Lex Fridman Podcast #455 - Adam Frank: Alien Civilizations and the Search for Extraterrestrial Life

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Lex Fridman
The following is a conversation with Adam Frank, an astrophysicist interested in the evolution of star systems and the search for alien civilizations in our universe. This is The Lex Fridman Podcast. To support it, please check out our sponsors in the description. And now, dear friends, here's Adam Frank. You wrote a book about aliens. The big question, how many alien civilizations are out there?

Adam Frank
Yeah, that's the question. The amazing thing is that, after two-and-a-half millennia of people yelling at each other, or setting each other on fire occasionally over the answer, we now actually have the capacity to answer that question. In the next 10, 20, 30 years, we're going to have data relevant to the answer to that question. We're going to have hard data finally that will, one way or the other … Even if we don't find anything immediately, we will have gone through a number of planets. We'll be able to start putting limits on how common life is. The one answer I can tell you, which was an important part of the problem, is how many planets are there? Just like people have been arguing about the existence of life elsewhere for 2500 years, people have been arguing about planets for the exact same amount of time. You can see Aristotle yelling at Democritus about this. You can see they had very wildly different opinions about how common planets were going to be, and how unique Earth was. And that question got answered. Which is pretty remarkable, that in a lifetime, you can have a 2500-year-old question. The answer is they're everywhere. There are planets everywhere. It was possible that planets were really rare. We didn't really understand how planets formed. If you go back to, say the turn of the 20th Century, there was a theory that said planets formed when two stars passed by each other closely, and then material was gravitationally squeezed out. In which case, those kinds of collisions are so rare that you would expect one in a trillion stars to have planets. Instead, every star in the night sky has planets.

Lex Fridman
One of the things you've done is simulated the formation of stars. How difficult do you think it is to simulate the formation of planet? Like simulate a solar system through the entire of the evolution of the solar system. This is a numerical simulation sneaking up to the question of how many planets are there.

Adam Frank
That, actually, we're able to do now. You can run simulations of the formation of planetary system. If you run the simulation, really where you want to start is a cloud of gas, these giant interstellar clouds of gas that may have a million times the mass of the Sun in them. You run a simulation of that, it's turbulent. Gas is roiling and tumbling. Every now and then, you get a place where the gas is dense enough that gravity gets hold of it and it can pull it downward, so you'll start to form a proto-star. A proto-star is basically the young star, this ball of gas where nuclear reactions are getting started. But it's also a disc. As material falls

inward because everything's rotating, as it falls inward, it'll spin up and then it'll form a disc. The material will collect in what's called an accretion disc or a proto-planetary disc. You can simulate all of that. Once you get into the disc itself and you want to do planets, things get a little bit more complicated because the physics gets more complicated. Now you got to start worrying about dust, because actually dust … Dust is the wrong word. It's smoke, really. These are the tiniest bits of solids. They will coagulate in the disc to form pebbles, and then the pebbles will collide to form rocks. And then the rocks will form boulders, et cetera, et cetera. That process is super complicated. But we've been able to simulate enough of it to begin to get a handle on how planets form. How you accrete enough material to get the first proto-planets, or planetary embryos as we call them. The next step is those things start slamming into each other to form planetary-sized bodies. Then the planetary bodies slam into each other. Earth, the Moon came about because there was a Mars-sized body that slammed into the Earth and basically blew off all the material. Then eventually formed the Moon.

Lex Fridman
And all of them have different chemical compositions, different temperatures?

Adam Frank
Yeah. The temperature of the material in the disc depends on how far away you are from the star.

Lex Fridman
Got it.

Adam Frank
It decreases. There's a really interesting point. Close to the star, temperatures are really high. The only thing that can condense, that can freeze out, is going to be stuff like metals. That's why you find Mercury is this giant ball of iron, basically. Then as you go further out, stuff, the gas gets cooler. And now you can start getting things like water to freeze. There's something we call the Snow Line, which is somewhere in our solar system, out around between Mars and Jupiter. That's the reason why the giant planets in our solar system, Jupiter, Saturn, Uranus, and Neptune, all have huge amounts of ice in them, or water and ice. Actually, Jupiter and Saturn don't have so much, but the moons do. The moons have so much water in them that there's oceans. We've got a number of those moons have got more water on them than there's water on Earth.

Lex Fridman
Do you think it's possible to do that kind of simulation to have a stronger and stronger estimate of how likely an Earth-like planet is? Can we get the physics simulation done well enough to where we can start estimating what are the possible Earth-like things that could be generated?

Adam Frank
Yeah, I think we can. I think we're learning how to do that now. One part is trying to just figure out how planets form themselves in doing the simulations. That cascade from dust grains up to planetary embryos, that's hard to simulate because you got to do both the gas, and you got to do the dust and the dust colliding, and all that physics. Once you get up to a planet-sized body, then you have to switch over to almost a different kind of simulation. Often what you're doing is you're assuming the planet this this spherical ball, and then you're doing a 1D, a radial calculation. You're just asking, "All right, what is the structure of it going to be? Am I going to have a solid iron core, or am I going to get a solid iron core with a liquid iron core out around it?" Like we have on Earth. Then you get a silicate, rocky mantle, and then a crust. All those details, those are beyond being able to do full 3D simulations from Ab Initio, from scratch. We're not there yet.

Lex Fridman
How important are those details, like the crust and the atmosphere, do you think?

Adam Frank
Hugely important. I'm part of a collaboration at the University of Rochester, where we're using the giant laser. Literally, this is called the Laboratory for Laser Energetics. We got a huge grant from the NSF to use that laser to slam tiny pieces of silica to understand what conditions are like at the center of the Earth. Or even more importantly, the center of Super-Earths. This is what's wild. The most common kind of planet in the universe, we don't have in our solar system. Which is amazing, right? We've been able to study or observe enough planets now to get a census. We have an idea of whose average, whose weird. Our solar system's weird, because the average planet has a mass somewhere between a few times the mass of the Earth, to maybe 10 times the mass of the Earth. That's exactly where there are no planets in our solar system. The smaller ones of those we call Super-Earths, the larger ones we call Sub-Neptunes. They're anybody's guess. We don't really know what happens to material when you're squeezed to those pressures, which is millions, tens of millions of times the pressure on the surface of the Earth. Those details really will matter of what's on in there, because that will determine whether or not you have, say for example, plate tectonics. We think plate tectonics may have been really important for life on Earth, for the evolution of complex life on Earth. It turns out, and this is the next generation where we're going with the understanding the evolution of planets and life. It turns out that you actually have to think hard about the planetary context for life. You can just be like, "Oh, there's a warm pond," and then some interesting chemistry happens in the warm pond. You actually have to think about the planet as a whole and what it's gone through in order to really understand whether a planet is a good place for life or not.

Lex Fridman
Why do you think plate tectonics might be useful for the formation of complex life?

Adam Frank
There's a bunch of different things. One is that the Earth went through a couple of phases of being a snowball planet. We went into a period of glaciation where pretty much the entire planet was under ice. The oceans were frozen. Early on in Earth's history, there was barely any land. We were actually a water world, with just a couple of Australia-sized cratons they called them, proto-continents. We went through these snowball Earth phases. If it wasn't for the fact that we had an active plate tectonics, which had a lot of vulcanism on it, we could have been locked in that forever. Once you get into a snowball state, a planet can be trapped there forever. Which is maybe you already had life formed, but then because it's so cold, you may never get anything more than just microbes. What plate tectonics does, because it fosters more vulcanism, is that you're going to get carbon dioxide pumped into the atmosphere, which warms the planet up and gets you out of the snowball Earth phase. But even more, there's even more really important things. I just finished a paper where we were looking at something called the Hard Steps Model, which is this model that's been out there for a long time that purports to say intelligent life in the universe will be really rare. It made all these assumptions about the Earth's history, particularly about the history of life and the history of the planet have nothing to do with each other. It turns out, and as I was doing the reading for this, that Earth probably, early on, had a more mild form of plate tectonics, and then somewhere about a billion years ago, it ramped up. That ramping up changed everything on the planet, because here's a funny thing. The Earth used to be flat. All the Flat Earthers out there can get excited for one second.

Lex Fridman
Clip it. It still is.

Adam Frank
What I mean by that is that there really weren't many mountain ranges. The beginning of, I think the term is orogenesis, mountain building, the true Himalayan-style giant mountains, didn't happen until this more robust form of plate tectonics, where the plates are really being driven around the planet. That is when you get the crusts hitting each other, and they start pushing into these Himalayan- style mountains. The weathering of that, the erosion of that puts huge amounts of nutrients, things that microbes want to use, into the oceans. And then what we call the net primary productivity, the bottom of the food chain, how much sugars they are producing, how much photosynthesis they are doing shot up by a factor of almost 1000. The fact that you had plate tectonics supercharged evolution in some sense. We're not exactly sure how it happened, but it's clear that the amount of life, the amount of living activity that was happening really got a boost from the fact that something there was this new vigorous form of plate tectonics.

Lex Fridman
It's nice to have turmoil. In terms of temperature, in terms of surface geometries, in terms of the chemistry of the planet, turmoil.

Adam Frank
Yeah, that's actually really true. Because what happens is, if you look at the history of life ... That's an excellent point that you're bringing up. If you look at the history of life on Earth, we get abiogenesis somewhere around at least 3.8 billion years ago. That's the first microbes. They take over enough that they really do, you get a biosphere. You get a biosphere that is actively changing the planet. But then you go through this period they called the Boring Billion, where it's a billion years and it's just microbes. Nothing's happening, it's just microbes. The microbes are doing amazing things. They're inventing fermentation. Thank you very much, we appreciate that. But it's not until you get probably these continents slamming into each other, you really get the beginning of continents forming and driving changes that evolution has to respond to. That on a planetary scale, this turmoil, this chaos is creating new niches, as well as closing other ones. Biology, evolution has to respond to that. Somewhere around there is when you get the Cambrian Explosion. It's when suddenly every body plan ... Evolution goes on an orgy, essentially. Yeah. It does look like that chaos or that turmoil was actually very helpful to evolution.

Lex Fridman
I wonder if there is some extremely elevated levels of chaos, almost like catastrophes behind every leap of evolution. You're not going to have leaps. In human societies, we have an Einstein that comes up with a good idea. But it feels like on an evolutionary timescale, you need some real big drama going on for the evolutionary system to have to come up with a solution to that drama. An extra complex solution to that drama.

Adam Frank
Well, I'm not sure if that's true. I don't know if it needs to be an almost extinction event.

Lex Fridman
Right.

Adam Frank
Because it's certainly true that we have gone through almost extinction events. We've had five mass extinctions. But you don't necessarily see that there was this giant evolutionary leap happening after those. With the comet impact, the K-T Boundary, certainly lots of niches opened up. That's why we're here, because our ancestors were little basically rodents, rats living under the footsteps of the dinosaurs. It was that comet impact that opened the route for us. That still took another 65 million years. It was like this thing immediately happened. But what we found with this Hard Steps Paper, because the whole idea of the Hard Steps Paper was it was one of these anthropic reasoning kinds of things. Where Brandon Carter said, "Oh, look. The intelligence doesn't show up on Earth until about almost close to when the end of the Sun's lifetime." He's like, "Well, there should be no reason why the Sun's lifetime and the time for evolution to produce intelligence should be the same." He goes through all this reasoning, anthropic reasoning. He ends up with the

idea that, "Oh, it must be that the odds of getting intelligence are super-low, and so that's the hard step." There was a series of steps in evolution that were very, very hard. Because of that, you can calculate some probability distributions. Everybody loves a good probability distribution, and they went a long way with this. But it turns out that the whole thing is flawed because, when you look at it, of course the timescale for the Sun's evolution and the timescale for the evolution on life are coupled, because the timescale for evolution of the Earth is coupled, is about the same timescale as the evolution of the Sun. It's billions of years. The Earth evolves over billions of years. Life and the Earth co-evolve. That's what Brandon Carter didn't see is that actually, the fate of the Earth the fate of life are inextricably combined. This is really important for astrobiology, too. Life doesn't happen on a planet, it happens to a planet. This is something that David Grinspoon and Sara Walker both say, and I agree with this. It's a really nice way of putting it. Plate tectonics, the evolution of oxygen, of an oxygen atmosphere, which only happened because of life. These things, these are things that are happening where life and the planet are sloshing back-and-forth. Rather than, to your point about do you need giant catastrophes, maybe not giant catastrophes. But what happens is, as the Earth and life are evolving together, windows are opening up, evolutionary windows. For example, life put oxygen into the atmosphere. When life invented this new form of photosynthesis about 2.5 billion years ago, that broke water apart to work to do its chemical shenanigans. It broke water apart and pushed oxygen into the atmosphere. That's why there's oxygen in the atmosphere. It's only because of life. That opened up huge possibilities, new spaces for evolution to happen. But it also changed the chemistry of the planet forever. The introduction of oxygen photosynthesis changed the planet forever, and it opened up a bunch of windows for evolution that wouldn't have happened otherwise. Like for example, you and I, we need that amount of oxygen. Big-brained creatures need an oxygen-rich atmosphere because oxygen is so potent for metabolism. You couldn't get intelligent creatures 100 million years after the planet formed.

Lex Fridman
So really, on a scale of a planet when there's billions and trillions of organisms on a planet, they can actually have planetary scale impact.

Adam Frank
Yeah.

Lex Fridman
The chemical shenanigans of an individual organism when scaled out to trillions can actually change a planet.

Adam Frank
Yeah. We know this for a fact now. There was this thing, Gaia Theory, which James Lovelock introduced in the '70s. And then, Lynn Margulis, the Biologist Lynn Margulis together. This

Gaia Theory was the idea that life takes over a planet, life hijacks a planet in a way that the sum total of life creates these feedbacks between the planet and the life, such that it keeps the planet habitable. It's kind of a homeostasis. I can go out … Right now outside, it's 100-degrees. And I go outside, but my internal temperature is going to be the same. I can go back to Rochester, New York in the winter, and it's going to be zero-degrees, but my internal temperature is going to be the same. That's homeostasis. The idea of Gaia Theory was that life, the biosphere exerts this pressure on the planet or these feedbacks on the planet, that even as other things are changing, the planet will always stay in the right kinds of conditions for life. Now when this theory came out, it was very controversial. People were like, "Oh my God, what are you, smoking weed?" There were all these Gaian Festivals with Gaian dances. It became very popular in the New Age community. But Lovelock actually, they were able to show that no, this has nothing to do with the planet being conscious or anything. It was about these feedbacks, that the biology, the biosphere can exert these feedbacks. We're still unclear whether there are true Gaian feedbacks, in the sense that the planet can really exert complete control. But it is absolutely true that the biosphere is a major player in Earth's history.

Lex Fridman
The biosphere fights for homeostasis on Earth.

Adam Frank
Okay. What I would say right now is I don't know if I can say that scientifically. I can certainly say that the biosphere does a huge amount of the regulation of the planetary state. And over billions of years, has strongly modified the evolution of the planet. A true Gaian feedback would be exactly what you said. The biosphere is somewhere … Sara Walker, and David Grinspoon, and I actually did a paper on this about the idea of planetary intelligence, or cognition across a planetary scale. I think that actually is possible. It's not conscious, but there is a cognitive activity going on. The biosphere, in some sense, knows what is happening because of these feedbacks. It's still unclear whether we have these full Gaian feedbacks, but we certainly have semi-Gaian feedbacks. If there's a perturbation on the planetary scale, temperature, insulation, how much sunlight's coming in, the biosphere will start to have feedbacks that will damp that perturbation. Temperature goes up, the biosphere starts doing something, temperature comes down.

Lex Fridman
Now I wonder if the technosphere also has a Gaian feedback or elements of a Gaian feedback? Such that the technosphere will also fight to some degree for homeostasis. Open question, I guess.

Adam Frank
Well, I'm glad you asked that question. Because that paper that David, and Sara, and I wrote, what we were arguing was is that over the history of a planet … When life first forms, 3.8

billion years ago, it's thin on the ground. You've got the first species, these are all microbes. There are not enough of them to exert any kind of these Gaian feedbacks. We call that an immature biosphere. But then as time goes on, as life becomes more robust and it begins to exert these feedbacks keeping the planet in the place where it needs to be for life, we call that a mature biosphere. I'm sure later on, we're going to talk about definitions of life and such. There's this great term called autopoiesis that Francisco Varela, the Neurobiologist Francisco Varela came up with. He said, "One of the defining things about life is this property of autopoiesis," which means self-creating and self-maintaining. Life does not create the conditions which will destroy itself. It's always trying to keep itself in a place where it can stay alive. The biosphere, from this Gaian perspective, has been autopoietic for billions of years. Now we just invented this technosphere in the last couple of hundred years. What we were arguing in that paper is that it's an immature technosphere. Because right now, with climate change and all the other things we're doing, the technosphere right now is destroying the conditions under which it needs to maintain itself. The real job for us if we're going to last over geological timescales, if we want a technosphere that's going to last tens of thousands, hundreds of thousands, millions of years, then we've got to become mature. Which means to not undermine the conditions, to not subvert the conditions that you need to stay alive. As of right now, I'd say we're not autopoietic.

Lex Fridman
Wow. I wonder if we look across thousands, tens of thousands, hundreds of thousands of years, that the technosphere should create perturbations as a way for developing greater and greater defenses against perturbations. Which sounds like a ridiculous statement. But basically, go out and play in the yard and hurt yourself, to strengthen. Or drink water from the pond.

Adam Frank
From the pond. Yeah, right. Get sick a few times.

Lex Fridman
To strengthen the immune system.

Adam Frank
Yeah. Well, you know it's interesting with the technosphere, we can talk about this more. We're just emerging as a technosphere, in terms of as an interplanetary technosphere. That's really the next step for us. David Grinspoon talks about it. I love this idea of anti-accretion. This amazing thing that, for the first time over the entire history of the planet, stuff is coming off the planet. It used to be everything just fell down, all the meteorites fell down. But now we're starting to push stuff out. The idea of planetary defense or such, we are actually going to start exerting perturbations on the solar system as a whole. We're going to start engineering, if we make it. I always like to say that if we can get through climate change, the prize at the end is the solar system. We'll be literally

engineering the solar system. But what you can think of right now with what's happening with the Anthropocene, the great acceleration that is the technosphere, is the creation of it, that is a giant perturbation on the biosphere. The technosphere sits on top of the biosphere, and if the technosphere undermines the biosphere for its own conditions of habitability, then you're in trouble. The biosphere is not going away. There's nothing we could do. The idea that we have to save the Earth is a little ridiculous. The Earth is not a furry little bunny that we need to protect. But it's the conditions for us. Humanity emerged out of the Holocene, the last 10,000 years interglacial period. We can't tolerate very different kinds of Earths. That's what I mean about a perturbation.

Lex Fridman
Before we forget, I got to ask you about this paper.

Adam Frank
Right.

Lex Fridman
It's pretty interesting. There's an interesting table here about hard steps. Abiogenesis, glucose fermentation to propionic acid, all kinds of steps, all the way to homo sapiens, animal intelligence, land ecosystems, endoskeletons. Eye precursor, so formation of the eye.

Adam Frank
Yeah.

Lex Fridman
Complex multicellularity.

Adam Frank
That's definitely one of the big ones.

Lex Fridman
Yeah. Interesting. What can you say about this chart? There are all kinds of papers talking about, what, the difficulty of these steps?

Adam Frank
Right. This was the idea. What Carter said was, "We're using anthropic reasoning." He said, "There must be a few very hard steps for evolution to get through to make it to intelligence." Some steps are going to be easy, so every generation, you roll the dice. Yeah, it won't take long for you to get that step. But there must be a few of them, and he said you could even calculate how many there were, five, six, in order to get to intelligence. This paper here, this plot is all these different people who've written all these papers. This is the point, actually.

You can see all these papers that were written on the hard steps. Each one proposing a different set of what those steps should be. There's this other idea from biology of the major transitions in evolution, MTEs, that those were the hard steps. But what we actually found was that none of those are actually hard. The whole idea of hard steps, that there are hard steps, is actually suspect. What's amazing about this model is it shows how important it is to actually work with people who are in the field. Brandon Carter was a brilliant physicist, the guy who came up with this. And then lots of physicists and astrophysicists like me have used this. But the people who actually study evolution and the planet were never involved. If you went and talked to an evolutionary biologist or a bio-geophysicist, they'd look at you when you explained this to them and they'd be like, "What? What are you guys doing?" It turns out, none of the details, or none of the conceptual structure of this matches with what the people who actually study the planet and its evolution.

Lex Fridman
Is it mostly about the fact that there's not really discrete, big steps? Is this a gradual, continual kind of process?

Adam Frank
Well, there's two things. The first most important one was that the planet and the biosphere have evolved together.

Lex Fridman
Together.

Adam Frank
That's something that most bio-geophysicists completely accept. It was the first thing that Carter rejected. He said, "No, that's probably not possible." And yet, if he'd only had more discussions with this other community, he would have seen, no, there are actually windows that open up. Then the next thing is this idea of whether a step is hard or not. Because for hard, what we mean by a hard step is, like I said, every time there's a generation, every time there's a next generation born, you're rolling the dice on whether this mutation will happen. The idea of something being a hard step, there's two ways in which something might even appear as a hard step and not be. Or actually not be a hard step at all. One is that you see something that has occurred in evolution that has only happened once. Let's take the opposite, we see something that's happened multiple times. Like wings, lots of examples of wings over lots of different evolutionary lineages. Making wings is not a hard step. There's certain other things that people say, "No, that's a hard step." Oxygen, the oxygen photosynthesis. But they tend to be so long ago that we've lost all the information. There could be other things in the fossil record that made this innovation, but they're just gone now so you can't tell, so there's information loss. The other thing is the idea of pulling up the ladder. That somebody, some species makes the innovation, but then it fills the niche and nobody else can do it again. Yeah, it only happened once but it happened once because

basically, the creature was so successful it took over, and there was no space for anybody else to evolve it. Yeah. The interesting thing about this was seeing how much, once you look at the details of life's history on Earth, how it really shifts you away from this hard steps model. It shows you that those details, as we were talking about with do you have to know about the planet, do you have to know about plate tectonics? Yeah, you're going to have to.

Lex Fridman
To be fair to Carter on the first point, it makes it much more complicated if life and the planet are co-evolving. Because it would be nice to consider the planet as a static thing that sets the initial conditions.

Adam Frank
Yeah.

Lex Fridman
And then we can, from an outside perspective, analyze planets based on the initial conditions they create. Then there's a binary yes or no at will it create life. But if they co-evolve, it's a really complex dynamical system, the way everything is ... Because it's much more difficult from the perspective of settee. Of looking out there and trying to figure out which ones are actually producing life.

Adam Frank
But I think we're at the point now, now there may be other kinds of principles that actually ... Co-evolution actually has its own. Not deterministic, you're done with determinism.

Lex Fridman
Yeah.

Adam Frank
But complex systems have patterns.

Lex Fridman
Yeah.

Adam Frank
Complex systems have constraints. That's actually what we're going to be looking for, are constraints on them. Again, nothing against Carter. It was a brilliant idea. But it just goes to show you ... I'm a theoretical physicist. Give me a simplified model, with dynamical equations and some initial conditions, I'm very happy. But there's this great XTC comic, where somebody's working something out on the board, and this physicist is looking over and saying, " Oh, oh, I just wrote down an equation for that. I solved your problem. Do you guys even have a journal for this?" The subtitle is Why Everybody Hates Physicists.

Lex Fridman
Yeah.

Adam Frank
Sometimes that approach totally works.

Lex Fridman
Yeah.

Adam Frank
Sometimes physicists, we can be very good at zooming in on what is important and casting the details aside so you can get to the heart of an issue. That's very useful sometimes. Other times, it obfuscates. Other times, it clouds over actually what you needed to focus on, especially when it comes to complexity.

Lex Fridman
Speaking of simplifying everything down to an equation, let's return back to the question of how many alien civilizations are out there and talk about the Drake Equation.

Adam Frank
Yeah.

Lex Fridman
Can you explain the Drake Equation?

Adam Frank
People have various feelings about the Drake Equation. It can be abused. The story actually is really interesting. Frank Drake in 1960 does the first ever astrobiological experiment. He gets a radio telescope, points it at a couple of stars, and listens for signals. That was the first time anybody had done any experiment about any kind of life in the history of humanity. He does it, and he's waiting for everybody to make fun of him. Instead, he gets a phone call from the government and says, "Hey, we want you to do a meeting on interstellar communications." He's like, "Okay." They organized a meeting with just eight people. A young Carl Sagan is going to be there as well. The night before, Drake has to come up with an agenda. How do you come up with an agenda for a meeting on a topic that no one's ever talked about before? What he does, what's so brilliant about the Drake Equation, is he breaks the problem of how many civilizations are there out there into a bunch of sub-problems. He breaks it into seven sub-problems. Each one of them is a factor in an equation that, when you multiply them all together, you get the number of civilizations out there that we could communicate with. The first term is the rate at which stars form. The second term is the fraction of those stars that have plants, F-sub-P. The next term is the number of planets in the habitable zone, the place where we think life could form. The next

term after that is the fraction of those planets where actually an abiogenesis event, life forms, occurs. The next one is the fraction of planets on which you start to get intelligence. After that, it's the fraction of planets where that intelligence goes on to create a civilization. Then finally, the last term, which is the one that we really care about, is the lifetime, have a civilization and how long does it last.

Lex Fridman
When you say we, we humans?

Adam Frank
We humans, because we're staring at multiple guns pointing at us.

Lex Fridman
Yeah.

Adam Frank
Nuclear war, climate change, AI. How long in general does civilizations last? Now each one of these terms, what was brilliant about what he did was, what he was doing was he was quantifying our ignorance. By breaking the problem up into these seven sub-problems, he gave astronomers something to do. This is always with a new research field, you need a research program or else you just have a bunch of vague questions. You don't even know really what you're trying to do. The star people could figure out how many stars were forming per year. The people who were interested in planets could go out and find techniques to discover planets, et cetera, et cetera.

Lex Fridman
These are their own fields. Essentially by creating this equation, he's launching new fields.

Adam Frank
Yeah. That's exactly … He gave astrobiology, which wasn't even a term then, a roadmap. "Okay, you guys go do this, you go do that." And then, a roadmap like, "Okay, you guys go do this, you go do that, you go do that." And it had such far-reaching effect on astrobiology because it did break the problem up in a way that gave useful marching orders for all these different groups. For example, it's because of the Drake equation in some sense that people who were involved in SETI pushed NASA to develop the technologies for planet hunting. There was this amazing meeting in 1978, two meetings, 1978 and 1979, that were driven in some part by the people who were involved in SETI getting NASA together to say, "Look, okay, look, what's the roadmap for us to develop technologies to find planets?" So, the Drake equation is absolutely foundational for astrobiology, but we should remember that it's not a law of nature. It's not equal to MC squared. And so, you can see it being abused in some sense. Yeah, it's generated a trillion papers. Some of those papers are good, I've written some of those. And some of those papers are bad, I'm not sure where my paper fits in on

those. I'm saying one should be careful about what you're using it for. But in terms of understanding the problem that astrobiology faces, this really broke it up in a useful way.

Lex Fridman
We could talk about each one of these, but let's just look at exoplanets.

Adam Frank
Yeah.

Lex Fridman
So, that's a really interesting one. I think when you look back hundreds of years from now, was it in the 90s when they first detected the first-

Adam Frank
Yeah. '92 and '95. '95 to me was really, that was the discovery of the first planet orbiting a sun-like star. To me, that was the water, the dam being broken.

Lex Fridman
I think that's one of the greatest discoveries in the history of science.

Adam Frank
I agree. I agree.

Lex Fridman
Right now, I guess nobody's celebrating it too much because you don't know what it really means. But I think once we almost certainly will find life out there, it will obviously allow us to generalize across the entire galaxy of the entire universe. So, if you can find life on a planet, even in the solar system, you can now start generalizing across the entire universe.

Adam Frank
You can, all you need is one. Right now, our understanding of life, we have one example. We have N equals one example of life. So, that means we could be an accident. It could be that we're the only place in the entire universe where this weird thing called life has occurred. Get one more example and now you're done, because if you have one more example, now you don't have to find all the other examples. You just know that it's happened more than once, and now you are from a Bayesian perspective, you can start thinking like, "Yeah. Life is not something that's hard to make."

Lex Fridman
Well, let me get your sense of estimates for the Drake equation. You've also written a paper expanding on the Drake equation, but what do you think is the answer?

Adam Frank
So, there was this paper we wrote, Woody Sullivan and I in 2016, where we said, "Look, we have all this exoplanet data now." So, the thing that exoplanet science and the exoplanet census I was talking about before have nailed is F sub P, the fraction of stars that have planets, it's one. Every fricking star that you see in the sky hosts a family of worlds. I mean, it's mind-boggling because those are all places, right? They're either gas giants, probably with moons, so the moons are places you can stand and look out. Or they're like terrestrial worlds where even if there's not life, there's still snow falling and there's oceans washing up on shorelines. It's incredible to think how many places and stories there are out there. So, the first term was F sub P, which is how many stars have planets. The next term is how many planets are in the habitable zone on average, and it turns out to be one over five, so around 0.2. So, that means you just count five of them go out at night and go one, two, three, four, five. One of them has an Earth-like planet in the habitable zone, like, whoa.

Lex Fridman
So, what defines a habitable zone?

Adam Frank
Habitable zone is an idea that was developed in the 1958 by the Chinese American astronomer, Xu Sheng, and it was a brilliant idea. It said, "Look, I can do the simple calculation. If I take a planet and just stick it at some distance from a star of what's the temperature of the planet? What's the temperature of the surface?" So now, give it a standard Earth-like atmosphere and ask, "Could there be liquid water on the surface?" We believe that liquid water is really important for life. There could be other things that's happening fine, but if you were to start off trying to make life, you'd probably choose water as your solvent for it. So basically, the habitable zone is the band of orbits around a star where you can have liquid water on the surface. You could take a glass of water, pour it on the surface, and it would just pull up. It wouldn't freeze immediately, which would happen if your planet is too far out and it wouldn't just boil away if your planet's too close in. So, that's the formal definition of the habitable zone. So, it's a nice strict definition, there's probably way more going on than that, but this is a place to start.

Lex Fridman
Well, we should say it's a place to start, I do think it's too strict of a constraint.

Adam Frank
I would agree.

Lex Fridman
We're talking about temperature where water can be on the surface. There's so many other ways to get the aforementioned turmoil where the temperature varies, whether it's volcanic,

so interaction of volcanoes and ice and all of this on the moons of planets that are much farther away, all this kind of stuff.

Adam Frank
Yeah. Well, for example, we know in our own solar system we have, say Europa, the moon of Jupiter, which has got a hundred-mile-deep ocean under 10 miles of ice. That's not in the habitable zone, that is outside the habitable zone, and that may be the best place. It's got more water than Earth does, all of its oceans. It's twice as much water on Europa than there is on Earth. So, that may be a really great for life to form, and it's outside the habitable zone. So, the habitable zone is a good place to start and it helps us. And there's reasons why you do want to focus on the habitable zone, because like Europa, I won't be able to see from across telescopic distances across light years. I wouldn't be able to see life on Europa because it's under 10 miles of ice. So, with the important thing about planets in the habitable zone is that we're thinking they have atmospheres. Atmospheres are the things we can characterize across 10, 50 light years and we can see biosignatures as we're going to talk about. So, there is a reason why the habitable zone becomes important for the detection of extra solar life.

Lex Fridman
But for me, when I look up at the stars, it's very likely that there's a habitable planet or moon in each of the stars, habitable defined broadly.

Adam Frank
Yeah, I think that's not unreasonable to say, especially since the formal definition, you get one in five, right? One in five is a lot, there's a lot of stars in the sky. So yeah, saying that in general, when I look at a star, there's a pretty good chance that there's something habitable orbiting it. It is not a unreasonable scientific claim.

Lex Fridman
To me, it seems like there should be alien civilizations everywhere. Why the Fermi paradox? Why haven't we seen them?

Adam Frank
Okay, the Fermi paradox. I love talking about the Fermi paradox because there is no Fermi paradox. Dun dun, dun dun. Yeah, so the Fermi paradox, let's talk a about the Fermi paradox and the history of it. So, Enrico Fermi, it's 1950, he's walking with his friends at Los Alamos nuclear weapons lab to the Cantina, and there had been this cartoon in the New Yorker, they all read the New Yorker. And the cartoon was trying to explain why there had been this rash of garbage cans being disappearing in New York. And this cartoon said, "Oh, it's UFOs." Because it's 1950, the first big UFO craze happened in '47. So, they were laughing about this as they're walking, and they started being physicists, started talking about interstellar travel, interstellar propulsion. Conversation goes on for a while, conversation turns to

something else, they've gone to other things. About 40 minutes later, over lunch, Fermi blurts out, "Well, where is everybody?" Typical Fermi sort of thing. He'd done the calculation in his head and he suddenly realized that, look, if intelligence is common, that even traveling at sub lights speeds a civilization could cross, hop from one star system to the other and spread it out across the entire galaxy in a few hundred thousand years. And he realized this, and so he was like, "Why aren't they here now?" And that was the beginning of the Fermi paradox. It actually got picked up as a formal thing in 1975 in a paper by Hart where he actually went through this calculation and showed and said, "Well, there's nobody here now, therefore, there's nobody anywhere." Okay, so that is what we will call the direct Fermi paradox, why aren't they here now? But something happened after SETI began, where people started to, there was this idea of the great silence. People got this idea in their head that like, "Oh, we've been looking for decades now for signals of extra-terrestrial intelligence that we haven't found any. Therefore, there's nothing out there. So, we'll call that the indirect Fermi paradox and there absolutely is no indirect Fermi paradox for the most mundane of reasons, which is money. There's never been any money to look. SETI was always done by researchers who were scabbing some time, some extra time from their other projects to look a little bit at the sky where the telescope, telescopes are expensive. So, Jason Wright, one of my collaborators, he and his students did a study where they looked at the entire search space for SETI, and imagine that's an ocean. All the different stars you have to look at, the radio frequencies you have to look at, how when you look, how often you look. Then they summed up all the SETI searches that had ever been done, they went through the literature. And what they found was if that search space, if the sky is an ocean and you're looking for fish, how much of the ocean have we looked at, and it turns out to be a hot tub. That's how much of the ocean that we've looked up. We've dragged a hot tub's worth of ocean water up and there was no fish in it, and so now are we going to say, "Well, there's no fish in the ocean." So, there is absolutely positively no indirect Fermi paradox, we just haven't looked, but we're starting to look. So finally, we're starting to look, that's what's exciting. The direct Fermi paradox, there are so many ways out of that. There's a book called 77 Solutions to the Fermi Paradox that you can pick your favorite one. It just doesn't carry a lot of weight because there's so many ways around it. We did an actual simulation, my group, Jonathan Carroll, one of my collaborators, we actually simulated the galaxy and we simulated probes moving at sub light speed from one star to the other, gathering resources heading to the next one. And so, we could actually track the expansion wave across the galaxy, have one IA biogenesis event, and then watch the whole galaxy get colonized or settled. And it is absolutely true that wave crosses, Hart was right, Fermi was right, that wave crosses very quickly. But civilizations don't last forever, so one question is when did they visit? When did they come to Earth? So, if you give civilizations a finite lifetime, let them last 10,000, 100,000 years, what you find is you now have a steady state. Civilizations are dying, they're coming back, they're traveling between the stars. What you find then is you can have big holes opened up. You can have regions of space where there is nobody for millions of years. And so, if we're living in one of those bubbles right now, then maybe we revisited but we revisited 100 million years ago. And there was a paper that Gavin Schmidt and I did that showed that if there was a civilization, whether it was dinosaurs or aliens that was here a 100 million years ago, there's no way to tell, there's no record left over, the fossil record is too sparse. The only way maybe you could tell is by looking at the isotopic strata to see if there was anything reminiscent of an industrial civilization. But the idea that you'd be able to find iPhones or toppled buildings after 100 million years is there's no way.

Lex Fridman
So, if there was an alien camp here, an alien village, a small civilization, maybe even large civilizations?

Adam Frank
Even a large civilization, even if it was-

Lex Fridman
100 million years ago?

Adam Frank
And it lasted 10,000 years, fossil record's not going to have it. Yeah, the fossil record is too sparse, most things don't fossilize.

Lex Fridman
Yeah.

Adam Frank
And 10,000 years is a blink in the eye of geological time. So, Gavin called this the Silurian Hypothesis after the Doctor who episode with the lizard creatures, the Silurians. And so, that paper got a lot of press, but it was an important idea, and this was really Gavin's, I was just helping with the astrobiology. That to recognize that like, "Yeah, we could have been visited a long time ago there just would be no record." Yeah, it's mind-blowing.

Lex Fridman
It's really mind-blowing.

Adam Frank
Yeah.

Lex Fridman
And it's also a good reminder that intelligent species have been here for a very short amount of time.

Adam Frank
Very short amount of time. Yeah. This is not to say that there was, so I was on Joe Rogan for exactly this paper, and I had to always emphasize, we're not saying there was a Silurian, but we're just saying that if there was, that's why I love Gavin's question. Gavin's question was just like, "How could you tell"? It was a very beautifully scientific question. That's what we were really showing is that unless you did a very specific kind of search, which nobody's done so far, there's not an obvious way to tell that there could have been civilizations here earlier on.

Lex Fridman
I've actually been reading a lot about ancient civilizations, and it just makes me sad how much of the wisdom of that time is lost and how much guessing is going on, whether it's in South America, what happened in the jungle.

Adam Frank
Like the Amazon, that was the conquistadors came and wiped everybody out, and especially just even the plague may have decimated. So yeah, how much of that civilization.

Lex Fridman
And there's a lot of theories, and because of archaeology only looks at cities, they don't really know the origins of humans.

Adam Frank
Yeah.

Lex Fridman
And there's a lot of really interesting theories, and there are of course controversial and there's a lot of controversial people in every discipline, but archaeology is a fascinating one because we know so little. They're basically storytellers, you're assembling the picture from just very few puzzle pieces, and it's fascinating. It's humbling and it's sad that there could be entire civilizations, ancient civilizations that are either almost entirely or entirely lost.

Adam Frank
Yeah. Well, the indigenous peoples of North America, there could have been millions and millions. We get this idea that like, oh, the Europeans came and it was empty. But it may have only been empty because the plague gets swept up from what happened in Mesoamerica, and they didn't really build cities. They didn't build wooden or stone cities, they built wooden cities.

Lex Fridman
Everybody seems to be building pyramids and they're really damn good at it. I don't know-

Adam Frank
What it is up with a pyramid. Why does that apply? What archetype in our brain is that?

Lex Fridman
And it is also really interesting, speaking of archetypes, is that independent civilizations formed and they had a lot of similar dynamics like human nature when it builds up hierarchies in a certain way, it builds up myths and religions in a certain way, it builds pyramids in a certain way. It goes to war, all this kind of stuff independently, which is fascinating.

Adam Frank
Santa Fe Institute, the stuff the Santa Fe Institute does on these as complex systems, the origin of hierarchies and such. Very cool.

Lex Fridman
Yeah, Santa Fe folks, complexity in general is really cool.

Adam Frank
Really cool.

Lex Fridman
What phenomena emerge when a bunch of small things get together and interact? Going back to this paper, a new empirical constraint on the prevalence of technological species in the universe. This paper that expands on the Drake equation, what are some interesting things in this paper?

Adam Frank
Well, so the main thing we were trying to do with this paper is say, "Look, we have all of this exoplanet data." It's got to be good for something, especially since two of the terms that have been nailed down empirically are two terms in the Drake equation. So, F sub P, that's the second term, fraction of stars that have planets, and then N sub E, the average number of planets in the habitable zone. Those are the second and third term in the Drake equation. So, what that means is all the astronomical terms have been nailed. And so, we said, "Okay, how do we use this to do something with the Drake equation?" And so, we realized is, "Well, okay, we got to get rid of time." The lifetime thing, we can't say anything about that, but if we don't ask how long do they last but instead ask, "What's the probability that there have been any civilizations at all?" No matter how long they lasted, I'm not asking whether they exist now or not, I'm just asking in general about probabilities to make a technological civilization anywhere and at any time in the history of the universe and that we were able to constrain. And so, what we found was basically that there have been 10 billion trillion habitable zone planets in the universe. And what that means is that those are 10 billion trillion experiments that have been run. And the only way that we're this whole process from

a biogenesis to a civilization has occurred is if every one of those experiments failed. So therefore, you could put a probability, we called it the pessimism line. We don't really know what nature sets for the probability of making intelligent civilizations, but we could set a limit using this. We could say, "Look, if the probability per habitable zone planet is less than 10 to the minus 22, 1 in 10 billion trillion, then yeah, we're alone." If it's anywhere larger than that, then we're not the first, it's happened somewhere else. And to me, that was mind-blowing. It doesn't tell me there's anybody nearby, the galaxy could be sterile. It just told me that unless nature's really has some bias against civilizations, we're not the first time this has happened. This has happened elsewhere over the course of cosmic history.

Lex Fridman
10 billion trillion experiments.

Adam Frank
Yeah, that's a lot of experiments.

Lex Fridman
That's a lot.

Adam Frank
Right.

Lex Fridman
1,000 is a lot.

Adam Frank
Yeah.

Lex Fridman
100 is a lot.

Adam Frank
Yeah.

Lex Fridman
If we, normal humans saw 100 experiments, and we knew that at least one time there was a successful human civilization built we would say for sure, in 100 you'll get another one.

Adam Frank
Yeah. So, that's why these kinds of arguments you have to be careful of what they can do. But I felt like what this paper showed was that the burden of proof is now on the pessimists. So, that's why we called it the pessimism line. Throughout history, there's been alien

pessimists and alien optimists, and they've been yelling at each other, that's all they had to go with. And with Giordano Bruno in 1600, they burned the guy at the stake for being an alien optimist. But nobody really knew what pessimism or optimism meant. We thought this was like the plank length, this was the plank length of astrobiology. Gave you an actual number that if you could somehow calculate what the probability of forming a technological civilization was, this thing shows you where the limit is. As long as you're above 10 to the minus 22, then you actually absolutely, it has occurred in the history. Other civilizations have occurred in the history of the universe.

Lex Fridman
So, to me, at least, the big question is FE, which is basically a biogenesis. How hard is it for life to originate in a planet? Because all the other ones seem very likely, everything seems very likely. The only open question to me is how hard is it for life to originate?

Adam Frank
There's lots of ways to, again, we don't know unless we look, and you had Sarah Walker around not too long ago, she's very interested in origins of life. So, lots of people are working on this. But I think it's hard looking at the history of the Earth, and again, you can do Bayesian arguments on this. But yeah, forming life I don't think is hard. Getting basic biology started, I don't think is hard. It's still wild, it's an amazing process that actually I think requires some deep rethinking about how we conceptualize what life is and what life isn't. That's one of the things I like about Sarah's work, we're pursuing on a different level about life as the only system that uses information. But still, regardless of all those kinds of details, life is probably easy to make. That's my gut feeling.

Lex Fridman
Day by day, this changes for me, but I just see that once you create bacteria, it is off to the races. You're going to get complex life as long as you have enough time. That boring billion, but I just can't imagine a habitable planet not having a couple of billion to spare.

Adam Frank
Yeah, a couple billion years to spare. There is a mystery there about why did it take so long with the Cambrian explosion, but that may be again, about these windows. That it couldn't happen until the window, the planet and the life had evolved together enough that they together opened the window for the next step. Intelligent life and how long intelligent, technological civilizations, I think there's a big question about how long those last. And I'm hopeful, but in terms of just, I think life is absolutely going to be common, pretty common in the universe.

Lex Fridman
Yeah. I think, again, if I were to bet everything, even in advanced civilizations are common. So, to me then the only explanation is the L. Our galaxy is a graveyard of civilizations.

Adam Frank
Yeah. You think about it, we've only been around, truly when we think about in Drake's definition, you had to have radio telescopes, that's been 100 years. And if we got another 10,000, 100,000 years of history, for us, it'd be pretty amazing. But that still, that wouldn't be long enough to really pop up the number of civilizations in the galaxy. So, you really need it to be hundreds of millions of years. And that raises a question, which I am very interested in, which is how do we even talk about, I call it the billion-year civilization. How do we even begin to hypothesize or think about in any kind of systematic way, what happens to a technological civilization across hundreds of millions to a billion years?

Lex Fridman
Yeah. How do you even simulate the trajectories as civilizations can take across that kind of timescale?

Adam Frank
Yeah.

Lex Fridman
When all the data we have is just for the 10,000 years or so, 20,000 years that humans have been building civilizations.

Adam Frank
Yeah.

Lex Fridman
And I don't know what you put it at, but maybe 100 years that we've been technological?

Adam Frank
And we're ready to blow ourselves to bits or drive ourselves off the planet. Yeah, no, it's really interesting. But there's got to be a way that I think that's really a frontier. So, you had David Kipping on not too long ago, and David and I did a paper and Caleb Scharf, David really drove this. Where it was a Bayesian calculation to ask the question, "If you were to find a detection, if you were to find a signal or a techno signature, would that come from a civilization that was younger your age or older?" And you could see, this is not hard to do, but it was great. The formalism, the formalism was hard. It's intuitive, but the formalism was hard to show that, yeah, they're older, probably much older. So, that means you really do need to think about like, "Okay, how do billion-year civilizations manifest themselves? What signatures will they leave?" And yeah, what's so cool about it, it's so much fun because you have to imagine the unimaginable. Obviously biological evolution can happen on those kinds of timescales, so you wouldn't even really be the same thing you started out as. But social forms, what kind of social forms can you imagine that would be continuous over that? Or maybe they wouldn't be continuous, should get they drop out, they destroy themselves, and

then they come back. So, maybe it's a punctuated evolution, but this is the fun part we have to work this out.

Lex Fridman
Well, one way to approach that question is what are the different ways to achieve homeostasis is you get greater and greater technological innovation. So, if you expand out into the universe and you have up to Kardashev scale, what are the ways you can avoid destroying yourself? Just achieve stability while still growing. That's an interesting question, I think it's probably simulatable?

Adam Frank
Could be, agent-based modeling you could do it with. So, our group has used agent-based modeling to do something like the Fermi paradox that was agent-based modeling. But you can also do this. People at Santa Fe have done this, other groups have done this to do use agent-based modeling to track the formation of hierarchies, the formation of stable hierarchies. So, I think it's actually very doable, but understanding the assumptions and principles that are going into it and what you can extract from those, that is what is the frontier.

Lex Fridman
Do you think if humans colonize Mars, the dynamic between the civilization on Earth and Mars will be fundamentally different than the dynamic between individual nations on Earth right now? That's a thing to load into the agent-based simulation we're talking about.

Adam Frank
Yeah. If we settle it, Mars will very quickly want to become its own nation.

Lex Fridman
Well, no, there's already going to be nations on Mars that's guaranteed-

Adam Frank
Yeah. And they're there on-

Lex Fridman
2 million people. The moment you have 1 million people, there's going to be two tribes.

Adam Frank
Right.

Lex Fridman
And then they're going to start fighting.

Adam Frank
Right.

Lex Fridman
And the question is, interplanetary fighting. How quickly does that happen and does it have a different nature to it because of the distances?

Adam Frank
Are you a fan of The Expanse? Have you watched The Expanse? Great show, I highly recommend to everybody. It's based on a series of books that are excellent. It's on Prime, six seasons, and it's basically about the settled solar system. It takes place about 300 years from now, and the entire solar system is settled, and it is the best show about interplanetary politics. The first season, actually, the journal, what was it? Foreign Affairs said the best show on TV about politics it takes place is interplanetary. So yeah, I think human beings being human beings, yes, there will be warfare and there will be conflict. And I don't think it'll be necessarily all that different because really I think within a few hundred years we will have lots of people in the solar system, and it doesn't even have to be on Mars. We did a paper where we look based on, because I always wanted to know about whether an idea in The Expanse was really possible. In The Expanse, the asteroid belt, what they've done is they have colonized the asteroid belt by hollowing out the asteroids and spinning them up and living on the inside because they have the Coriolis force. And I thought like, "Wow, what a cool idea." And when I ran the blog for NPR, actually talked to the guys and said, "Did you guys calculate this to see whether it's possible?" Sadly, it's not possible. The rock is just not strong enough that if you tried to spin it up to the speeds you need to get one third gravity, which is what I think the minimum you need for human beings. The rock would just fall apart, it would break. But we came up with another idea, which was that if you could take small asteroids, put a giant bag around them, a nanofiber bag and spin those up, it would inflate the bag. And then even a small couple of kilometer wide asteroid would expand out to, you could get a Manhattan's worth of material inside. So, forget about even colonizing Mars space stations or space habitats with millions of people in them. So anyway, the point is that I think within a few hundred years, it is not unimaginable that there will be millions, if not billions of people living in the solar system.

Lex Fridman
You think most of them will be in space habitats versus on Mars on the planetary surface?

Adam Frank
It's a lot easier on some level. It depends on how with nanofabrication and such, but getting down to gravity well is hard. So, there's a certain way in which it's a lot easier to build real estate out of the asteroids, but we'll probably do both. I think what'll happen is the next, should we make it through climate change and nuclear war and all the other, and AI? The next 1,000 years of human history is the solar system. And so, I think we'll settle every nook

and cranny we possibly can, and what I love about, what's hopeful about it is this idea you're going to have all of these pockets, and I'm sure there's going to be a Mormon space habitat. Whatever you want, a libertarian space habitat, everybody's going to be able to create, there'll be lots of experiments in human flourishing. And those kinds of experiments will be really useful for us to figure out better ways for us to interact and have maximum flourishing, maximum wellness, maximum democracy, maximum freedom.

Lex Fridman
Do you think that's a good backup solution to go out into space, so to avoid the possibility of humans destroying themselves completely here on Earth?

Adam Frank
Well, I think I want to be always careful with that, because like I said, it's centuries that we're talking about. So, the problem with climate change, and same thing with nuclear war, it's breathing down our necks now. So, trying to establish a base on Mars it's going to be so hard that it is not even going to be close to being self-sufficient for a couple a century at least. So, it's not like a backup plan now, we have to solve the problem of climate change, we have to deal with that. There's still enough nuclear weapons to really do horrific things to the planet for human beings. So, I don't think it's a backup plan in that way, but I do think, like I said, it's the prize. If we get through this, then we get the entire solar system to play around and experiment with and do really cool things with.

Lex Fridman
Well, I think it could be a lot less than a couple of centuries if there's a urgency, a real urgency, like a catastrophe. Maybe a small nuclear war breaks out where it's like, holy shit, this is for sure a bigger one is looming. Maybe if geopolitically the war between China and the United States escalates where there's this tension that builds and builds and builds and it becomes more obvious that we need to really, really [inaudible 01:05:39].

Adam Frank
Yeah. I think my only dilemma with that is that I just think that a self-sufficient base is so far away. That say you start doing that and then there is a full-scale nuclear exchange that base is, it's not going to last because the self-sufficiency requires a kind of economy. Literally a material economy that we are so far from with Mars that we are centuries from. Like I said, three centuries, which is not that long, two to three centuries. Look at 1820, nobody had traveled faster than 60 miles an hour unless they were falling off a cliff. And now we routinely travel at 500 miles an hour, but it is centuries long. So, that's why I think we'd be better off trying to solve these problems than I just think the odds that we're going to be able to create a self-sufficient colony on Mars before that threat comes to head is small. So, we'd have to deal with the threat.

Lex Fridman
That's an interesting scientific and engineering question of how to create a self-sufficient colony on Mars or out in space as a space habitat where Earth entirely could be destroyed, you could still survive.

Adam Frank
Yeah. Because it's really what about, thinking about complex systems? A space habitat would have to be as robust as an ecosystem. As the kind of thing, you go out and you see a pond with all the different webs of interactions. That's why I always think that if this process of going out into space will help us with climate change and with thinking about making a long-term sustainable version of human civilization. Because you really have to think about these webs, the complexity of these webs and recognize the biosphere has been doing this forever. The biosphere knows how to do this. And so, A, how do we build a vibrant, powerful technosphere that also doesn't mess with the biosphere, mess with the biosphere's capacity to support our technosphere? So, by trying to build space habitats, in some sense, you're thinking about building a small-scale version of this. So, I think the two problems are going to feedback on each other.

Lex Fridman
Well, there's also the other possibility of the movie Darren Aronofsky's Postcard from Earth, where we can create this life gun that just shoots as opposed to engineering everything. Basically, seeding life on a bunch of places and letting life do its thing, which is really good at doing it seems like. So, as opposed to with a space habitat, you basically have to build the entire biosphere and technosphere, the whole thing-

Adam Frank
The whole thing.

Lex Fridman
... by yourself. If you just, hey, the aforementioned cockroach with some bacteria, place it in Europa, I think you'd be surprised what happens.

Adam Frank
Yeah.

Lex Fridman
Honestly, if you put a huge amount of bacteria, a giant number of organisms from Earth into on Mars, on some of these moons of the other planets in the solar system, I feel like some of them would actually find a way to survive.

Adam Frank
The moon is hard, the moon may be really hard. But I wonder if somebody must've done these experiments. Because we know they're extremophiles, we know that you can go down 10 miles below the Earth's surface. And there are things where there's no sunlight, the conditions are so extreme and there's lots of microbes having a great time living off the radioactivity in the rocks. But they had lots of time to evolve to those conditions, so I'm not sure if you dumped a bunch of bacteria, so somebody must've done these experiments. How fast could microbial evolution occur in under harsh conditions that you maybe get somebody who figures out, " Okay, I can deal with this." I think the Moon's too much because it's so sterile. But Mars, I don't know, maybe. I don't know, but it's an interesting idea.

Lex Fridman
I wonder if somebody has done those experiments.

Adam Frank
Yeah, you think somebody would, let's take a bunch of microbes-

Lex Fridman
The harshest possible condition of all different kinds, temperature, all this kind of stuff.

Adam Frank
Right, pressure, salinity, and then just dump a bunch of things that are not used to it, and then just see, does everybody just die? That's it.

Lex Fridman
The thing about life, it flourishes in a non-sterile environment where there's a bunch of options for resources, even if the condition is super harsh- ... Options for resources, even if the condition is super harsh. In the lab, I don't know if you can reconstruct harsh conditions plus options for survival. You know what I mean? You have to have the huge variety of resources that are always available on a planet somehow, even when it's a super harsh condition. So that's actually not a trivial experiment and if somebody did that experiment in the lab, I'd be a little bit skeptical because I could see bacteria doesn't survive in this kind of temperature. But then I'd be like, "I don't know. I don't know."

Adam Frank
Right. Are there other options? Is the condition rich enough?

Lex Fridman
Rich enough, yeah.

Adam Frank
There's an alternative view though, which is, there's this great book by Kim Stanley Robinson called Aurora. So there's been 1,000,000 sentry ship stories where Earth sends out a generation ship or sentry ship, and it goes to another planet and they land and they colonize. And on this one, they get all the way there and they think the planet's going to be habitable. And it turns out that it's not habitable for earth life. There's bacteria or prions actually, that just kill people in the simplest way. And the important thing about this book was the idea that life is actually very tied to its planet. It may not be so easy. I just thought it was a really interesting idea. I'm not saying necessarily supporting it, but that actually, life reflects the planetary conditions... Not the planetary, the planet itself, the whole lineage, the whole history of the biosphere. And it may not be so easy to just be like, "Oh, just drop it over here and it'll..." Because the bacteria, even though they're individual examples of life, and I believe this the true unit of life, it's not DNA, it's not a cell, it's the biosphere. It's the whole community.

Lex Fridman
Yeah. That's actually an interesting field of study is how when you arrive from one planet to another... So we humans arrive to a planet that has a biosphere, maybe a technosphere, what is the way to integrate without killing yourself or-

Adam Frank
Or the other one?

Lex Fridman
Or the other one? Let's stick to biology. That's an interesting question. I don't know if we have a rigorous way of investigating that.

Adam Frank
Because everything on life has the same lineage. We all come from LUCA, the last universal common ancestor. And what you see is often in science fiction, people will do things like, "Oh, well, it's okay," because that metabolism, that biochemistry is so different from ours that we can coexist because they don't even know each other.

Lex Fridman
Right.

Adam Frank
And then the other version is you get there, you land, and instantly, the nose bleeds and you're dead. So it's-

Lex Fridman
Unfortunately, I think it's the latter.

Adam Frank
Yeah, it feels like the alien kind of thing.

Lex Fridman
So as we look out there, according to the Drake equations we just discussed, it seems impossible to me that there's not civilizations everywhere. So how do we look at them, this process of SETI?

Adam Frank
I have to put on my scientist hat and just say, my gut feeling is that dumb life, so to speak, is common. I can see ways in which intelligent civilizations may be sparse, but until... We got to go look, it's all armchair astronomy.

Lex Fridman
That's from a rigorous scientific perspective. From my bro science perspective, it seems, again, smoking the aforementioned weed-

Adam Frank
Smoking the weed, yeah. After the bong hit, it seems so.

Lex Fridman
Honestly, it really just seems impossible to me that there's not potentially dead, but advanced civilizations everywhere in our galaxy.

Adam Frank
Yeah, yeah. The potentially dead part, I think, right. It could be that making civilizations is easy, they just don't last long. So when we went out there, we'd find a lot of extinct civilizations.

Lex Fridman
Extinct civilizations. Yeah. Apex predators don't survive. They get better, better, better.

Adam Frank
Right.

Lex Fridman
And they die, kill themselves all somehow. Anyway. So just how do we find them?

Adam Frank
Yeah. So SETI, Search for Extraterrestrial Technology is a term that I am not fond of using anymore. Some people in my field are. So I'm sorry folks, but what I really like is the idea of technosignatures because I think to me, SETI is the... First of all, intelligence. We're not

really looking for intelligence. We're looking for technology, and SETI, the classic idea of SETI is the radio telescopes and contact, Jodie Foster with the headphones. That whole thing is still part, it's still active, there's still great things going on with it, but suddenly, this whole new window opened up. When we discovered exoplanets, we now found a new way to look for intelligence civilizations or life in general in a way that doesn't have any of the assumptions that had to go into the classic radio SETI. And specifically, what I mean is we're not looking for somebody sending us a beacon. You really needed that with a classic model, for a bunch of different reasons. You have to assume they wanted to be found and they were sending you a super powerful beacon. Now, because we know exactly where to look and we know exactly how to look, we can just go about looking for passive signatures of the civilization, going about its civilizationing business, without asking whether they want to be contacted or not. So this is what we call a biosignature or a technosignature. It is an imprint in the light from the planet of the activity of a biosphere or a technosphere, and that's really important. That is why the whole Gaia idea ends up being astrobiological, that biospheres and technospheres are so potent, they change the entire planet, and you can see that from 20 light years. So let's give an example of a biosignature to start off with, which would be a signature of a biosphere, oxygen. Right? On earth at least, we know that oxygen is only in the atmosphere because life put it there. If life went away, the oxygen, and particularly oxygen and methane, that pair, they would disappear very quickly. They'd react away. They'd all be gone. So if you find a planet with oxygen and methane, that's a good bet that there's a biosphere there. Okay, what about technospheres? Technospheres, so I'm the principal investigator on the first grant NASA has ever given to do these exoplanet technosignatures. For reasons we can talk about, NASA had gotten pretty gun-shy about funding anything about intelligent life, but okay. What's an example of a technosignature? Well, one could be atmospheric, "Pollution." I'm going to put, "Pollution," in quotes here because it doesn't have to be pollution, but gases like chlorofluorocarbons. So we dumped a huge amount of chlorofluorocarbons into the atmosphere by mistake. It was affecting the ozone, but we put so much in there that actually, this is one of the things we did, we did a paper where we showed, you could detect it across interstellar distances. You could look at the atmosphere, look at the light coming from a distant planet, pass the light through a spectrograph and see the spectral lines, the fingerprint, the spectral fingerprint of chlorofluorocarbons in an atmosphere. And that would for sure tell you that there was a technological civilization there, because there's no other way to make chlorofluorocarbons except through some kind of industrial process.

Lex Fridman
So in the case of the biosphere, you're looking for anomalies in the spectrograph?

Adam Frank
I wouldn't necessarily call these anomalies. For biosignature, I'm looking for things that a geosphere, right? That just rock and air wouldn't produce on its own.

Lex Fridman
What kind of chemicals would life produce?

Adam Frank
Right. And that's the interesting thing. So we can use earth as an example. We can say, look, oxygen. We know there would be no oxygen in the atmosphere if it wasn't for dimethyl sulfide, which is a compound that phylloplankton dump into the atmosphere, a lot of it, that's sometimes mentioned. And there was a paper that somebody wrote where it was like, "Well, we're not saying we see it, but there's a bunch of noise in the spectra right there." So there's a whole list of things that earth has done that are in the atmosphere that might be biosignatures, but now we're reaching an interesting point. The field has matured to the point where we can start asking about agnostic biosignatures, things that have nothing to do with earth's history, but we think that would still be indications of this weirdness we call life. What is it in general that life does that leaves an imprint? So one of these things could be the structure of the network of chemical reactions that biology always produces very different chemical networks, who's reacting with who, than just rock and water. So there's been some proposals for networked biosignatures. Information theory, you can try and look at the information that is in the different compounds that you find in the atmosphere, and maybe that information shows you like, "Oh, there's too much information here. There must've been biology happening. It's not just rock." Same thing for techno. That's what we're working on right now, for technosignatures as well.

Lex Fridman
So how do you detect technosignatures?

Adam Frank
Okay. So with technosignatures, I gave the example of chlorofluorocarbons. So that would be an example of, and again, that one is a non-agnostic one, because we sort of like, "Oh, we produced chlorofluorocarbons. Maybe they will." And there's solar panels. The glint off of solar panels will produce the way the light is reflected off of solar panels, no matter what it's made out of actually. There was a paper that Manasvi Lingam and Avi Loeb did in... I think it was 2017. We've just followed up on it. That actually could act as a technosignature. You'd be able to see in the reflected light this big jump that would occur because of... City lights, artificial illumination. If there's really large scale cities like Coruscant and Star Wars or Trantor in the foundation, those city lights would be detectable, the spectral imprint of those across 20, 30 light years. So our job in this grant is to develop the first ever library of technosignatures. Nobody's really ever thought about this before. So we're trying to come up with all the possible ideas for what a civilization might produce that could be visible across interstellar distances. And are these good ones or are these ones going to be hard to detect or such?

Lex Fridman
City lights. So if a planet is all lit up with artificial light across 20 to 30 light years, we can see it.

Adam Frank
Yeah. If you looked at earth at night from a distance, looked at spectra and you had sensitive enough instruments, you'd be able to see all the sodium lights and the reflected light off of. They bounce off the ground, the light bounces off the ground. So you'd convolve the sodium lamps with the reflected spectra from the ground. And yeah, you'd be able to see that there's city lights. Now, increase that by a factor of 1,000 if you had a trantor, and you'd be able to detect that across interstellar distances. Thomas Beatty did this work, who's now working with us.

Lex Fridman
What do you think is the most detectable thing about earth?

Adam Frank
Wow, this is fun. We just have Sophia Sheikh, who's part of our collaboration, just did a paper. We did earth from earth. If you were looking at earth with earth technology for a bunch of different technosignatures, how close would you have to be to be able to detect them? And most of them turn out to be… You'd have to be pretty close, at least out to the Oort cloud, but actually, it is our radio signatures still, that is still most detectable.

Lex Fridman
By the way, when you said you had to be pretty close and then you said the Oort cloud, that's not very close. But you mean from an interstellar perspective.

Adam Frank
Interstellar distance, because we really want to know is I'm sitting here on earth, I'm looking at these exoplanets, the nearest star is four light years away. So that's the minimum distance. So if I'm looking at exoplanets, what kind of signals could I see?

Lex Fridman
What is detectable about earth with our current technology from our nearest solar system?

Adam Frank
Oh my God, there's all kinds of stuff. Well, like the chlorofluorocarbons, you can see earth's pollution, and I think city lights, you had to be within the solar system.

Lex Fridman
If they do direct imaging of earth-

Adam Frank
They're going to need much more powerful, but let me tell you, let's talk about direct imaging for a moment because I just have to go on, this is such a cool idea. So what we really want, and the next generation of space telescopes and such is we're trying to do direct imaging. We're trying to get an image of a planet separated from its star to be able to see the reflected light or the actual emission from the planet itself.

Lex Fridman
By the way, just to clarify, direct imaging means literally a picture?

Adam Frank
A picture, but the problem is that even with the thing that's going to come after JWST, it's going to be a pixel. You're not going to get any kind of resolution. You'll be able to get the light from it, which you'll be able to pass through a spectrograph, but you're not going to be able to take a picture. But there is this idea called the solar gravity lens telescope, I think that's what it is. And the idea is insane. So their general relativity says, "Look, massive bodies distort space. They actually curve space-time." So the sun is a massive body, and so that means that the light passing through the sun gets focused like a lens. So the idea is to send a bunch of telescopes out into the Oort cloud, and then look back towards the sun towards an exoplanet that is behind… Not directly behind the sun, but is in the direction of the sun. And then let the sun act like a lens and collect, focus the light onto the telescope and you would be able to get, and they've done… It's amazing. This idea is insane. They'd be able to get, if everything works out, 24 kilometer resolution. You'd be able to see Manhattan on an exoplanet. And this thing, it sounds insane, but actually, NASA, the team has already gotten through three levels of NASA… There's the NASA program for, "Give us your wackiest idea." And then the ones that survive that are like, "Okay, tell us whether that wacky idea is even feasible?" And they're marching along. And the idea is that they even have plans for how you'd be able to get these probes out into the Oort cloud on relatively fast time scales. You need to be about 500 times as far from the sun as earth is, but right now, the idea seems to hold together. So probably when I'll be dead, but when you're an old man, it's possible that something like this… Could you imagine having that kind of resolution, a picture of an exoplanet down to kilometers? So I'm very excited about that [inaudible 01:24:26].

Lex Fridman
I can only imagine having a picture like that, and then there's some mysterious artifacts that you're seeing.

Adam Frank
Yeah.

Lex Fridman
It's both inspiring and almost heartbreaking that we can see. I think we would be able to see a civilization where there's a lot of scientists agree that this is very likely something and then we can't-

Adam Frank
We can't get there. But again, this is the thing about being long-lived. We've got to get to the point where we're long-lived enough that... Let's imagine that we find, say 10 light years away, we find a planet that looks like it's got technosignatures. Righ? It doesn't end there. That would be the most important discovery in the history of humanity, and it wouldn't be like, "Well, okay, we're done." The first thing we do is we build bigger telescopes to try and do those imaging. And then the next thing after that, we plan a mission there. We would figure out, with Breakthrough Starshot, there was this idea of trying to use giant lasers to propel small spacecrafts, light sails, almost to the speed of light. So they would get there in 10 years and take pictures. So if we actually made this discovery, there would be the impulse. There would be the effort to actually try and send something to get there. Now, we probably couldn't land, so maybe we take 30 years to build, 10 years to get there, 10 years to get the picture back. Okay, you're dead, but your kids are... You know what I mean? So it becomes now this multi-generational project. How long did it take to build the pyramids? How long did it take to build the giant cathedrals? Those were multi-generational projects, and I think we're on the cusp of that kind of project.

Lex Fridman
I think that would probably unite humans.

Adam Frank
I think it would play a big role. I think it would be helpful. Human beings are a mess, let's face it. That's why I always say to people, discovery of life, of any kind of life, even if it was microbial life, it wouldn't matter, that to know that we're not an accident, to know that there is probably... If we found one example of life, we'd know that we're not an accident and there's probably lots of life and that we're a community. We're part of a cosmic kind of community of life, and who knows what life has done? All bets are off with life.

Lex Fridman
Since we're talking about the future of telescopes, let's talk about our current super sexy, awesome telescope, the James Webb Space Telescope, that I still can't believe actually worked.

Adam Frank
I can't believe it worked either. I was really skeptical. I was like, "Okay, guys. All right, sure."

Lex Fridman
We only got one shot for this incredibly complicated piece of hardware to unfold. So what kind of stuff can we see with it? I've been just looking through different kinds of announcements that have been detected. There's been some direct imaging-

Adam Frank
Yes, like a single pixel.

Lex Fridman
The kinds of exoplanets were able to direct image I guess would have to be hot.

Adam Frank
Hot, reasonably far away from the star. I think JWST is really at the hairy edge of being able to do much with this. What's more important I think, for JWST is the spectra. And the problem with spectra is that there's not sexy pictures. It's like, "Hey, look at this wiggly line," but be able to find and characterize atmospheres around terrestrial exoplanets is the critical next step. That's where we are right now. In order to look for life, we need to find planets with atmospheres. And then we need to be able to do this thing called characterization, where we look at the spectral fingerprints for what's in the atmosphere. Is there carbon? Is there carbon dioxide? Is there oxygen? Is there methane? And that's the most exciting thing. For example, there was this planet K2-18b, which they did a beautiful job getting the spectra, and the spectra indicated it may be an entirely new kind of habitable world called a hycean world, hycean meaning hydrogen ocean world. And that is a kind of planet that it would be in the super earth, sub-Neptune domain we were talking about, maybe eight times the mass of the earth. But it's got a layer of hydrogen, of an atmosphere of hydrogen. Hydrogen is an amazing greenhouse gas. So hydrogen will keep the planet underneath it warm enough that you could get liquid water, you can get a giant ocean of liquid water, and that's an entirely different kind of planet. That could be habitable planet. It could be a 60 degree warm ocean. So the data that came out of JWST for that planet was good enough to be able to indicate like, "Oh yeah, you know what? From what we understand with the models, this looks like it could be a hycean world."

Lex Fridman
And it's 120 light years away from earth.

Adam Frank
And so isn't that amazing? It's 120 light years away, but we can see into the atmosphere. We can see to the atmosphere so well that we can be like, "Oh, look, methane." Methane was a five sigma detection. You knew that the data were so good that it was the gold standard of science.

Lex Fridman
What about detecting maybe through direct imaging or in other ways, megastructures, that the civilizations build?

Adam Frank
You know what's great about megastructures is first of all, it's fun to say, who doesn't want to say megastructure? Alien, megastructure, right? Every morning, I'm looking for an opportunity to say that. So the err example of this is the Dyson sphere, which is amazing because it was literally 1960 that this idea came up.

Lex Fridman
Can you explain the Dyson sphere?

Adam Frank
Yeah, the Dyson sphere. So Freeman Dyson, one of the greatest physicists ever, who was very broad-minded and thought about a lot of different things. He recognized that as civilizations progress, what they're going to need is ever more energy to do ever more amazing things. And what's the best energy source in a solar system? It's the star. Right? So if you surrounded the star with solar collecting machines, sunlight collecting machines... Anyway, the limit of this would actually build a sphere, an actual sphere around your star that had all solar panels on the inside. You could capture every photon the star produced, which is this insane amount of light. You would have enough power now to do anything to re-engineer your solar system. So that was a Dyson sphere. It turns out that a Dyson sphere doesn't really work, it's unstable, but a Dyson swarm, and that's really what he meant, this large collection of large orbiting structures that were able to collect light.

Lex Fridman
So he didn't actually mean a rigid sphere structure.

Adam Frank
Right.

Lex Fridman
He basically meant a swarm. So like you said, then the limit basically starts to look-

Adam Frank
People started to say, "Yeah, it was like a sphere." And we actually almost thought we might've found one of these back with a Bajoyan star. The way we detect planets is through the transit method where the planet passes in front of the star and there's a dip in the starlight. It's a little eclipse basically, and we know exactly what they should look like. And then with this one star, there were these really weird transits where it was like this little dragon's tooth, and then there'd be another one and another one and another one, and then

nothing, and then three more. And in the paper that was written about this, they went through the list of, it could be comets, it could be chunks of a broken up planet, and it could also be an alien megastructure. And of course, the news picked up on this and everybody's newsfeed the next day, "Alien megastructures discovered." Turns out, sadly, they were not alien megastructures. They were probably gas or dust clouds, but it raised the possibility like, "Oh, these are observable." And people have worked out the details of what they would look like. You don't really need direct imaging. You can do transits, right? They're big enough that when they pass in front of the star, they're going to produce a little blip of light because that's what they're supposed to. They're absorbing starlight. So people have worked out like, "Well, a square one or a triangular one."

Lex Fridman
But that wouldn't be a distance sphere. That would be like one object.

Adam Frank
One object, right. If it's a swarm, you'd expect the light to be blinking in and out as these things pass in front of… If you've got thousands of these, much of the time, they'll be blotting out the star. Sometimes they won't be. Right? And so you're going to get an irregular transit signal.

Lex Fridman
One you wouldn't expect from a star that doesn't have anything.

Adam Frank
Exactly. Or just a planet or a couple of planets. There'd be so many of these that it would be like, "Beep, beep, blip, blip, blip, blip, blip."

Lex Fridman
And that usually doesn't happen in a star system because there's only just a handful of planets.

Adam Frank
That's exactly what it is. Everything's coagulant. In a stable solar system, you get a handful of planets, five, 10, that's it probably, and nothing else. So if now suddenly you see lots of these little micro transits telling you there's something else that's big enough to create a transit, but too many of them, and also, within a regular shape, the transit itself, that these could be megastructures.

Lex Fridman
How many people are looking for megastructures now?

Adam Frank
Well, the main groups looking for megastructures are again, Jason Wright at Penn State, and collaborators. The way they're looking for it though is for infrared light because the second law of thermodynamics says, "Look, if you capture all of this starlight, your thing's going to warm up and emit an infrared." It's going to be waste heat, waste heat and waste light from this.

Lex Fridman
That feels like a louder, clearer way to detect it.

Adam Frank
Right. And that's actually why Dyson proposed it. He wasn't really proposing it because he was saying, "This is what civilizations are going to do." He proposed it because he was like, "Oh, we want to start looking for alien civilizations. Here's something that would have a detectable signature." So Jason and company have done pretty good searches, and recently, they made news because they were able to eliminate a lot of places. "No, these are not Dyson Spheres," but they did have a couple that were anomalous enough that they're like, "Well, this is what it would look like." It's not a detection. They were saying they would never say it's a detection, but they were not non-detections.

Lex Fridman
And they're potential candidates.

Adam Frank
Potential candidates, yeah.

Lex Fridman
Love it. We have megastructure candidates. That's inspiring. What other megastructures do you think that could be? So Dyson Sphere is about capturing the energy of a star.

Adam Frank
Yeah.

Lex Fridman
There could be other-

Adam Frank
Well, there's something called the Clark Belt. So we have a bunch of satellites that are in geosynchronous orbit. Nothing naturally is going to end up in geosynchronous orbit. Geosynchronous orbit is one particular orbit that's really useful if you want to beam things straight down, or if you want to put a space elevator up. Right? So there's this idea that if a civilization becomes advanced enough that it's really using geosynchronous orbit, that you

actually get a belt, something that would actually be detectable from a distance via a transit. There's been a couple papers written about the possibility of these Clark Belts, densely occupied Clark Belts being a megastructure. It's not as mega as a Dyson swarm, but it's planetary scale.

Lex Fridman
You think it's detectable, Clark Belt?

Adam Frank
It could be. In our list of technosignatures, it would be down there, but it would be… Again, if you had an advanced enough civilization that did enough of this, you'd have a Clark Belt. And the question is whether or not it's detectable?

Lex Fridman
Yeah, probably Dyson sphere is the… That's the more exciting thing too.

Adam Frank
That's the go-to one. Yeah.

Lex Fridman
Speaking of the Dyson Sphere, let's talk through the Kardashev scales.

Adam Frank
Right.

Lex Fridman
What is the Kardashev scale and where are humans on it?

Adam Frank
Right. So the Kardashev scale was at the same time. This is this golden age of SETI, like '59 to '65 when it just starts. Frank Drake has done his first experiment. People are like, "Oh my God, this is even possible." And so people are just throwing out these ideas and as I said in the book, science is conservative. And what I mean by that is it holds onto its best ideas. So Kardashev comes up with this idea that, "Look, if we're…" Again, it's always about detectability. "If we're looking for civilizations, we should think about what are the, "Natural," stages," natural in quotes, "That a civilization goes through?" And he was thinking in terms of energy use, like a good physicist. So he said, "Look, the first hurdle in terms of energy or threshold that a civilization will go through is using all the starlight that falls onto a planet." He called that a type one civilization. In whatever way you're doing it, some large fraction of the starlight that falls on your planet, you're using for your own ends. The next would be to use all the starlight there is from that star. Right? So that's the Dyson sphere. So Dyson had already proposed his idea of the swarm and Kardashev was picking up. So that's a type two

civilization. Type three is galactic scale, a civilization that could use all the starlight in a galaxy. So where are we now? Remarkably, on a log scale. We're at 0.7 of a type one.

Lex Fridman
So we're not even type one?

Adam Frank
No, no, no. We're not even type one, but according to… There was a paper written by a group that said, "Can we continue on our path? We'll be at a type one at around 2300."

Lex Fridman
2300. So this is on a log scale?

Adam Frank
Yeah.

Lex Fridman
So 0.7. So type one is about 10 to the 16th watts. Type two is 10 orders of magnitude larger than that, 10 to the 26th watts, and I think estimate for the galaxy is another 10 orders of magnitude.

Adam Frank
Yeah, because there's a 100,000,000,000 star of order, 100,000,000 stars.

Lex Fridman
So that's a lot.

Adam Frank
That's a lot energy.

Lex Fridman
Do you think humans ever get to type one?

Adam Frank
I think that there's a problem with type one, which is that we already know about climate change. The effects of our harvesting energy to do the work of civilization is already changing the climate state, and that's something that Kardashev couldn't have recognized. There's the first law of thermodynamics, which is just about the different forms of energy. Then there's the second law, which is about when you use that energy, Kardashev wasn't thinking about the second law. If you get all that energy and you use it, there is waste heat. You don't get to use it all. Right? Second law tells you that if I have a tank of gasoline, I can only use a certain fraction of the energy in that tank, and the rest is going to go to heating

up the engine block. So that second law tells you that you can only use so much energy before the climate state is like, "Uh-oh, sorry, it's going to change on you." So there's a way in which we probably can't get to a type one without devastating the earth's climate. The most important thing actually here is probably, this is why space becomes… So the colonization or settlement of space. If we have an idea that we've been working on for a while called service worlds, that at some point you probably move a lot of your industry off world. We've got Mercury, for example. There's nothing on Mercury, there's no life on Mercury. Why don't you put your energy harvesting there? Because you can't mess with the biosphere. The biosphere is more powerful than you are. And so there's limits to how much energy we can harvest to do work on the earth without really adversely affecting the biosphere.

Lex Fridman
It does seem that the best response to the climate change is not to use less technology, but to invent better technology and to invent technology that avoids the destructive effects.

Adam Frank
This is the frontier where you are, and that was the topic of my last book, Light of the Stars. It's like you have to do the astrobiology of the Anthropocene. You have to see the transition that we're going through now of the Anthropocene on a planetary astrobiological framework. And that paper we were talking about with a 10 billion trillion worlds, that was actually in service of the work I was doing for this other book where I wanted to know how often do you go through an… Does every technological civilization trigger its own planetary crisis, its own climate Anthropocene crisis? And the answer we actually came up from doing models was like, yeah, probably. And then the question is, are you smart enough to figure out how to readjust what you're doing technologically so that all boats rise? You want to figure out how to do this so that the biosphere becomes even more productive and healthy and resilient. So yeah, right. It's the kind of technology. I think there's probably absolutely limits on how much energy you can use, but how do you use that energy? And then also, getting off planet eventually. If you want to use 10 times more energy than that, you're going to not going to do it on world.

Lex Fridman
So how do we detect alien type one, two, and three civilizations? So we've been kind of talking about basically type one civilization detection.

Adam Frank
Yeah. Right,

Lex Fridman
Maybe with the Dyson sphere, you start to get a little bit more type two, but it feels like if you have a type two civilization, it won't be just the Dyson sphere.

Adam Frank
Right.

Lex Fridman
It feels like that. Just for the same reason you mentioned climate change, but now at the star system level, they're probably expanding, right? So how would you detect a type two?

Adam Frank
How about propulsion plumes? Right? If you're expanding... No, no.

Lex Fridman
Yeah, that's great. That's great.

Adam Frank
I literally just put in a NASA proposal now. Thomas Beatty, who's joined us, he's at the University of Wisconsin, has an idea to look for plumes. Right? If you have a solar system-wide civilization and you got space truckers going back and forth from Mars to... They're doing the insettlest run, they're accelerating and decelerating the whole way there. If you want to get to Mars in a couple of weeks, you have your fusion drive on the entire way out there. You flip and burn and have it on. So you also always have gravity. You have thrust gravity. So would those plumes be detectable? Because now you've got spaceships going all over the place and the odds that the plume is going to cross your field of view could become pretty high. So yeah, I think that's one idea of looking for large-scale interplanetary, which is like when you're getting to a type two. Another possibility is looking for the tailings of asteroid mining. This was an idea, it was a group at Harvard Smithsonian, that to be able to look for... If you're really chewing up asteroids to build space habitats, there'd be dust particles left around and would they look different from just say the dust from just regular collisions?

Lex Fridman
So pollution of all different kinds.

Adam Frank
Pollution of all different kinds

Lex Fridman
And trash also?

Adam Frank
Okay, so trash is an interesting idea when you come to the actual solar system. There's a whole other field of technosignatures, which are things in the solar system. What if somebody came by 1,000,000 years ago and left some stuff? So the earth has been showing

biosignatures for billions of years. A species like us, at our level, looking at earth, would've been able to know that earth had life on it, had a biosphere for billions of years. So maybe somebody sent something by a half a billion years ago. So this idea of looking say at the Moon for artifacts that have been there for a long time is something that a number of people are doing. We're just working on a paper where we just calculated, this was super fun. We calculated how long would the lunar lander exist on the Moon before micrometeorites just chewed it down? How long would you be able to land on the Moon and go, "Oh, look, somebody was here and left some debris." So there's this process called gardening, which is just the micrometeorite, constant rain of micrometeorites, and that's where you get the lunar regolith. That fine powder on the Moon is because of this gardening. And it turns out it is literally hundreds of millions to billions of years-

Lex Fridman
Oh, nice.

Adam Frank
That the lunar lander will be visible.

Lex Fridman
Oh, so we should be able to find artifacts.

Adam Frank
If there are artifacts on there, and people have proposed doing this with artificial intelligence. The Moon has been mapped down to a couple of meters with various probes and all that data is sitting there. So why not use machine learning to look through all those things and look for anything that looks not like the lunar surface? And they did a test program where they gave the computer, I don't know, 50 miles around the Apollo 11 or maybe it was Apollo 17 site, and it instantly was able to pull out the lander.

Lex Fridman
The whole task of looking for anomaly, something that looks not like the lunar surface. You make it sound obvious, but it's not exactly obvious. Detect something that doesn't look right about this room?

Adam Frank
Yeah.

Lex Fridman
It's actually really difficult.

Adam Frank
Really difficult. It's really difficult. And what's cool, it's a really information theoretic kind of proposal. You really have to use information theory to say, "What's the background?" How do I define something that I can say, "That looks weird?"

Lex Fridman
Yeah, maybe when you're looking at a spectrograph or something, it's still like… [inaudible 01:45:00] or something, it's going to look really weird potentially. We're hypothesizing all the things that humans would build and how do we detect that.

Adam Frank
Right.

Lex Fridman
But that could be really weird stuff.

Adam Frank
That's why there's this emphasis now on these agnostic signatures. So, actually disequilibrium is a nice one. One way to define life is it is a system that is far from equilibrium, it's alive, because as soon as it dies, it goes back to equilibrium. And so, you can look at all chemicals in an atmosphere, even if you don't know whether these could be chemicals that you have no idea whether or not they have anything to do with life. But the degree of disequilibrium, the degree to which they show that that atmosphere has not, the chemicals have not all just gone down to, they've all reacted away to an equilibrium state. You can actually tell that in very general ways using what's called the Gibbs free energy, and that's a signature. If you see an atmosphere that is wildly out of equilibrium that indicates that there's something happening on that planet biosphere or technosphere that is pumping gases into the atmosphere, that is keeping the whole system from relaxing.

Lex Fridman
So, is it possible we can detect anomalies in spacetime?

Adam Frank
Well, you could detect, and there's been some work on this with the Alcubierre drive, these proposals for warp drives, and we can talk about that later, I'm skeptical of those. Because it may really be possible, you just can't go faster than the speed of light. But people have done work on what would be the signature of an Alcubierre drive? What would be the signature? Could you detect if you're using a drive like that, then you certainly are distorting spacetime, which means any light that's passing by, its trajectory has gotten altered because it had to pass through the distorted spacetime. So yeah, there are possibilities along with that. One of the funny things, I don't know if they've gotten past this, but somebody calculated the problem with the Alcubierre drive or this warp drive was that if

you dropped out of warp, there would be this spray of gamma rays that would sterilize any planet in front of you. So, it's like, "Well yeah, you probably don't want to do that," but that would be a great bios or techno signature, another planet obliterated.

Lex Fridman
So, you think it's not possible to travel fast than the speed of light?

Adam Frank
I wouldn't say that. I wouldn't say that, but what I think, if you look at the physics, we understand, every possibility for faster than light travel really relies on something that doesn't exist. So, the cool thing is Einstein's field equations, you can actually play with them, the equations are right there. You can add things to the right or left-hand side that allow you to get something like the Alcubierre drive. That was a metric that showed you like, "Oh, it's a warped bubble." It's a warping of spacetime that moves through spacetime faster than the speed of light. Because nothing can move across space faster than the speed of light, but spacetime itself can move faster than the speed of light. But here's the problem with all of those proposals is they all need something. The thing you added, the little fictional term you added into the equations is something called exotic matter and it doesn't exist. It's really just something we dreamed up to make the equation to do what we wanted them to do. So, it's a nice fiction but really right now, we live in this weird moment in history of the great acceleration where the technology we used now is completely different from the technology we used 10 years ago is remarkably different from the technology from 100 years ago. But I remember playing Assassin's Creed where everybody's like, "What is it, it's 1200?" And everybody's like, "Stab, stab, stab." And I was like, "Yeah, it's a great game." And then I got Assassin's Creed II and it was 300 years later and everybody's like, "Stab, stab, stab." And it was like 300 years and the technology hadn't changed and that was actually true for most of human history. You used your great-grandfather's tools because there was no need to have any other new tools and you probably did his job. So, we could be fooled into thinking like, "Oh, technology's going to go on forever, we're always going to find new advances." As opposed to sometimes things just flatten out for a long time. So, you have to be careful about that bias that we have living in this time of great acceleration.

Lex Fridman
Yeah. But also, it is a great acceleration and we also are not good at predicting what that entails if it does keep accelerating. So, for example, somebody like Eric Weinstein often talks about we underinvest in theoretical physics research. Basically, we're trying too hard for traditional chemical propulsion on rockets versus trying to hack physics, warp drives and so on.

Adam Frank
Yeah.

Lex Fridman
Because it's really hard to do space travel, and it seems like in the long arc of human history, if we survive the way to really travel across long distances is going to be some new totally new thing.

Adam Frank
Right.

Lex Fridman
So, it's not going to be an engineering problem, it's going to be a physics problem-

Adam Frank
A fundamental physics problem.

Lex Fridman
Fundamental physics problem.

Adam Frank
Yeah. I agree with that in principle, but I think there's a lot of ideas out there. String theory, people have been playing with string theory now for 40 years, it's not like there hasn't been a lot of effort. And again, I'm not going to predict, I think it's entirely possible that there's incredible boundaries of physics that have yet to be poked through, in which case then all bets are off. Once you get fast interstellar travel, whoa, who knows what can happen? But I tend to be drawn to science fiction stories that take the speed of light seriously. What kind of civilization can you build where it takes 50 years to get to where you're going and a 50 years back? So, I don't know. Yeah, there's no way I'm going to say that we won't get warp drives. But as of right now, it's all fictional. It's barely even a coherent concept.

Lex Fridman
Well, it's also a really exciting possibility of hacking this whole thing by extending human lifespan or extending our notion of time and maybe as dark as to say, but the value of an individual human life versus the value of life from the perspective of generations.

Adam Frank
Yeah.

Lex Fridman
So, you can have something like a generational ship that travels for hundreds of thousands of years and you're not sad that you'll never see the destination because you have the value for the prolonged survival of humanity versus your own individual life.

Adam Frank
Yeah. It's a wild ethical question, isn't it? That book I told you about Aurora, I love the book because it was such a inversion of the usual. Because I love science fiction, I've read so many generation ship stories. And they get to that planet, the planet turns out to be uninhabitable. It's inhabited, but it's uninhabitable for Earth because again, he has this idea of life is particular to their planets. So, they turn around and they come back, and then when they land, the main character goes, there's still people who are arguing for more generation ships, and she goes, and she punches the guy out because she spent her whole life in a tube with this. I thought that was a really interesting inversion. The interesting thing about, we were talking about these space habitats.

Lex Fridman
Yes.

Adam Frank
But if you really had a space habitat, not some super cramped, crappy, usual version of a century ship. But if you had these space habitats that were really like the O'Neill cylinders, they're actually pretty nice places to live, put a thruster on those. Why keep them in the solar system? Maybe space is full of these traveling space habitats that are in some sense, they're worlds in and of themselves.

Lex Fridman
There's the show Silo, which raises the question of basically, if you are putting on a generational ship, what do you tell the inhabitants of that ship? You might want to lie to them.

Adam Frank
Yeah.

Lex Fridman
You might want to tell them a story that they believe.

Adam Frank
Right.

Lex Fridman
Because there is a society, there's human nature. It's like how do you maintain a homeostasis of that little society? That's a fascinating technical question, the social question, the psychology question

Adam Frank
The generation ship too, which I talked about in the book, the idea of also you talked about the extending human lifetimes or the stasis, the cryostasis, which is a mainstay of science fiction that you can basically put in suspended animation and such. None of these things we know are possible. But what's so interesting, and this is why I love science fiction, the way it seeds ideas, all these ideas we're going to talk about because they've been staples of science fiction for 50 years.

Lex Fridman
The whole field of cryogenics.

Adam Frank
Yeah. Where are we at with that?

Lex Fridman
Yeah. I wonder what the state of the art is for complex organism. Can you freeze? How long can you freeze? And then unfreeze maybe with bacteria you could do freeze.

Adam Frank
Oh, bacteria can last. This is the thing about panspermia, how long can a bacteria survive in a rock that's been blasted? If there's a comet impact across interstellar distances, that does seem to actually be possible. People have done those kinds of calculations, it's not out of the realm of possibility. But a complex organism or multi-systems, with organs and such.

Lex Fridman
Also, what makes an organism? Which part do you want to preserve? Because maybe for humans, it seems like what makes a personality? It feels like you want to preserve a set of memories. If I woke up in a different body with the same memories, I pretty much, I would feel like I would be the same person.

Adam Frank
Altered Carbon, that's a great series. I think it's on Netflix, that's a really great series where that's exactly the idea of sleeves. Everybody's able to, you can re-sleeve in another body, and it raises exactly this question. It's not the greatest cyberpunk, but it's pretty good, it's got some great action sequences too.

Lex Fridman
As we get better and better advancements in large language models that are able to be fine-tuned on you, it raises a question because to me, they've already passed the Turing test as we traditionally have defined it. So, if there's going to be an LLM that's able to copy you in terms of language extremely well, it's going to raise ethical and I don't know, philosophical questions about what makes you, you. If there's a thing that can talk exactly

like you, what is the thing that makes you? It's going to speak about your memories very effectively.

Adam Frank
This leads us to, if we're going to get to the blind spot. I am of the opinion, heretical in some camps that the brain is not the minimal structure for consciousness, it's the whole body. It's embodied and may actually, in some sense, it's communities actually. So yeah, I could be wrong, but this is what this whole work that I did with Marcelo Gleiser and Evan Thompson, the philosophy of science. Which is interesting, because it leads to this question about, "Oh, maybe we should just download ourselves into computers." That's another story that one tells. I'm super skeptical about those, but that's one of the narratives about interstellar travel. And that anybody we meet is going to be a machine anyway, whether it's downloaded bodies or it's just going to be artificial intelligence. There's the whole idea of how long does biological evolution last? Maybe it's a very short period before everybody goes to, or the machines take over and kill you, or it's some hybrid. look like

Lex Fridman
What do you think aliens look like? So, we talked about all the different kinds of bio signatures that might leave or techno signatures, but what would they look like when we show up? Are they going to have arms and legs? Are they going to be recognizable at all? Are they going to be carbon-based?

Adam Frank
Yeah. So, great question, and this question gets to the heart of thinking about life, about what life is. And this is the physical part of that, there's also the informational part of it. But let's just talk about the physical part of it, which is anything that we're going to call life is probably going to work on Darwinian evolution. That's the nice thing about Darwinian evolution, just like we know the laws of physics are general, the laws of Darwinian evolution are this logic, this basic logic that anything we'd reasonably call life probably has to operate under these kinds of principles. And so, evolution's about solving problems to survive that the environment presents. And the environment's always going to present these problems in physical and chemical terms, so that you'd expect a balance between what we call convergence, evolutionary convergence and evolutionary contingency. So, if you've got to move along a surface, a hard surface and air, then the idea of some kind of jointed stick legs makes sense that you're probably going to trigger that. If you look at Earth's history multiple times, multiple lineages that had nothing to do with each other are going to solve the problem of getting towards energy sources using some kind of stick-like apparatus.

Lex Fridman
So, that's about movement?

Adam Frank
Yeah. So, that's one problem that has to be solved. The one problem that has to be solved is I got to get to food, right?

Lex Fridman
Yeah.

Adam Frank
Another problem is they got to get away from predators. You've seen wings, we've seen wings, the line that went through dinosaurs to birds involved wings, insects evolved wings, mammals evolved wings. If the gas is dense enough that a curved surface, if you move through the curved surface, it's going to produce lift. Yeah, there you go, evolutionary trip on that. So, I think you can expect certain classes of solutions to the basic problems that life is going to be presented with stay alive, reproduce. But one of the weird things about with the UFO things is that you always see like, "Oh, they all look like humans, they're just basically humans with triangular heads." And that's where we get to contingency. So, what we've been talking about is convergence. You expect that evolution will converge on wings multiple times when presented with the problems that wings can solve. But contingency is accidents that you've got something that's evolving a certain kind of wing, a leathery wing. And then the climate changes and they all die out, end of story or an asteroid, total accident, asteroid hits. And so, contingency accidents play also a huge role in evolution. And one of the things that lots of evolutionary biologists have talked about is the idea that if you ran the tape of Earth's history over again, would you get the same creatures? Now, Stephen Jay Gould was of the opinion that no way, you wouldn't find anything on Earth that resembled any species today. They've done experiments actually on this with E. coli. You take a bunch of E. coli, you let them evolve for a while, you take a bunch of them out, freeze them, let one, let that population continue to evolve, the other one's frozen. Now, started over again with the frozen. And it seems to be that contingency tends to win. At least from what we can tell, that's not a hard result, but in those experiments, what you find is that accidents really do matter. And this is important, so yes, you should expect legs or jointed sticks, how many joints they're going to be? Anybody's guess. Do you expect humanoids, things with a sensing apparatus on top of a shoulder with two arms and two legs? That's probably a pretty random set of occurrences that led to that.

Lex Fridman
I guess what is a brain versus the nervous system? Where is most of the cognition competition going on?

Adam Frank
Yeah.

Lex Fridman
You could see that in organisms. Actually, I don't know how the brain evolved. Why does it have to be in one place?

Adam Frank
It doesn't have to be. So, my favorite word, word of the day is liquid brains. This idea of distributed cognition, which fascinating idea, and we've come to understand how much distributed cognition there is. Obviously, you social animals like termites, and ants, that's an example of distributed cognition, the organism is the whole colony. This is one thing that's been really interesting in the state of the study for aliens, is that when we've come to recognize that human intelligence, the kinds of things that go into intelligence are distributed all across the biosphere. Lots of different examples of things show various pieces of what we have. Jason Wright described it as a deck of cards. The cards are all there, we got the hand that actually led to the technological progress that we see. But the basic idea of using tools, the basic idea of recognizing each other eye to eye, all the things that we define as intelligence. You can find many places in many other places across many other lineages across the earth. So, they could be very, very different with something like, yeah, maybe the hive mind idea or bacterial colonies that actually managed to come to their own version of high cognition.

Lex Fridman
Well, I wonder if we stretch out time across 10s, 20 billion years, whether there's an Darwinian evolution stops working at some point in terms of the biology or the chemistry of the organisms, and it switches to ideas for example. It's much more rapidly you're operating maybe, I guess it's a kind of Darwinian evolution on the space of memes or whatever, as [inaudible 02:02:36]-

Adam Frank
Technology seems to operate, but certainly markets can operate in ways that look very Darwinian.

Lex Fridman
So, basically a planet is working hard to get to the first kind of organism that's able to be a nice platform for ideas to compete.

Adam Frank
Yeah.

Lex Fridman
And then it stops evolving there, and then these ideas that take off.

Adam Frank
Right. Because yeah, cultural Lex it's true. It's amazing that cultural evolution totally disconnects from the Darwinian process. But I'd be careful to say that a planet is working hard to do this. Because really looking at us, what we think of as ideas and culture, and it's quite possible we're going to make it another 200 years, and this is gone because it actually wasn't a very good idea long-term, we just don't know.

Lex Fridman
So, maybe the idea generation organism is actually the thing that destroys.

Adam Frank
Not the biosphere, because again, but it destroys itself. It may not be very long- term, it may be very potent for a short period of time but that it's not sustainable. It doesn't become, like we were talking about before, mature. It's very hard to make it into integrated into a mature bio/technosphere. And of course, evolution that is not working for anything. Well, here's the actually interesting thing, so people are very much evolutionary biologists will get their hair will stand on end if you start talking about evolution, having a purpose or anything. But the very interesting thing about purpose is that once you do get to a idea generating species or collective organism, yeah, then all bets are off and there is goals, there is teleology. Now suddenly, absolutely, there's a direction implied. So that's a cool interesting thing that once you get to that, evolution stops being goalless and directionless and suddenly, yeah, we're the ones who supply or any kind of creature like us has an absolute direction that way they decide on.

Lex Fridman
Although you could argue that from a perspective of the entire human civilization, we're also directionless. We have a sense that there's a direction in this cluster of humans.

Adam Frank
Yeah.

Lex Fridman
And then there's another cluster has a different sense of direction, there's all kinds of religions that are competing. There's different ideologies that are competing.

Adam Frank
Yeah.

Lex Fridman
And when you just zoom out across, if we survive across thousands of years, it will seem directionless. It will seem like a pinball.

Adam Frank
It's an unholy mess. But at some point, the expansion into the solar system say, that would be both direction. Depending on how you look at it, it was directional. There was a decision that the collective of human beings made to like anti-accrete, to start spreading out into the solar system. So, that was definitely a goal there that may have been reached in some crazy nonlinear way, but it still a goal was set and it was achieved.

Lex Fridman
If there's advanced civilizations out there, what do you think is the proper protocol for interacting with them? Do you think they would be peaceful? Do you think they would be warlike? What do we do next? We detect the civilizations through all the technosignatures we've been talking about, maybe direct imaging, maybe there's really strong signal. We come up with a strategy of how to actually get there.

Adam Frank
Yeah.

Lex Fridman
But then the general says, they always do, the military industrial complex-

Adam Frank
We've watched that movie.

Lex Fridman
What kind of rockets and do we bring rockets?

Adam Frank
Right. Well, this general question also leads to many messaging, extraterrestrial intelligence, and I'm definitely of the opinion of you should be very careful. I don't think it's necessarily a bad idea to have your head below the grass. The people who advocate like, "Oh yeah, we should be sending powerful messages that are easily detectable into interstellar space." I'm like, "Why would you?" Because we just don't know, I'm not going to say they are warlike. I'm not going to say they're not warlike, I have no idea. But we sure as hell, well, first of all, who gets to decide that? The idea that a bunch of astronomers who happen to have a radio telescope, Who Speaks for Earth, which I think was a great book somebody wrote. So, definitely we should be cautious, I would say, because we just have zero information. And the idea, you used to have this idea of, well, if they're advanced, they've managed to survive. So of course, they're going to be wearing togas and be singing kumbaya, but I just wouldn't assume that. It's also possible though that their cognitive structure is so different that we're not even living in the same universe in a certain way. I think we have to be prepared for that. We may not even be able to recognize each other in some way as cognizing beings. One of my favorite movies is Arrival, I don't know if you've ever seen that one. I really love that one

because they literally, they have a different language. They have a different cognitive structure in terms of their language, and they're literally living in a different physics.

Lex Fridman
Different physics, different language, different everything. But in the case of Arrival, it can at least recognize that they're there.

Adam Frank
And they managed to cross the language barrier. Yeah.

Lex Fridman
But that's, both sides have an interest in communicating, which you suppose that an advanced civilization would have a curiosity. Because how do you become advanced without curiosity about the mysteries about the other.

Adam Frank
But also, if they're long-lived, they may just be like, "We're not even interested. Say 10 million years ago, we were really interested in this, in communicating with you youngins, but now we're not at all." And that's just one of the beauties of this again, is how to think about this systematically because you're so far past the hairy edge of our experience of what we know that you want to think about it. You don't want to be like, "Don't know, can't say anything," because that's not fun. But you also have to systematically go after your own biases. So, one of the things I loved about Arrival too was Carl Sagan always had this idea, "We'll teach them math, we'll teach them our math, then they'll teach us their math, and then we'll be telling each other, knock-knock jokes and swapping cures for cancer." And in the movie, they send a Carl Sagan guy in and a linguist, and the Carl Sagan guy fails immediately. And it's the linguist who understands that language is actually embodied. Language is not just something that happens in your head, it's actually the whole experience and she's the one who breaks through. And it just points to the idea that how utterly different the cognitive structures of a different species should be. So somehow, we have to figure out how to think about it, but be so careful of our biases or figure out a systematic way to break through our biases and not just make science fiction movies. You know what I mean?

Lex Fridman
Yeah. Speaking of biases, do you think aliens have visited Earth? You've mentioned that they could have visited and started civilizations and we wouldn't even know about it if it was 100 million years ago. How can we even begin to answer this question, whether-

Adam Frank
Got to look, got to figure out ways to look. So, it's not high on my list of things that I think are probable, but it certainly, it needs to be explored. And unless you look, you never know. So, looking on the moon, where would we find if aliens had passed through the solar system

anytime in the last 3 billion years, where might we find artifacts? Where might artifacts still be around? Earth? Probably not because of weathering and resurfacing. The moon's a good place. Certain kinds of orbits, maybe they parked a probe in an orbit that was stable. So, you got to figure out which orbits actually you could put something there and it'll last for a billion years. So, those are the kind of questions. Like I said, it's not high on my list of thinking this could happen, but it could happen. Unless you look, you don't know.

Lex Fridman
Speaking of biases, what about if aliens visiting Earth is the elephant in the room? Meaning the potential of aliens, say seeding life on earth?

Adam Frank
You mean in that directed panspermia, [inaudible 02:10:33]-

Lex Fridman
Directed panspermia.

Adam Frank
Yeah.

Lex Fridman
Or seeding some aspect of the evolution.

Adam Frank
Like 2001.

Lex Fridman
Yeah.

Adam Frank
Yeah. It's a great story, but always with Occam's razor or whatever with science. If I can answer that question without that extra very detailed hypothesis, then I should. And the idea that evolution is a natural process, that's what I would go for first. That just seems it's so much easier to do it that way than adding, because it's kind of a duo sex machina thing of like, "Oh, then the aliens came down and they solved that problem that you're trying to solve by just coming down and putting their finger on the scales."

Lex Fridman
So, to you, the origin of life is a pretty simple thing that doesn't require an alien?

Adam Frank
I wouldn't say that, it's not a simple thing. Because all you're doing is kicking the can down the road. The aliens formed, right? So, you're just saying like, " All right, I'm just kicking the can down the road to the aliens. What was their abiogenesis event?

Lex Fridman
Well, so from a different perspective, I'm just saying, it seems to me that there's obviously advanced civilizations everywhere throughout the galaxy and through the universe from the Drake equation perspective. And then if I was an alien, what would I do? I've gotten a chance to learn about the uncontacted tribes in the Amazon. I recently went to the Amazon, and you get to understand how they function and how the humans in the Amazon, they're in contact with the civilized world, how they interact with the uncontacted tribes. First of all, the uncontacted tribes are very violent towards the outside world, but everybody else tried to stay away from them. They try to protect them, don't talk about them, don't talk about their location and all this kind of stuff. And I've begun to internalize and understand that perspective of why you're doing that. And if I was an alien civilization, I probably would be doing a similar kind of thing. And of course, there's always the teenager or the troll who's going to start messing with this stuff or the scientists.

Adam Frank
Yeah, right.

Lex Fridman
And so, from our perspective, yes. And if you're in the Truman Show like Occam's razor, but also the Occam's razor from the perspective of the alien civilization, we have to have the humility to understand that that interaction will be extremely difficult to detect, that it would not be obvious.

Adam Frank
Right. I understand the logic of what you're saying, but the problem for me with that is that first you have to assume that alien civilizations are common, which I'm not sure about it, that most of them may be dead or they're not. While I think that life is common, and again, this is just my biases. So now, the problem is how do we sort out the biases we're bringing or the assumptions we're bringing in from the causal chain that comes out of that? I would first want to try and do this without, if we're looking at the origin of life or the evolution of life on Earth. I'd want to do it just on its own without asking for this other layer because it requires a bunch of these other assumptions which also have their own breaking of causal chains. Because the idea that when you ask, what would you do if you were an alien? But again, alien minds could be so unbelievably different that they wouldn't even recognize the question you just posed.

Lex Fridman
Right.

Adam Frank
Because it's just like we have a very particular cognitive structure or cognitive, and we're very governed by, even if you went and talked to, this is an interesting thing to think about. If I could suddenly magically appear 100,000 years ago and talked to a hunter-gatherer about their worldview and their motivations, I might find something that, or no resemblance to things that I think are sort of, "Oh, that's what naturally humans do."

Lex Fridman
Well, let me ask you this question. Let's together do the thought experience.

Adam Frank
Yeah.

Lex Fridman
If we either create a time machine that allows us to travel back and to talk to them.

Adam Frank
Yeah.

Lex Fridman
Or we discover maybe a primitive alien civilization on a nearby star system, what would we do?

Adam Frank
Yeah. I think that's a great question. It's interesting how that even brings up the ethical questions. Let's say that we'd have to first sort out what are the consequences for them and what do we feel our ethical responsibilities are to them?

Lex Fridman
And also, sorry, from a capitalist perspective, what are we to gain from this interaction?

Adam Frank
Right. You look at the way the missionaries, missionaries had these interactions because they thought converting them to whatever religion they were was the most important, that's what the gain was. So, from our perspective, we'd have to sort that out. I think given if we're doing this thought experiment, we are curious, and I think eventually we'd want to reach out to them.

Lex Fridman
I think when you say we, let's start with the people in this room, right?

Adam Frank
Yeah.

Lex Fridman
I wonder who the dominant forces are in the world, because I think there's a lot of people, the military they'll probably move first so they can steal whatever advantage they can from this new discovery so they can hurt China or China hurt America. That's one perspective. Then there's the capitalist school will see how the benefits and the costs here, and how can I make money off of this? There's opportunity here, there's gold in them hills. And I wonder, and I think the scientist is just not going to, unlike the movies-

Adam Frank
We're not going to get much say.

Lex Fridman
They're going to put them-

Adam Frank
"Hey guys, wait a minute."

Lex Fridman
They would engage probably. Just as a human society as we are now, we would engage and we would be detectable, I think.

Adam Frank
In our engagement.

Lex Fridman
In our engagement.

Adam Frank
Yeah, probably.

Lex Fridman
So, using that trivial bias logic, it just feels like aliens would need to be engaging in a very obvious way. Just brings up that old direct for me paradox for me. What do you make of all the UFO sightings?

Adam Frank
I am all in favor of an open, agnostic, transparent, scientific investigation of UFOs and UAPs. But the idea that there's any data that we have that links UFOs and UAPs to non-human technology, I just think the standards, none of what is claimed to be the data lives up to the standards of evidence. So, let's just take a moment on that idea of standards of evidence, because I made a big deal about this both in the book and elsewhere whenever I talk about this. So, what people have to understand about science is we are really, our scientists, we are really mean to each other, we are brutal to each other. Because we have this thing that we call standards of evidence, and it's the idea of you have a piece of evidence that you want to link to a claim. And under what conditions can you say, "Oh, look, I've got evidence of this claim X, Y, and Z." And in science, we are so mean to each other about whether or not that piece of evidence lives up to the standards that we have. And we spent 400 years determining what those standards are, and that is why cell phones work. If you didn't have super rigorous standards about what you think that's, "Oh, this little antenna, I've invented a new kind of antenna that I can slip into the cell phone and I can show you that it works." If you didn't have these standards, every cell phone would be a brick. And when it comes to UFOs and UAPs, the evidence you have and the claim that though this shows that we are being visited by non-human, advanced civilization just doesn't even come close to the same standards. I'm going to have to obey or whatever live under. If my team, the group I work with is one of them says, "Look, we've discovered and he wants to announce that, oh, we've discovered a technosignature on an alien planet." We're going to get shredded as we expect to be, we expect to be beaten up. And the UAP, UFO community should expect the same thing. You don't get a pass because it's a really cool topic. So, that's where I am right now. I just don't think any of the evidence is even close to anything that could support that claim.

Lex Fridman
Well, I generally assign a lot of value to anecdotal evidence from pilots. Not scientific value, but just like it's always nice to get anecdotal evidence as a first step. Because I was like, "I wonder if there's something there." But unfortunately, with this topic, there's so much excitement around that there's a lot of people that are basically trying to make money off of it. There's hoaxes all this kind of stuff. So, even if there's some signal, there's just so much noise it's very difficult to operate with. So, how do we get better signal? So, you've talked about if we wanted to really search for UFOs on Earth and maybe detect things like weird physics, what kind of instruments would we be using?

Adam Frank
Yeah, so in the book, I talked about the idea that this is really stupid, but you want to look up, you want to look down and you want to look all around.

Lex Fridman
I think that's brilliant. It's simple, not stupid. It's like literally.

Adam Frank
Yeah, right. So, you want to do ground-based detectors, upward-looking, ground-based detectors of the kind we're already building for meteors, for tracking meteors. You want to have space-based detectors, put them on satellites, this is what the NASA UAP panel was thinking about. And then probably on, we have lots of people in the sky there should be detectors on the planes, or at least some kind of alert system that if a pilot says, "Oh, look, I'm seeing something I don't understand." Boop presses the red button, and that triggers the ground. I'm seeing something I don't understand. Boop. Presses the red button and that triggers the ground-based and space-based data collectors. And then the data collectors themselves, this is something that people really don't understand and it's so important. In order to actually do science with anything, the data you have, you have to understand where it came from down to the nth degree. You have to know how that camera behaves in a bunch of different wavelengths. You have to have characterized that. You have to know what the software does, what the limits of the software are possible. You have to know what happened to the camera. Was it refurbished recently? In every spectral wavelength in all of its data collection and processing, you have to know all of those steps and have them all characterized because especially if you want to claim like, "Oh my God, I saw something, take a right-hand turn at Mach-500." Right? You better have all of that nailed down before you make that kind of claim. So we have to have characterized detectors looking up, down, and maybe on planes themselves, we need a rational search strategy. So let's say you want to lay out these ground-based detectors. Where do you put them? Right? There's only so much money in the world, so do you want to put them near places where you've seen a lot of things beforehand or do you want to have them try and do sparse coverage of the entire country? And then you need the data analysts analysis, right? You're going to have so much data, so many false positives or false triggering that you need a way of sorting through enormous amounts of data and figuring out what you're going to throw out and what you're going to keep, and all of these things we're used to doing in other scientific enterprises. And without that, if we don't do that, we're going to be having the same damn argument about these things for the next 100 years.

Lex Fridman
But if I asked you, I give you $1 trillion and asked you to allocate to one place looking out, SETI or looking at Earth, should you allocate it?

Adam Frank
Oh God, looking out. Looking out. Because that's the, as I always like to say, here's my codification of this. If you said, "Hey, Adam, I'd like to find some Nebraskans." And I said, "Oh, good, let's go to the Himalayas." You'd be like, "Why am I going there?" I'm like, "Well, maybe there's some Himalayas, some Nebraskans in Himalayas." You'd say, "No, no. Let's go to Nebraska." If we're looking for aliens, why don't we look on alien planets where they live? We have that technology now as opposed to the bucket of assumptions that you have to come up with in order to say like, "Oh, they're here right now. They just happen to be here right

now." And also the very important thing, I called this the high beam argument to deal with the UFO stuff, you have to answer these weird, irrational things that are happening. Like, okay, there's an advanced civilization that is visiting Earth regularly. They don't want to be detected. They've got super powerful technology, but they really suck at using it because we keep seeing them, we keep seeing them, but then they disappear. I mean, explain to me what rational world that works under. So there's that whole sort of argument. You've got to explain why if they want to stay hidden, are they so bad at it? So that's why I take that level of difficulty and then I put it on top of where should I look? I should look at where they're from. That makes me want to look at do the telescopic stuff.

Lex Fridman
Yeah, I think the more likely explanation is either the sensors are not working correctly or it's secret military technology being tested.

Adam Frank
Absolutely. I mean, listen, that's why again, I think UAP, absolutely UAP should be studied scientifically, but if I had to make a bet and it's just a bet, I would say this is pure state adversary stuff. When I did, I did a New York Times op-ed for this in 2021, which blew up, and so I had a lot of people talking to me. While I was doing that. I sort of looked at the signals intelligence people, the SIGINT and EINT, electronic intelligence communities, and what they were saying about the New York Times articles and the various videos, and really none of them were talking about UFOs. They were all talking about pure state. That's why I learned the word pure state adversaries, how even simple drone technologies and you purposely want to do this. You want to fake signals into the electronics of their adversary, so they crank it up so then you can just soak up all the electromagnetic radiation and know exactly what those advanced radars can do.

Lex Fridman
That said, I'm not saying that's what this is. If I was the head of an alien civilization and I chose not to minimize the amount of contact I'm doing, I would try to figure out what would these humans, what would these aliens like to see? That's why the big heads in the humanoid form, I mean, that's kind of how I would approach communication. If I was much more intelligent, I would observe them enough. It's like, all right, if I wanted to communicate with an ant colony, I would observe it long enough to see what are the basic elements of communication. And maybe I would do a trivial thing, do a fake ant in there.

Adam Frank
Right. A robot ant.

Lex Fridman
A robot ant, but then it's not enough to just do a robot ant. You have to do a robot ant that moves in the way they do, and maybe aliens are just shitty at doing the robot ants. But no, I just wanted to make the case for that,

Adam Frank
This is the plot actually of a great science fiction book called Eon by Greg Baer, and the idea was these sort of, this is actually where my first, I became sort of more than agnostic, anti-medy, because the idea is that yes, our aliens come, they sort of make their arrival and really their point is to get rid of us. It's the dark forest hypothesis. And what they do is they literally, the way they present themselves is in this sort of classic UFO thing, and they do it and they arrive at, this was during the Soviet Union. They arrive at the USSR, they arrive in China, and they're kind of faking us out so that we never can organize ourselves against... So it was really, they did exactly what you're talking about, but for nefarious purposes.

Lex Fridman
Okay, let me ask the pothead question. Yet another pothead-

Adam Frank
Another pothead. The whole conversation-

Lex Fridman
I'm sorry.

Adam Frank
Boggs before breakfast.

Lex Fridman
It's signs and pothead questions back and forth. Okay, what if aliens take a form that's unlike what we kind of traditionally envision in analyzing physical objects? What if they take the form of say ideas? What if real pothead, if it's consciousness itself, like the subjective experience as an alien being, maybe ideas and is an easier one to visualize? Because we can think of ideas as entities traveling from human to human.

Adam Frank
I made the claim that the most important, that finding life any kind of life would be the most important discovery in human history. And one of the reasons is, again, as I said, that life, if we're not an accident and there's other life, then there's probably lots of other life. And because the most significant thing about life is it can innovate, right? If I give you a star and tell you the mass and the composition, you can basically pretty much use the laws of physics, tell exactly what's going to happen to that star over its entire lifetime. Maybe not the little tiny details, but overall it's going to be a white dwarf, if it's going to be a black hole

end of story. If I gave you a single cell and said, "What's going to happen in a few billion years?" You'd never be able to predict a giant rabbit that can punch you in the face, right?

Lex Fridman
Yeah.

Adam Frank
A kangaroo. So life has this possibility of innovating, of being creative. So what it means is, and that's kind of a fundamental definition of what it means to be alive. It goes past itself. So give life enough time and what are the end result? That's why I love science fiction so much. At some point, does life reach a point where it climbs into the laws of physics itself. It becomes the laws of physics or these sort of lie at the extreme limits of thinking about what we mean by reality, what we mean by experience. But I'm not sure there was much we can do with them scientifically, but they're open-ended question about the open-ended nature of what it means to be alive and what life can do.

Lex Fridman
Since you said it's the biggest question, which is an interesting thought experiment, what is the biggest scientific question we can possibly answer? Some people might say about what happened before the Big Bang, some big physics questions about the universe. I could see the argument for how many alien civilizations or if there's other life out there? You want to speak to that a little bit? Why is it the biggest question in… Why is it number one in your top five?

Adam Frank
I've evolved in this, right? I started off as a theoretical physicist. I went into computational astrophysics, magnetohydrodynamics of star formation, but I always was a philosophy minor. I always had these sort of bigger questions sort of floating around the back of my mind. And what I've come to now is the most important question for physics is, what is life? What the hell is the difference between a rock and a cell, fundamentally? And what I really mean by this, this is where I'm going to go non-traditional, is that really the fundamental question that is agency. What does it mean to be an autonomous agent? How the hell does that happen? I'm not a reductionist. I'm not somebody who's just like, well, you just put together enough chemicals and bing, bang, boom, and it suddenly appears there's something that really is going to demand a reconception of what nature itself is. And so yeah, black holes are super cool. Cosmology is super cool. But really this question of what is life? Especially, from by viewing it from the inside, because it's really about the verb to be. Really what is the most impressing philosophical question beyond science? Is the verb to be, what is being? This is what Stephen Hawking said when he talked about, "What puts the fire in the equations? The fire." The fire is this presence and this is where it touches things like whatever you want to say it, the sacred, spirituality, whatever you want to talk about. My first book was about science and human spirituality. So this question of life, what makes life

as a physical system so different is to me much more because that is where being appears. Being doesn't appear out there. The only place that ever appears to any of us is us. I can do this kind of projection into this third person thing, but nobody ever has that, that God's eye view. That's a story we tell. This is where, this between us is where the verb to be, appears.

Lex Fridman
So this is something that you write about in The Blind Spot, why science cannot ignore human experience, sort of trying to pull the fire into the process of science. And it's a kind of critique of materialism. Can you explain the main thesis of this book?

Adam Frank
Yeah. So the idea of The Blind Spot is that there is this thing that is central to science. So we're using the blind spot as a metaphor. So the eye has an optic nerve, and the optic nerve is what allows vision to happen. So you can't have vision without the optic nerve, but actually you're blind to the optic nerve. There's a little hole in your vision where the optic nerve is. And what we're saying is that science has something like this. There's something that without which science would not be possible, but that science, the way it's been configured, and actually, when we mean the blind spot, I'll get into exactly what I mean what it is, but it's not really science. It is a set of ideas that got glued onto science. It's a metaphysics that got glued on science. And so what is that thing? What is the blind spot? It's experience. It is presence. And if I experience, people have to be very careful. I'm not talking about being an observer. There's lots of words for it. There's direct experience. There is presence. Being. The life world. Within the philosophy called phenomenology. There's the life world. It's this sort of raw presence that you can't get away from until you die. And then who the hell knows that as long as you're around, it's there. And what we're saying is that, that is the way to say this, that is the precondition for the possibility of science and the whole nature of science, the way it has evolved is that it purposely pushed that out. It pushed that out. So it could make progress, and that's fine for a certain class of problems. But when we try to answer, when we try and go deeper, there's a whole other class of problems. The nature of consciousness, the nature of time, quantum mechanics, that comes back to bite us. And that if we don't learn how to take, understand that, that is always the background, that experience is always the background. Then we just end up with these paradoxes and that require this intellectual yoga to get out of.

Lex Fridman
I think you give a bunch of examples of that. Looking at temperature as a number is a very objective, scientific way of looking at that. And then there's the experience of the temperature.

Adam Frank
And how you build the parable of temperature that we call it. So what is the blind spot? We use the term it's a constellation. It's not just materialism. It's a constellation of ideas that are

all really sort of philosophical views. They're not what science says, but because of the evolution of the history of science and culture got like pin the tail on the donkey, they were sort of pinned on and to tell us that this is what science says. So what is it? One is reductionism that you are nothing but your nerve cells, which are nothing but the chemistry, which is nothing but all the way down to quarks. That's it. So that's reductionism. The objective frame that science gives us this god's eye view, this third-person view of the world to view the world from the outside. That's what science bequeaths to us, that view. Physicalism, that everything in the world is basically made of stuff. There's nothing else to talk about that, that's all there is. And everything can be reduced to that. And then also the reification of mathematics, that mathematics is somehow more real than this. And there's a bunch of other things. But all these together, what they all do is they end up pushing experience out and saying experience is an epiphenomena. Consciousness. I tend not to use the word consciousness. I think it leads us in the wrong direction. We should focus on experience because it is a verb kind of in a way. It is verb-like and by being blind to that, we end up with these paradoxes and problems that really not only block science, but also have been detrimental to society as a whole, especially where we're at right now.

Lex Fridman
So you actually say that, that from a perspective of detrimental society, that there's a crisis of meaning, and then we respond to that in a way that's counterproductive to these bigger questions, scientific questions. So the three ways responses you mentioned is scientific triumphalism, and then on the other side is rejecting science completely, both on the left and the right. I think the postmodernist on the left and the anti-establishment people on the right, and then just pseudoscience that kind of does this in-between thing. Can you just speak to those responses and to the crisis of meaning?

Adam Frank
Right, right. So the crisis of meaning is that on the one hand, science wants to tell us that we're insignificant. We're not important. We're just biological machines. And so we're basically an insignificant part of the universe. On the other hand, we also find ourselves being completely significant. In cosmology, we have to figure out how to look from the inside. At cosmology, we're always the observers. We're at the center of this collapsing wavefront of light. Quantum mechanics, it really comes in, it comes the measurement problem just puts us front and center. And we've spent 100… Some people spent 100 years trying to ignore the measurement part of the measurement problem. So on the one hand, we're insignificant, and on the other hand, we're central. So which one is it? And so this all comes from not understanding actually the foundational role of experience, this inability, we can't do science without already being present in the world. We can't reduce what happens in science to some sort of formal… A lot of it is about we love our formal systems, our mathematics, and we're substituting. That's one of the things that, there's two philosophers we really like for our heroes. One is Husserl, who is a mathematician, who invented phenomenology. And the other is Whitehead, who's one of the greatest

mathematicians of the 20th century. And Husserl came up with this idea of the surreptitious substitution. Part of The Blind Spot is substituting a formal system, a calculus of data for actual experience that that's more important. And so let me just do, before I go to those three responses, let's just do the parable of temperature because I think people can... It'll help them understand what we mean. So think about degree Celsius. We have in the modern scientific culture we live in, we think like, oh yeah, degree Celsius. They're out there. The universe, the molecular cloud in space is 10 degrees Kelvin. The way we got there is we've forgotten how that idea is rooted in experience. We started off with science by, we had the subjective experience of hot and cold. I feel hot, I feel cold, you feel hot, you feel cold. Science was this process of trying to extract from those experiences what Michel Bitbol philosopher calls, "The structural invariance." The things that we could both kind of agree on. So we figured out like, oh, we could make a gradiated little cylinder that's got mercury in it and that hot things will be higher in on that gradiated cylinder, cold things will be lower, and we can both kind of figure out what we're going to agree on are our standards for that. And then we have thermometry, yay. We have a way of having a structural invariant of this sort of very personal experience of hot or cold. And then from that, we can come up with thermodynamics, etc. And then we end up at the bottom of that with this idea of everyday I wake up and I check my phone and I'm like, oh, it's going to be 60 degrees out. Great. And we start thinking that 60 degrees is more real than hot and cold. That thermodynamics, the whole formal structure of thermodynamics is more real than the basic experience of hot and cold that it came from. It required that bodily experience that also, not just me, I have to tell you, it's part of my communication with you, cold today, isn't it? That from that basic irreducible experience of being in the world with everything that it involves, I developed degree Celsius, but then I forgot about it. I forgot the experience. So that's called the amnesia of experience. So that's what we mean by how the blind spot emerges, how we end up, how science purposely pushes experience out of the way so it can make progress, but then it forgets that experience was important. So where does this show up? Why is this? What are the responses to trying to get this back in and where this crisis of meaning emerge? So scientific triumphalism is the idea that the only thing that's true for us are scientific truths. Unless it can be codified in a formal system and represented as data, captured in some kind of scientific causal network, it doesn't even exist. And anything else that's not part of it that can be formalized in that way is an epiphenomenon. It's not real. So scientific triumphalism is this response to the weirdness of, I could call it the mystery, the weirdness of experience by just ignoring it completely. So there's no other truth. Art, music, human spirituality, it's all actually reducible it neural correlates. So that's one way that it's been dealt with. The other way is this sort of, right, you've got on the postmodern, the left academic left, you get this thing, science is just a game. It's just a game from the powerful come up with, which is also not true. Science is totally potent and requires an account for what is happening. So that's another way to push science away or respond to it. The denial, science denial that happens. That's also another way of not understanding the balance that science is trying, that we need to establish with experience. And then there's just pseudoscience, which wants to sort of say, oh, the new age movement or whatever, which wants to deal with experience by kind of elevating it in this weird pseudo spiritual way or that doesn't have the rigor of science. So all of these ways, all of these responses, we have this difficulty about experience. We need to understand how experience fits into the web of meaning, and we don't really have a good way of doing it yet. And the point of the book was to identify very clearly how the problem manifests, what the problem is, and what its effects are in the various sciences.

Lex Fridman
And by the way, we should mention that at least the first two responses, they kind of feed each other just to observe the scientific community, those who gravitate a little bit towards the scientific triumphalism, is an arrogance that builds in the human soul. I mean, it has to do with PhDs, it has to do with sitting on an academic throne, all those things. And the human nature with the egos and so on, it builds. And of course, that nobody likes arrogance. And so those that reject science, the arrogance is fuel for the people that reject science.

Adam Frank
I absolutely agree.

Lex Fridman
It just goes back and is this divide that builds.

Adam Frank
Yeah, no, and that was a problem when you saw, so like I said, my first book was about science and human spirituality. So I was trying to say that science is actually, if we look at what happens in human spirituality, not religion. Religion is about politics, but about for the entire history of the species, we've had this experience of, for lack of a better word, the sacredness. I'm not connecting this God or anything. I'm just saying this experience of the more, and then with the new atheist movement, you got people saying that, "Anybody who feels that is an idiot." They just can't handle the hardcore science. When in fact their views of the world are so denuded of, they can't even see the role that experience plays in how they came up with their formal systems. And experience fundamentally is weird, mysterious, it's, it kind of goes down forever in some sense. There is always more. So yeah, that arrogance then just if you're telling everybody who's not hardcore enough to do the standard model of cosmology, that they're idiots, that's not going to bode well for the advance of your project.

Lex Fridman
So you're proposing at least to consider the idea that experience is fundamental, experience is not just an illusion that emerges from the set of quirks, that there could be something about the conscious experience of the world that is at the core of reality?

Adam Frank
But I wouldn't do it. I wouldn't because there is panpsychism, right? Which wants to say-

Lex Fridman
Right. So that's all the way there. So panpsychism is, that's literally one of the laws of physics is consciousness.

Adam Frank
Right. But see what all those do is just the idea of say, physicalism versus idealism, which are kind of the two philosophical schools you can go with. Physicalism says, "All that exists as physical." Idealism says, "All that exists is mind." We're actually saying, "Look, both of these to take either of those positions is already to project out into that third-person view. And that third-person view we want to really emphasize is a fiction." It's a useful fiction when you're doing science. If I want to do the Newtonian physics of billiard balls on a pool table, great. I don't want to have to think about experience at all, right? But if I'm asking deeper questions, I can't ignore the fact that there really is no person view and that any story I tell about the world is coming from, it's not just first person, but it's literally because I'm going to argue that experience always involves all of us. Experience always originates out of a community. That you are always telling those stories from the perspective of already existing, of already being in experience. So whatever account we want to give of the world is going to have to take that as experience as being irreducible and the irreducible starting point. So ultimately, we don't have an answer. That's when people are like, "Well, what are you suggesting is the alternative?" It's like, look, that's the good work of the next science to come. Well, our job was to point out the problem with this, but what we would argue with is, and we're thinking about the next book, is this is really going to require a new conception of nature. That doesn't sort of jump to that third-person... That fictional third-person view and somehow figures out how to do science. Recognizing that it always starts from experience. It always starts from this field of experience. Or in phenomenology, the word is the life world that you're embedded in. You can't un-embed yourself from it. So how do you do... So one of the things that Whitehead said was, "We have to avoid the bifurcation of nature." And what he meant by that is the bifurcation into scientific concepts, wavelength. Think about seeing a sunset. You can say like, "Oh look, it's just wavelengths and scattering particles." And your experience of the redness, the actual experience of the redness and all the other things. It's not just red. There's no qualia, there's no pure redness. Everything that's happening in the experiential part is just an epiphenomena. It's just brain states, whatever. He said, "You can't do that. They're both real. They're both accounts. They both need to be integrated." And so that required, I think, really a different of what we mean by nature.

Lex Fridman
Is it something like incorporating in the physics, in the study of nature, the observer, the experiencing observer, or is that still also looking from a third-person?

Adam Frank
I think that that's what we have to figure out. And so actually a great place to think about this is quantum mechanics, because one of the things we're arguing is look.. In the chapter that I wrote on, because I wrote on, because I wrote this with Evan Thompson, who's a wonderful philosopher, and Marcelo Gleiser, who's a theoretical physicist. When I was writing the chapter on the origin of The Blind Spot, sort of how this emerged out of history, the subheader was like, "Well, it made sense at the time." Because it did. It really, there was a reason why people adopted this third person, God's eye deterministic view. This view of sort of like, yeah, the perfect clockwork of the universe. Yeah, totally made sense. But by the time you got to the beginning of the 20th century, science itself was telling you, "Eh-eh." And no place does this appear more than in quantum mechanics, right? Quantum mechanics slams you with the idea of the measurement problem. And most important thing about quantum mechanics is you have a dynamical equation, the Schrodinger equation, which you put in, like we talked about before, you have initial conditions and now you've got a differential equation and you crank out the differential equation and it makes predictions for the future, right? Exactly like Newtonian physics or its higher versions of the Lagrange or Hamiltonians. But then this other thing happens where it's like, oh, by the way, as soon as you look at it, as soon as the measurement is made, I have a whole nother set of rules for you. That's what we call the born rule. And it was telling you right from the beginning that measurement matters, right? So when you're asking, how will we do this? Quantum mechanics is actually pointing to how to do it. So there's been all these different interpretations of the quantum mechanics. Many of them try to pretend the measurement problem isn't there. Go to enormous lengths like the many-worlds interpretation, literally inventing an infinite number of unobservable parallel universes to avoid the thing that quantum mechanics is telling them, which is that measurements matter. And then you get something like QBism, which is I'm going to advocate for, is a new interpretation of quantum mechanics, which puts the Born rule at the center. Instead of focusing on the Schrodinger equation and the weird things that come out of it, like Schrodinger's cat and all that other stuff. It says, "No, no, actually the real mystery is the Born rule. Let's think about the Born rule." And like you said, that puts the agent, the agent and information at the center of the whole thing.

Lex Fridman
So that's not a thing you're trying to get rid of? That's the thing you're trying to integrate at the center of the thing in quantum mechanics, it becomes super obvious, but maybe the same kind of thing should be incorporated in every layer of study of nature.

Adam Frank
Absolutely. That's exactly it. So one of the things that's really interesting to me, so we have a project, I'm part of a big project that Chris Fuchs and Jacques Pienaar on QBism. So I've been part of that. And what I've been amazed by is the language they use. So what's cool about QBism is it comes from quantum information theory. It's a pretty modern version of

thinking about quantum mechanics. And it's always about do you have an agent who makes an action on the world? And then the information they get from that action through the experiment, that's the action on the world. Updates, their priors updates, their Bayesian, that's why it's called QBism. Quantum Bayesianism updates how the information they've gotten from the world. Now, this turns out to be, it's kind of the same language that we're using in a project that's about the physics of life, where we have a grant from the Templeton Foundation to look at semantic information and the role of semantic information in living systems like cells. So we have Shannon information, which is a probability distribution that tells you basically how much surprise there is in a message. Semantic information focuses on meaning, right? Focuses on in a very simple way, just how much of the information that the agent, the critter is getting from the world actually helps it survive. That's the most basic idea of meaning. We can get all philosophical about meaning, but this is it. Does it help me stay alive or not? And the whole question of agency and autonomy that occurs in this setting of just asking about how do cells move up a chemical gradient to get more food? Kind of has the feel the same sort of architecture as what's going on in quantum mechanics. So I think what you said is exactly it, how do we bring this sort of recognition? That there's always us, the agent or life the agent interacting with the world and drawing both giving information and passing information back as a way of doing science, doing hardcore science with experiments, but never forgetting that agency, which also means experience in some sense, is at the center of the whole thing.

Lex Fridman
So you think there could be something like QBism, Quantum Bayesianism that creates a theory, like a Nobel Prize winning theory, sort of hardcore real theories that put the agent at the center.

Adam Frank
Yes. That's what we're looking for. I think that is really, that's the exciting part. And it's a move, the scientific triumphalist thing says, you understand why people love this? I have these equations. And these equations represent, there's this platonic ideal that they are, they exist eternally on their own. It's kind of quasi-religious, right? It's sort of somehow, look, these equations are the, you're reading the mind of God, but this other approach to me is just as exciting because what you're saying is there's us and the world, they're inseparable. It's always us and the world. And what we're now finding about is this co-creation, this interaction between the agent and the world such that these powerful laws of physics that need an account. In no way am I saying these laws aren't important. These laws are amazing, but they need an account, but not an account that strips, that turns the experience, turns the agent into just an epiphenomena, that it pushes the agent out and makes it seem as if the agent's not the most important part of the story.

Lex Fridman
So if you pull on this thread and say, there's a whole discipline born of this, putting the agent as the primary thing in a theory, in a physics theory, is it possible it just breaks the whole thing open? So there's this whole effort of unifying general relativity and quantum mechanics of coming up with a theory of everything. What if these are the tip of the iceberg? What if the agent thing is really important?

Adam Frank
So listen, that would be kind of my dream. I'm not going to be the one to do it because I'm not smart enough to do it. Marcelo and I have for a while have been sort of critical of where foundational physics has been for a while. With string theory, I've spent my whole life listening to talks about, "String theory, real soon." And it's gotten ever more disconnected from data, observations. There were people talking for a while that it is post-empirical. I always wanted to write a paper or an article that was like, physicists have been smoking their own stash. There's this way we've gotten used to, you have to out-weird the other person, my theory has 38 dimensions. My theory is 22 dimensions, but it's got psychedelic squirrels in it. And so there's a problem. I don't need to tell you there's a crisis in physics or there's a crisis in cosmology. Other people have used that. That's been the headline on scientific American stories. So clearly another direction has to be found, and maybe it has nothing to do with this, but I suspect that because so many times the agent or having to deal with the view from the inside or the role of agency. When it comes to time thinking that you can replace the block universe with the actual experience of time. Clocks don't tell time. We use clocks to tell time. So maybe that even the fundamental nature of time can't be viewed from the outside, that there's a new physics theory that is going to come from, that comes from this agential, informational, computational view. I don't know. But that's kind of what I think it would be fertile ground to explore.

Lex Fridman
Yeah, time is really interesting one. Time is really important to us humans. What is time?

Adam Frank
Yeah, right. What is time? So the way we have tended to view it is we've taken, this is what, when Husserl talks about the surreptitious substitution, we've taken Einstein's beautiful, powerful, formal system for viewing time, and we substituted that for the actual experience of time. So the block universe, where next Tuesday is already written down in the block universe, the four dimensional universe, all events are already there. Which is very potent for making certain kinds of predictions within the scientific framework. But it is not lived time. And this was pointed out to Einstein, and he eventually recognized it. Very famous meeting between Henri Bergson, who was the most famous philosopher of the early 20th century and Einstein, where Einstein was giving a talk on relativity- The 20th century and Einstein, where Einstein was giving a talk on relativity and Berkson, whose whole thing was about time and it was about duration. He wanted to separate the scientific image of time,

the map of time from the actual terrain, which he used the word duration like we humans where duration for us is full. It's stretched out. It's got a little bit of the past, a little bit of the future, a little bit of the present. Music is the best example, right? You're hearing music, you're both already anticipating what's going to happen and you are remembering what's going on. There's a kind of phenomenal structure there, which is different from the representation of time that you have with the formal mathematics. And the way we would look at this is that the problem with the surreptitious substitution, the problem with the blind spot is it says, "Oh, no, no, the formal system is time," but really the only place time appears is with us, where we're so having a theory that actually could start with us and then stretch out into the universe rather than imposing this imaginary third-person view back on us. Could, that's a route towards a different way of approaching the whole problem.

Lex Fridman
I just wonder who is the observer? I mean, define what the agent is in any kind of frame is difficult.

Adam Frank
Is difficult, but that's the good work of the science ahead of us. So what happened with this idea of the structural invariance I was talking about? So we start with experience, which is irreducible. There's no atoms of experience. It's a whole, and we go through the whole process, which is a communal process, by the way. There's a philosopher, Robert Crease, who talks about the workshop that started in the 1700s, 1600s, we developed this communal space to work in, sometimes it was literally a physical space, a laboratory where these ideas would be pulled apart, refined, argued over, and then validated. And we want to the next step. So this idea of pulling out from experience, these thinner, abstract, structural invariance, the things that we could actually do science with, and it's kind of like, we call it an ascending spiral of abstraction. So the problem with the way we do things now is we take those abstractions, which came from experience, and then with something like a computational model of consciousness or experience, we think we can put it back in. You literally pulled out these super thin things, these abstractions neglecting experience because that's the only way to do science. And then you think somehow, oh, I'm going to jam experience back in and have an explanation for experience.

Lex Fridman
So do you think it's possible to show that something like free will is quote, unquote real if you integrate experience back into into the physics model of the world?

Adam Frank
What I would say is that free will is a given. And that's the thing about experience. So one of the things that Whitehead said, I really love this quote. It says, "It's not the job of either science or philosophy to account for the concrete. It's the job to account for the abstract." The concrete, what's happening between us right now, is just given. It's presented to us

every day. It's presented to me. If you want an explanation, fine, but the explanation actually doesn't add anything to it. So that free will in some sense is the nature of being an agent. To be an agent agency and autonomy are sort of the two things that are, they're equivalent. And so in some sense, to be an agent is to be autonomous. And so then the question really to ask is, can you have an account for agency and autonomy that captures aspects of it's arising in the world or the way it and the world sort of co-arise. But the idea why we argue about free will often is because we already have this blind spot view that the world is deterministic because of our equations, which themselves, we treat the equations as if they're more real than experience. And the equations are a paler… They don't corral experience. They are a thinner representation. As we like to say, "Don't confuse the map for the terrain." What's happening between us right now and all the weirdness of it. That's the terrain. The map is what I can write down on equations. And then in the workshop, do experiments on. Super powerful, needs an account, but experience overflows that.

Lex Fridman
What if the experience is an illusion? How do we know what if the agency that we experience is an illusion?

Adam Frank
An illusion looking from where? Because that already requires to take that stance is you've already pushed yourself into that third person view. And so what we're saying is that third person view, which now you're going to say like, "Oh, I've got a whole other set of entities, of ontological entities," meaning things that I think exist in God's living room in spite that are independent of me and the community of living things I'm part of.

Lex Fridman
So you're pushing it elsewhere just like there's a stack of turtles is probably, if this experience, the human experience is an illusion, maybe there's an observer for whom it's not an illusion. So you always have to find an observer somewhere.

Adam Frank
And that's why fundamentally the blind spot, especially the scientific triumphalist part is following a religious impulse. It's wanting the god's eye view. And what's really interesting, and when we think about this and the way this gets talked about, especially publicly, there's a line of philosophical inquiry that this language gets couched in and it is actually a pretty, it's only one version of philosophy. So it is pretty much what we call the analytic tradition. But there's even in Europe or in the Western tradition for Western, what we'll call western philosophy, there's phenomenology. And Heidegger and Merleau-Ponty, which took an entirely different track. They were really interested in the structure of experience. They spent all their time trying to understand, trying to develop a language that could kind of climb into the circle. That is experience, right experience. You're not going to be able to start with axioms and work your way to it. It's given. So you have to kind of jump in and then

try and find a language to account for its structure. But then, so that has not been part of this discussion about you'll never, good luck finding a YouTube video where someone, a famous scientist is talking about science from a phenomenological point of view, even though it's a huge branch of philosophy. And then you get the philosophies that occurred from other cores of civilization. So there's the western core out of which comes the Greeks and the Judeo- Christian Islamic tradition. But then you get India and you get Asia and they developed their own. They were highly complex societies that developed their own responses to these questions. And they, for reasons they had contemplative practice. They were very focused on direct, trying to directly probe attention and experience. They asked questions in ways that the West never really did. Phenomenology kind of started it, but there's philosophers like Nagarjuna and Vasubandhu. They're like the Plato and the Aristotle of those philosophies. And they were really focused on experience in the West. I think maybe because we had the Judeo-Christian tradition where we already had this kind of God who was going to be the frame on which you could always point to that frame in the traditions that came from the classical philosophies of India and Asia. They started always with this. They wanted to know about experience. Their whole philosophies and their logic and their argumentation was based on, I've got this experience, I can't get out of this experience. How do I reason from it? So I think there's a lot of other philosophical traditions that we could draw from. Not slavishly, we don't all have to become Buddhists to do it, but there are traditions that really tried to work this out in a way that the Western traditions just didn't.

Lex Fridman
But there's also the practical fact that it's difficult to build a logical system on top of experience. It's difficult to have the rigor of science on top of experience. And so as science advances, we might get better and better. The same is it's very difficult to have any kind of mathematical or kind of scientific rigor to why complexity emerges from simple rules and simple objects, sort of the Santa Fe questions.

Adam Frank
But I think we can do it. I think there's aspects of it. I mean, as long as you're never trying to, "This is what experience is," I think that's kind of where you're never going to have a causal account of experience just given. But you can do lots about, and that's what the good work is to how do I approach this? How do I approach this in a way that's rigorous that I can do experiments with also? But so for example, I was just reading this beautiful paper that was talking about in this is what we're counting with our semantic information too. Causal closure. Love this idea. The idea that... So we talked about autopoiesis a while back, the idea that living systems, they are self creating and self maintaining. And so the membrane, cell membrane is a great example of this, right? The cell membrane, you can't have a cell without a cell membrane. The cell membrane lets stuff through, keeps other stuff out. But the cell membrane is part of the processes and it's a product of the processes that the cell membrane needs, right? In some sense, the cell membrane creates itself. So there's this

strange, it's always with life, there's always this strange loop. And so somehow figuring out how to jump into that strange loop is the science that's ahead of us. And so this idea of causal closure accounting for how the, we talk about downward causation. So reductionism says everything only depends on the microstate. Everything just depends on the atoms. That's it. If you know the Lagrangian for the standard model, you are done. Of course, in principle, you need God's computer, but fine. In principle, it could be done. Causal closure, and I was just reading this great paper that sort of argues for this. There's ways in which using Epsilon machines and all this machinery from information theory, that you can see ways in which the system can organize itself so that it decouples from the microstates. Now, the macrostate fundamentally no longer needs the microstate for its own description, its own account of the laws, whether that paper is true or not. It's an example of heading down that road. There's also Robert Rosen's work. He was a theoretical biologist who he talked about closure to efficient cause that living systems are organizationally closed, are causally closed so that they don't depend anymore on the microstate. And he had a proof, which is very contentious. Nobody knows if it's some argue it's true, some argue it's not. But he said that because of this, living systems are not church-turing complete, they cannot be represented as formal systems. So in that way, they're not axioms, they're not living systems will not be axioms. They can only be partially captured by algorithms. Now again, people fight back and forth about whether or not his proof is valid or not. But I'm saying them giving you examples of when you see the blind spot, when you acknowledge the blind spot, it opens up a whole other class of kinds of scientific investigations. The book we thought was going to be really heretical. Obviously most public facing scientists are very sort of in that, especially scientific triumphant. So we were just waiting for the fight. Then the review from science came out and it was totally pro… It was very positive. We're like, "Oh my God." Then a review came out in Nature Physics and it was totally positive. Then a review came out in the Wall Street Journal, kind of criticized, not capitalism, but we criticized all industrial economies for that they had been touched by the blind spots, socialism, communism. It doesn't matter. These extractive sort of had that sort of view that the is just reducible to resources. The Wall Street Journal gave us a great review. So it feels like there's actually out there, there is some, among working scientists in particular, there is some dissatisfaction with this triumphalist view and a recognition that we need to shift something in order to jump past these hurdles that we've been arguing about forever and we're sort of stuck in a vortex.

Lex Fridman
Well, it is. I mean, I think there is a hunger to acknowledge that there's an elephant in the room, that we're just removing the agent. Everyone is doing it and it's like, yeah, yeah, there's the experience and then there's the third-person perspective on the world. And so, man, science from, applying scientific rigor from a first-person perspective is very difficult. I mean, it's fascinating.

Adam Frank
I think we can do it. Also, the thing, what's really interesting is I think it's not just first-person, first and second, because one idea is that, the idea that, oh, science gives us this objective third-person view. That's one way of talking about objectivity. There's a whole other way is that I do the experiment. You do the experiment, we talk to each other, we agree on methods, and we both get the same result. That is a very different way of thinking about objectivity, and it acknowledges that when we talk about agents, agency and individuality are flexible. So there's a great paper, speaking of Santa Fe by David Krakauer, where they looked at sort of information, theoretic measures of individuality. And what you find is it's actually pretty fluid. My liver cell is an individual, but really it's part of the liver. And my liver is a separate system, but really it's part of me. So I'm an individual, yay. But actually I'm part of a society and I couldn't be me without the entire community of say, language users. I wouldn't even be able to frame any questions. And my community of language users is part of ecosystems that are alive, that I am a part of, a lineage of. This is like Sarah Walker stuff, and then those ecosystems are part of the biosphere. We're never separable as opposed to this very atomizing, the triumphal, this science view is wants like Boltzmann brains, you're just a brain floating in the space.

Lex Fridman
There is a fascinating degree to which agency is fluid. You are an individual, but you and I talking is the kind of individual, and then the person listening to this right now is also an individual. I mean, that's a weird thing too.

Adam Frank
That's a weird thing, right?

Lex Fridman
Because there's a broadcast nature too.

Adam Frank
This is why information theoretic. So the idea that we're pursuing now, which I get really excited about, is this idea of information architecture or organization. Organizational organization. Because physicalism is like everything's atoms, but Kant recognized, Kant is apparently the one who came up with the word organism. He recognized that life has a weird organization that would see specifically different from machines. And so this idea that how do we engage with the idea that organization, which is often I can be cast in information theoretic terms or computational terms even. It's not really quite physical. It's embodied in physical, in the physical. It has to instantiate in the physical, but it also has this other realm of design, not design like intelligent design, but there's a… The organization itself is a relationship of constraints and information flow. And I think again, that's an entirely new interesting way that we might get a very different kind of science that would flow out of that.

Lex Fridman
So going back to Kant and organism versus machine. So I showed you a couple of legged robots.

Adam Frank
Very cool.

Lex Fridman
Is it possible for machines to have agency?

Adam Frank
I would not discount that possibility. I think there's no reason I would say that it's impossible that machines could, whatever it manifests that strange loop that we're talking about that autopoiesis I don't think there's a reason to say it can't happen in silicon. I think whatever, it would be very different from us, the idea that it would be like, oh, it would be just like us. But now it's instantiated and I think it might have very different kind of experiential nature. I don't think what we have now, the LLMs are really there, but yeah, I'm not going to say that it's not possible.

Lex Fridman
I wonder how far you can get with imitation, which is essentially what LLMs are doing. So imitating humans, and I wouldn't discount either the possibility that through imitation you can achieve what you would call consciousness or agency or the ability to have experience. I think for most of us humans to think, oh, that's just fake. That's copying. But there's some degree to which us, we humans are just copying each other. We just are really good imitation machines coming from babies. We were born in this world and we're just learning to imitate each other. And through the imitation and the tension in the disagreements in the imitations. We gain personality, perspective, all that kind of stuff.

Adam Frank
Yeah, it's possible, right? It's possible. But I think probably the view I'm advocating would say that one of the most important parts of agency is there's something called, E-four. The E-four theory of cognition, embodiment, enaction, embedding, and there's another one, extension. But so the idea is that you actually have to be in a body which is itself part of an environment that is the physical nature of it and of the extension with other living systems as well is essential. So that's why I think the LLMs are not going to, it's not imitation. It's going to require, this goes to the brain in the VAT thing. I did an article about the brain in the vat, which was really Evans, I was reporting on Evans. Where they did the brain in the VAT argument. But they said, "Look, in the end, actually the only way to actually get a real brain in the VAT is actually to have a brain in a body." And it could be a robot body, but you still need a brain in the body. So I don't think LLMs will get there because they can't. You really need to be embedded in a world, at least that's the E-four idea.

Lex Fridman
The E-four, the 4E approach to cognition argues that cognition does not occur solely in the head, but is also embodied, embedded, enacted, and extended. And by way of extra cranial processes and structures, they're very much in vogue. 4E cognition has received relatively few critical evaluations. This is a paper, but reflecting on two recent collections, this article reviews the four E paradigm with a view to assessing the strengths and weaknesses. It's fascinating. I mean, yeah, the branches of what is cognition extends far, and it could go real far.

Adam Frank
Right. There's a great story about an interaction between Jonas Salk, who was very much a reductionist, the great biologist, and Gregory Bateson, who was a cyberneticist, and Bateson always loved to poke people. And he said to Salk, he said, "Where's your mind?" And Salk went, "Up here," and Bateson said, "No, no, no, out here." And what he really meant was this extended idea. It's not just within your cranium to have experience. Experience in some sense is not a thing you have. It is a thing you do. Almost perform it in a way, which is why both actually having a body, but having the body itself be in a world with other bodies is, from this perspective, is really important. And it's very attractive to me. And again, if we're really going to do science with them, we're going to have to have these ideas crash up against data, crash up against, we can't just armchair it or couch quarterbacking it, but I think there's a lot of possibility here. It's a very radically different way of looking at what we mean by nature.

Lex Fridman
What do you make of the fact that this individual observer, you as an individual observer only get a finite amount of time to exist in this world? Does it make you sad?

Adam Frank
No, actually it doesn't make me sad. Okay, so full reveal, I have been doing contemplative practice in the zen tradition for 30 years. I've been staring at a wall for 30 years, and it's taught me a lot. I really value what that practice has given me about the nature of experience. And one of the things it's taught me is I don't really matter that very much. This thing I call Adam Frank is really, it's kind of a construct. There's this process going on of which I am actually fundamentally, and that's super cool, but it's going to go. I don't know where it came from. It's going to go, I don't really need it to, and then who the hell knows? I'm not an advocate for an afterlife, but just that what I love, zen, has this idea of beyond birth and death, and they don't mean reincarnation. What they mean is, "Dude, you don't even really understand what life is." You know what I mean? I'm like this core level of your own experience. So your ideas about what death is are equally ill-formed. The contemplative practice really tries to focus on experience itself. Spend five days at a zen session doing contemplative practice from 7:00 AM. until 9:00 PM, obviously with breaks. And you'll really get a much deeper understanding of what my own experience is. What is it really like? It

forces you to learn how to stabilize your attention because attention is kind of like this thing. It's usually just like, "Oh, over there. Oh, my foot hurts. Oh, I got to do my taxes. Oh, what's that guy over there? Why is he wearing those stupid shoes?" And with a contemplative practice, you learn how to stabilize it. And once you stabilize it, you can now begin to sort of explore the phenomenal nature of it. So what I think I've learned from that is kind of whatever, I'm not really kind of real to begin with. The Adam Frank part, the identity, the thing, and the part of me that is real is everything's coming and going. It's all coming and going. Well, how could I ever not come and go? And the entire world is just, Buddhism has this idea of co-dependent arising. Nothing exists, nothing has self-nature. Nothing exists by itself. It's an endless, infinitely connected web.

Lex Fridman
But still, there's a deliciousness to the individual experience. You get attached to it and it ends and it's good while it last, and it sucks that it ends. You can just be like, "Ah, well, everything comes and goes," but I was eating ice cream yesterday. I found this awesome low-carb ice cream called, Delights here in Austin, and it ends. And I was staring at the empty container, and it was-

Adam Frank
That's beautiful, man. I love that.

Lex Fridman
You could say, "Yeah, well, that's how it all is, but..."

Adam Frank
Can I say that what I've learned from, because I love your idea of the deliciousness of it. But what I think happens with contemplative practice when it deepens is that you're not just saying, this is I do koan practice. So this is a tradition in zen that it was established, it was a teaching method that was established a thousand years ago. They're these book of koans. And every koan, if you've ever read Godel, he's got a whole chapter on koans. They're kind of non-logical problems that you have to work on. One of my favorite one was, "Stop the sound of the distant temple bell." You're like, "What?" Every time my teacher gives it to him, I'm like, "What are you talking about?" This is the whole zen thing of up is down, but down is up. You must understand this. So your job with these koans is to sit with them, is to sit with them until you realize what the thing is trying to teach you what aspect of experience it's trying to teach you. So there's no answer. No. And in fact, actually, you don't give an answer. You actually usually have to demonstrate. The first time when I did a call on and the guy was like, "Don't tell me the answer, show me the answer." I was like, what are you talking about? But after doing these for years now, I've kind of learned the language of them. So I could never tell you. If I told you the answer, I could give you a call and tell you the answer. You'd be like, "What?" It's not the words, it's the So your experience of like, yeah, the cup is empty. With a contemplative practice as it deepens over years, it really does take years. Just like anything

in math, it took me years to understand the Lagrangians. You kind of come to a deeper understanding with yeah, the words of, it's not just like, oh, everything changes. You actually feel that movement. You feel it with breath to breath, and it really becomes, sometimes I have this feeling, this is messed up, but of just joy and it's not connected to anything. That's what I've kind of gotten from practice. It's just like, yeah, that passage, that infinite passage of moment to moment that is truly the way things are. And it's okay. It's not okay because I have a feeling about it. Okay. I want it to be okay. It just is okay. And so really, it's a pretty awesome thing.

Lex Fridman
Yeah, that's beautiful. Maybe it's the genetics, maybe it's the biochemistry in my brain, but I generally have that joy about experience, amorphous joy. But it seems like, again, maybe it's my Eastern European roots, but there's always a melancholy that's also sitting next to the joy, and I think it always feels like they're intricately linked. So the melancholy is about, maybe about the finiteness of experience, and the joy is just about the beauty of experience, and they're just kind of sitting there.

Adam Frank
Which is cool actually, because I'm also, I come from Eastern, my roots are Eastern European as well, going back, and I get it right, but that's also the cool thing. I think one of the things is, well, that is what it is. That is what it is. You don't have to do anything. You don't have to manipulate it or move it around or yeah, this is the experience.

Lex Fridman
Can you speak to just the practical nature of sitting there from 7:00 AM to 9:00 PM?

Adam Frank
I'm like, what the hell are you doing, bro?

Lex Fridman
What's powerful? What's fascinating to you? What have you learned from just the experience of staring at a wall?

Adam Frank
Yeah. Yeah. So not really. I mean, you're staring. You're facing a wall, and what you're doing is you're just sitting with, there's different meditative practices, there's counting breaths. So that's usually what I do. I sit down and I start counting breaths, and for the first half hour it's just like, blah, blah, blah. Like I said, I'm thinking about my taxes. I'm thinking about what I got to do later on, yada, yada, yada. First time I ever did a full session, a two-day session, I swear to God, I had Bruce Springsteen's, Born To Run album track through from the beginning to the end with the pauses. This was back in when there were LPs with the fricking pauses.

Lex Fridman
Nice.

Adam Frank
My mind was just like, I need to do something. So it literally played the whole album in order.

Lex Fridman
That's pretty cool, actually.

Adam Frank
Yeah, it was pretty amazing to see because you really do, you see the dynamics of your mind. But what happens is, and this took me a while, I used to hate sitting. I do it, but after a while the mind gets exhausted. That part of the mind, the upper level, the roof brain chatter is just like, there's nothing else to do. And then you get bored. And now I realize that's when something interesting is going to happen. You drop down and now it's a very physical practice. People think you're just sitting there not thinking or thinking about not thinking. Actually, it becomes a very physical process where you're really just following the breath, you're kind of riding the breath and it gets very quiet. And within that quietness, there's a path. Because obviously there's been, Buddhism is always not about thinking, but there's a huge literature. So these guys are always about, don't think. I've written all this stuff, but they're guideposts. They're like the finger pointing at the moon. And there's the idea of first, your mind is usually scattered. Right now, when I walk out, I'm going to go get the Uber and everything. My mind's going to be all over the place, but with sitting, first, you concentrate the mind so that there's no more scatter anymore. The thoughts are still happening, but you're just not there happening up there. You're not even paying attention to them. And then as time goes on, you unify the mind, which is this very powerful thing where kind of the self drops away and there's just this presence. It's kind of like a raw presence, and that's often where the joy up wells from, but you sit with whatever, maybe you're going to sit and maybe you're going to go through an hour of being bummed out about your mom who died or something. You're just going to sit with whatever comes up you're going to make. That's why the sitting part, you're making the commitment. I'm going to sit here with whatever comes up, I will not be moved. And then what You come away with it actually over time, it actually changes kind of who you are. I'm still the asshole I was from New Jersey growing up, but I just have more space now for things.

Lex Fridman
Once Jersey, always Jersey.

Adam Frank
Always Jersey.

Lex Fridman
But I love the Bruce Springsteen is just blasting in your head.

Adam Frank
Yeah, that was amazing.

Lex Fridman
Why are we here? What do you think is the purpose, the meaning of human existence?

Adam Frank
It's good that we just had the last conversation because I'm going to give this answer, which is so corny. It's love, and I'm not messing around. Because really actually, what happens, so within Buddhism, there's the idea of the Bodhisattva principle. You're here to help. You're just here to help, right? Compassion. That's a really essential part of this path, of the Dharma path. And when I first started, I was like, "I don't care about compassion. I'm here for knowledge." I started contemplative practice because of the usual thing I was suffering. The reason everybody comes to things like this, life was hard. I was going through stuff, but I also wanted knowledge. I wanted to understand the foundational nature of reality. So it was like compassion or whatever. But then I found out that you can't get that. You can't get those. You can't go to this level without compassion. Somehow in this process, you realize that it really is about helping all sentient beings. That's the way they frame, just being here to help. So I know that sounds cornball, but especially for a guy from Jersey, which is the main thing is to get over. Your job is to get over. But that's really what I found. It is actually kind… And so that joy, the joy, some of that joy is just, it's like this. One of the things I have when I have really, there's a kind of experience I'll have in contemplative practice, which will carry out into the world, which is just this gratitude for the fact that the world gives you everything, and there's a certain way, just the blue sky and the breath, the world is just giving you itself completely unhindered. It holds nothing back. And yeah, that's kind of the experience. And then you kind of like, "Oh, I need to be helpful, because who's not having this experience."

Lex Fridman
So just love for the world as it is?

Adam Frank
Love for the, and all the beings who are suffering. Everybody's suffering, everybody's suffering. Your worst political opponent, they're suffering. And our job is just to try and drop our biases and our stories and see this fundamental level at which life is occurring.

Lex Fridman
And hopefully there's many alien civilizations out there going through the same journey, out of suffering, towards love.

Adam Frank
That may be a universal thing about what it means to be alive.

Lex Fridman
I hope so.

Adam Frank
I hope so too. Either that or they're coming to eat us.

Lex Fridman
Especially if they're a type three civilization.

Adam Frank
That's right. And they got really big guns.

Lex Fridman
Well, this was truly mind-blowing. Fascinating. Just awesome conversation. Adam, thank you for everything you do, and thank you for talking today.

Adam Frank
Oh, thank you. This was a lot of fun.

Lex Fridman
Thanks for listening to this conversation with Adam Frank. To support this podcast, please check out our sponsors in the description. And now, let me leave you with some words from Carl Sagan. "The cosmos is all that is or ever was, or ever will be. Our feeblest, contemplations of the cosmos stir us. There's a tingling in the spine, a catch in the voice, a faint sensation as if a distant memory or falling from a height. We know we are approaching the greatest of mysteries." Thank you for listening and hope to see you next time.