make this much, much more difficult than looking for a needle in a haystack.

But we are throwing a lot more resources at the problem then we were back in 1961 when Frank Drake first started looking for communications. I guess it's a balance. Do you think that if we wait a little bit longer, if we throw more computational resources at this, if we throw more observational resources at this, we'll eventually find something? Or do you think that the silence is already telling us something?

Julia Galef: Have we gotten any evidence in the last, say, 50 years that — obviously, nothing is conclusive, but has any evidence pointed towards or away from any of the potential solutions to the Fermi Paradox?

… Or Fermi problem. I should really call it the Fermi problem, that's more accurate than paradox.

Stephen Webb: Yeah, I think Fermi problem's a better way of stating it, since he just asked the question.

Julia Galef: Yeah.

Stephen Webb: Well, it's interesting that back when Fermi asked that question, he wouldn't have known for certain whether other stars had planets.

That was a feasible answer to the question back in the last century. Certainly, the early part of the last century. Some astronomers believed that planets came into being through the close collision of two stars. If that were the case, then planetary systems would be rare and that would be a solution to the problem.

Julia Galef: Right.

Stephen Webb: Of course we now know that stars come with planets. There are a trillion or more planets in the galaxy. I think we're almost taking it for granted nowadays that astronomers can find exoplanets at the rate of, I don't know, one a month or whatever. It's an incredible technological advance to be able to do that.

Certainly, when I was a student studying astronomy, it was deemed back then unlikely that we'd have this sort of technology that we have now to find exoplanets almost on demand.

This though again harks back to this paradoxical element. Our technology is increasingly impressive, and last year the discovery of multi-messenger astronomy, we can discover colliding neutron stars through the gravitational wave in ... It's an incredible technological advance. So we can study now astronomical events not just throughout the electromagnetic spectrum, but with gravitational waves too.

These are fantastic developments in technology. If you can imagine an early civilization following this same technological path of progress, what might they be able to do in 1,000 years, in 10,000 years, if they survive? Presumably, very, very impressive things. Where are they? I think our experience, if we attribute it to them, does really add to that paradoxical element.

Julia Galef: I alluded when I was just introducing the book that you break down the 75 solutions into roughly three kinds of solution.

There's, "Well actually, aliens have already been here." Or, "There are signs. We just haven't detected them." That's number one.

Number two is "We shouldn't expect that aliens, if they do exist, would have made it to our corner of the galaxy."

Then number three is, "There aren't aliens. We're essentially alone."

Could you ... Feel free to correct my summary of either of any of those three categories if you want. And could you maybe pick one or two of your favorite solutions in each category, just to give us a sense of the range?

Stephen Webb: Well, in terms of them being here, it's an immediate answer to the problem, isn't it? It's probably the most popular solution. If you were going to go out and ask 100 people-

Julia Galef: Non-experts, I presume.

Stephen Webb: Non-experts, yeah. Just people in the street. They'd tell you that, "Well, they're here and the evidence is UFOs."

Science isn't a democratic process, so I don't think we should put too much stock in that. I've seen a UFO, but it's much more likely that my brain was misinterpreting the data that my eyes were feeding it.

Julia Galef: It was a technically a UFO, it was an unidentified flying object —

Stephen Webb: It was.

Julia Galef: Not necessarily a spacecraft.

Stephen Webb: I think that's the problem, isn't it? That people identified them.

Julia Galef: Right. UFOs very quickly become IFOs.

Stephen Webb: Exactly.

But there's, still, interesting twists actually on this idea that they're here. For example, directed panspermia, this idea that Earth was deliberately seeded by life.

Julia Galef: Meaning that humans are ... We actually are aliens.

Stephen Webb: In a sense. That life came to Earth quite deliberately. Earth itself was seeded deliberately. No less a scientist than Francis Crick came up with this sort of idea.

Panspermia was an old idea that life somehow floats from star to star, or planet to planet. That goes back a long way. Crick came up with this idea of directed panspermia, so some other intelligence deliberately seeds a planet. I think Star Trek has used that idea.

Or the "zoo" hypothesis. This idea, which a surprising number of my colleagues don't dismiss —

Julia Galef: The zoo hypothesis being that we're in a zoo?

Stephen Webb: Yeah. That we're deliberately being sheltered, if you like, from the notion that there are lots and lots of many more advanced civilizations out there. I find that, myself, not convincing, but some people do adhere to it.

There's an interesting ... You mentioned alien life on Earth. There's another possibility that there really is alien life here on Earth, in the sense that we don't know how life got started here on Earth, and that's one of the reasons that directed panspermia is an idea. It sort of pushes back the problem of the origin of life.

Julia Galef: Right.

Stephen Webb: If life really were easy to come into being from non-life, it's possible that it started several times here on Earth. It might then have a different genetic code, or it might use right-handed amino acids, or something might be different from the life that we know it. I think it's interesting that it's possible that alien life, alien life that came into being here on Earth at the same time as the life we know, could potentially still be around. It would be great to look for that sort of sign.

Julia Galef: Wouldn't it be kind of coincidental if life on Earth had originated from the stars and also, independently, on Earth? Aren't we sort of violating Occam's Razor by positing both of those things?

Stephen Webb: No, this is really a separate thing. Forgetting panspermia, the notion that maybe life just came into being multiple times here on Earth. It came into being once, we know, because it gave rise, eventually, to us. But all life on Earth, for instance, uses left-handed amino acids and a certain genetic code and so on. It's possible, if life really is easy to come into being from non-life, that some different version of life came into being back when Earth was really young, just as a natural process.

Julia Galef: Right.

Stephen Webb: I think it would be really interesting to try and find that sort of shadow biosphere, it's called, because that would prove ... Or if we could find life on Enceladus or Mars or wherever. Life that came into being independently of the life that gave rise to us — then I think we'd know that life is easy to start, and the barriers that there might be towards creating a technological civilization, the barrier isn't abiogenesis. Because if it's happened multiple times, it's going to happen everywhere.

Julia Galef: It would be an incredible coincidence if it was hard to create and yet happened multiple times in our own solar system.

Stephen Webb: Yeah, yeah.

Julia Galef: Right, and so we know the barrier can't be the number of potentially habitable planets, because we've already estimated that, and we know that it can't be — sorry, in the scenario you've outlined — it couldn't be abiogenesis. So it would have to be the difficulty of developing intelligence, like human-level intelligence. Or the difficulty of making it to spacefaring capability as a civilization.

Or the solution would have something to do with the will to travel, or the type of travel or signal sent out, or something like that.

Stephen Webb: Exactly. I think it pushes the barrier to a different spot.

Julia Galef: Right.

Stephen Webb: Of course, at present we don't know whether abiogenesis is difficult or not.

Julia Galef: Right.

Stephen Webb: I think that's why it's such an important job for scientists to go and look for other examples of life. We need to explore Mars, Enceladus, perhaps those of the moons where water might exist. We really need to try and find out whether life has come into being independently of life here on Earth.

Because if it has, then I think that vastly raises the odds that the universe is teaming with life.

Julia Galef: Right.

Stephen Webb: Then, as you say, why then don't we see intelligent life? Then the question is perhaps that barrier is the rise of intelligence. Or, quite chillingly, maybe the barrier lies ahead of us.

Julia Galef: Right, it would foretell a much higher risk of doom in our own path — if the resolution to the Fermi problem is that civilizations that are intelligent enough to potentially develop spacefaring technology end up destroying themselves before getting to that point.

To jump ahead a bit to the third category, which is "We are essentially alone in the universe": can we talk about how to estimate, to even begin to start trying to estimate, how hard it is, or how rare we should think it would be, for intelligent life to develop? Conditional on life.

Stephen Webb: Well, in a sense, we just don't know, do we? That's one of the problems.

Julia Galef: That's why I tried to add so many qualifiers to my estimate! "Begin to start trying to maybe someday estimate…"

Stephen Webb: Yes. To my mind, when we look at intelligence, I mentioned earlier that there are a number of intelligent species, I would class them as intelligent species, on this planet. We all know about dolphins. Birds, some types of birds are really very clever. Their brain is small, but the computational capacity within them is really quite impressive.

Julia Galef: Or cephalopods, right? Octopi are pretty amazing.

Stephen Webb: Cephalopods, absolutely amazing creatures, and very different sort of intelligence as well.

Julia Galef: Right.

Stephen Webb: Very different to humans. The last common ancestor we shared with these creatures goes way back.

So they presumably are perceiving and understanding the world in very different ways, but they are not going to go on to create a starfaring civilization. Why should they? Evolution doesn't have that as an end goal. They are quite happily doing the stuff that cephalopods or birds do. It's just what they do.

Julia Galef: But-

Stephen Webb: Sorry, go on.

Julia Galef: No, I just, that seems — that's correct of course, but still, doesn't it seem like human-level intelligence probably isn't mindbogglingly rare if we got several part-way successes just on Earth? Wouldn't it be a weird world in which it was pretty easy to — pretty easy in the sense that evolution did it multiple times on Earth — to create "part-way to human level" intelligence, but there was only one actual human-level intelligence in the whole universe?

Stephen Webb: Well, I'm not arguing necessarily that the barrier is there, but if you look at Earth, of the 50 billion species or however many there have been, there's only one species that is remotely capable of delivering a starfaring civilization, and that would be us. I think that's because we have a very, very specific set of attributes that happened to enable us to do this.

Evolution didn't have that as an end goal. We're not at the top of some sort of evolutionary tree. It just happens to be our set of characteristics that enable us to be able to do that. I can quite see a solution to the Fermi paradox being not necessarily one large barrier, but a succession of smaller barriers.

Julia Galef: Like what?

Stephen Webb: Well if you start, say, with habitability, general habitability. Then you need a planet to be stable, climate-stable, over a period of billions of years. Then you need a planet where abiogenesis takes place. Then you need a planet where complex, multicellular lifeforms come into being. Then you need a planet where that complex, multicellular lifeform develops intelligence.

And that intelligence has to be of a social nature. We're looking for social creatures with the ability to communicate via a complex grammar, because reaching the stars is not going to be the pursuit of an individual. These creatures, these social creatures with a complex form of language, they need to develop an advanced technology. They need to develop mathematics and science to understand the universe, and they need to persist for a certain length of time. There are plenty of external threats, gamma ray bursts, or supernovae or asteroid strikes. Plenty of internal threats that they have to overcome.

So that's eight barriers. Say it's a one in a thousand chance at each of those eight barriers. That immediately knocks the chances down to be effectively zero.

Julia Galef: It's interesting. One of the things I was going to bring up is you, several times in the book, you make reference to this principle… I don't know if you gave it a name, but I've been thinking of it as the "non-exclusivity principle" or problem, which is: Many solutions to the Fermi problem that seem plausible, like for example "Well maybe alien civilizations decide that it's not safe to try to contact other civilizations, and so that's why we don't see any signs of them."

…The problem with a lot of solutions like that is, as you point out, they would have to apply to basically all the alien civilizations. It would have to be true that all the alien civilizations would think that way. Because even if a few of them didn't, then we would see signs of alien life. So they're very brittle solutions.

But it sounds like you're saying now that if we allow for multiple small solutions to the Fermi problem, then the brittleness goes away. Is that right?

Stephen Webb: I think so. I have a problem with people who generalize, that they are quite happy to suggest that there are 10,000 advanced civilizations out there, but the reason that they don't appear, for instance, is that they're all following, I don't know, the Prime Directive, Star Trek's Prime Directive.

Julia Galef: Right, right.

Stephen Webb: I find that sort of cultural homogeneity that's assumed across 10,000 very, very different, presumably different life forms — I find that implausible. And, as you say, brittle. A brittle solution.

Julia Galef: Yeah.

Stephen Webb: Personally, I find it plausible that a series of small barriers, if you like, or perhaps one large barrier — maybe abiogenesis is a barrier. We don't know how life got going. Either one very large barrier early on, or multiple smaller barriers, I think has the capacity to address the Fermi problem.

But we don't know. I think that's why it's absolutely vital that we search. We need to look for other forms of life within the solar system. We don't spend nearly enough money on the search for extraterrestrial intelligence. I don't think we're as creative as we could be in looking for signs of what might be very, very strange civilizations out there…

Julia Galef: But your preferred solution is category three, we are alone?

Stephen Webb: It's not my preferred solution. I —

Julia Galef: Sorry, "preferred" epistemically, not necessarily emotionally.

Stephen Webb: Yes, yes. I'd very much like to live in one of these interesting Star Wars, Star Trek galaxies — but the silence of the universe tells me, I think, that we're alone.

But I do think it's such an important question in science now. It addresses, it asks us about our place in the universe. We can't let it go without significant, I think, amounts of resource being thrown at this problem.

Julia Galef: There was one other solution that I wanted to see if you can counter. It's pretty recent, so it wouldn't have made it into your book.

It's in a paper by Anders Sandberg, Toby Ord and Eric Drexler, and it's called Dissolving the Fermi paradox. What they say is: Look, the way people have approached the Fermi paradox in the past is they've plugged in plausible values into the Drake Equation for "number of habitable planets," and "probability of life per planet," et cetera, and then they've multiplied those together. But that's not actually what you should be doing. You should not be multiplying point estimates together.

You should be essentially multiplying distributions. So you should have some probability distribution over the number of habitable planets, and some probability distribution over how hard it is for life to develop, et cetera.

And when you multiply distributions together, you actually get much more probability weight on the low end of the spectrum, in addition to the high end of the spectrum. It just means more uncertainty distributed across the board. So it's much more plausible that you could end up with Earth containing the only intelligent civilization, because you've just spread out more uncertainty than you would have had with point estimates.

It's unclear what the distribution should be, but they just take some example point estimates from different people who have estimated the values of the Drake Equation. And they do log-normal sampling, and what they end up with is something like an 8% chance — given the point estimates people have made for the values in the Drake Equation — an 8% chance that Earth is the only intelligent civilization.

How do you feel about that solution?

Stephen Webb: Yes, it came out, unfortunately, after the book was published. I find it really quite an elegant approach. I think you've summed it up perfectly. They take their distributions from the estimates that appear in the literature, as the proxy — but, yeah, exactly. If you do that, I think the conclusion of the paper is that you shouldn't be surprised if we live in a universe that is empty. Given the uncertainties in these estimates, it's not surprising if we find ourselves in that situation. But that's, again, not to say that we are alone.

Julia Galef: Right, it's just that, right. It should be less surprising, that's all.

Stephen Webb: Yes. It's just not a surprising result necessarily.

Julia Galef: Yeah. It's just so interesting that we can take the estimates that people have already made, that caused them to find it surprising if we lived in an uninhabited universe, or if we were the only intelligent civilization. We take those exact estimates and then create distributions, instead of letting people just use their point estimates, and get a very different result. Yeah, I guess that's why I agree it's elegant, an elegant solution.

Stephen Webb: Yes, it's a nice paper, and I'd recommend anyone to read it.

It's interesting as well that if you talk to biologists about this problem, they're much less likely, in my experience, to be of the opinion that there must be hundreds, thousands, tens of thousands of intelligent civilizations out there, than physicists.

Physicists tend to be, I think, much more of the opinion that, yeah, we've got this big number, 10^12 planets out there, so — they tend, I think, to make this point estimate ... They do what Fermi did, and they come up with a largish number. It's an interesting perhaps scientific cultural divide.

Julia Galef: What's your diagnosis of the divide?

Stephen Webb: I think we physicists, we're just arrogant. We know everything.

Julia Galef: Arrogant? I mean, I'm not disputing that, but arrogant in the sense that you think ... How is it arrogant to think that life, that abiogenesis would be easy?

Stephen Webb: Well, I think there are elements that a biologist would think of as contingent, whereas a physicist might well take a much more deterministic view.

Julia Galef: I see.

Stephen Webb: I'm generalizing.

Julia Galef: Well, I asked you to, so don't feel bad.

Stephen Webb: Yeah. But in my experience, those two populations tend to look at it in a slightly different way. Biologists would look at just the unlikeliness of our sort of intelligence, perhaps, appearing.

Julia Galef: Right.

Stephen Webb: Versus a physicist who might well look at, perhaps implicitly in their thinking, being that intelligence is a goal towards which evolution is heading.

Julia Galef: Ah, I see.

Stephen Webb: I don't think it is.

Julia Galef: Interesting. Well, I want to let you go, Stephen, but before I do, I want to invite you to nominate the Rationally Speaking pick of this episode.

I'd like it to be something, some book or blog or article that you don't agree with. Or at least you definitely don't fully agree with. But that you think is nevertheless well-reasoned or compelling enough that it deserves attention.

What would your pick be?

Stephen Webb: It's not a book that I disagree with, but it's a book that takes perhaps a different approach to what I've been explaining here. It's called *The Cosmic Zoo: Complex Life on Many Worlds*. It was published in, I think December 2017, so it's quite recent. It's by Dirk Schulze-Makuch.

Dirk takes this approach that once life starts, and we don't know how, that almost inevitably, it's going to explore various pathways that lead to a complex biosphere, the sort of biosphere that we experience here on planet Earth. So Dirk would take the view that many of the steps that I might argue are perhaps unlikely are actually likely. It's well written. It's beautifully argued and well recommended.

Julia Galef: Excellent. I will link to The Cosmic Zoo along with Where Is Everybody? And your website where people can check out several of your other books as well.

Stephen, it's been a pleasure having you on the show. Thanks so much for joining us.

Stephen Webb: Really enjoyed it. Thank you, Julia.

Julia Galef: This concludes another episode of Rationally Speaking. Join us next time for more explorations on the borderlands between reason and nonsense.