NICHOLAS DIBELLA: So I hope I've impressed you all over the past couple of weeks about how interesting the universe is. If it's infinite, if the universe is an infinite thing, which all her observations seem to indicate that it is, we're all consistent with the idea of the universe being infinite, than anything that is possible happens. So we exist here. We humans exist on this planet we call Earth.

So we're obviously possible. And so we obviously happen. But in an infinite universe, not only does everything that's possible happen, it happens infinitely many times.

So, in particular, we should expect to find infinitely many copies of this planets, and infinitely many copies of this room, these chairs in the exact configuration here, with you, and so forth, and so on. So if the universe is infinite, obviously there should be infinitely many intelligent extraterrestrial civilizations. That's just a simple consequence of assuming that the universe is infinite.

Now, I mentioned last time that it's important to distinguish between the whole universe, which is the whole universe, and the observed universe, which is only just a small part of it. The universe has a finite age. It's about 14 billion years old.

And since then, light has only had a certain amount of time to reach us from all the galaxies and all the objects in the universe. And it hasn't had time to reach us from everything.

We're gradually seeing more and more of the universe. But there's only a finite amount of stuff that we can see. And the finite amount of stuff that we can see forms the observed universe.

And it's obviously not infinite. We can't possibly see the infinitude of the whole universe. But the observed universe is still pretty big.

The observed universe has a diameter of about 80 billion light years across. And a light year is how far light travels in a year. So 80 billion light years comes out to about 500,000 billion, billion miles. So that's five, followed by 23 zeros.

And that's how many miles across the observed universe. That's equivalent to making a trip across the equator of the Earth six, followed by 19 zeros, so 60 billion, billion times. So the observed universe is pretty big.

Now, much of the universe is empty space. But not all of it is, obviously, because we see galaxies and so forth. So in fact, there are about 100 billion galaxies that we see in the observed universe.

For those of you who don't know scientific notation, this 10 with the subscript 11, just means 1, followed by 11 zeroes. That's a lot of galaxies. And each one of these galaxies has about 100 billion stars inside of it. So 10 to the 11th stars in each galaxy.

So if you ask, how many stars are there in the observed universe? You just take these two numbers, multiply them together. And you get 10 to the 22 stars in the observed universe.

Now, you might wonder, how many planets are there in the observed universe? Well, we don't know how many of these stars actually have planetary systems like our own. But we've observed actually about on the order of 300 or so additional planets outside of our solar system, extra-solar planets.

We call them exoplanets. And we've been able to come up with a number of the proportion of stars that actually have planets. And so we get a number of something like 30% of stars also have planets.

Let's assume, for just simplicity, that each star has one planet. So that gives us 30% of this number, which is 3, times 10 to the 21 planets. Now, how many of these planets could possibly support life?

That's another important question that you might be wondering about. We also don't know the answer to this question. But a reasonable guess is that 1% of planets are habitable.

So this gives 3, times 10 to the 19th habitable planets. Now, how many of these habitable planets actually go on to develop life? I mean, they can develop life. But do they?

We also don't know that answer. But you can make a reasonable guess that maybe 10% of planets that can support life, do support life, so just 10% of this number. So that gives 3, times 10 to the 18th planets with life in the observed universe.

If the universe is infinite, you would expect there to be infinitely many. But in the observed universe, that's certainly a lot of planets with life. Now, an even more important question, and a more interesting question, and a much harder question, is how many of these planets with life have intelligent life?

I mean, not just life to begin with-- life can be very primitive. It can be in the form of bacteria, or single-celled things. But how many of these planets actually have intelligent life? We have no idea of that answer.

But you can make a couple of guesses. I mean, just look at the sheer number. 3 times 10 to the 18th, that's three billion, billion planets that have life. Let's suppose that 1% of them have intelligent life.

If 1% have intelligent life, that gives rise to 3 times 10 to the 16th intelligent alien species in the observed universe. Of course, the number could be much, much smaller than this. So what if it's, say, 0.000000001%? That's 1, 2, 3, 4, 5, 6, 7-- let's make another 0, 1% have intelligence.

So this is 10 to the minus 10. That's the proportion that have intelligent life. So you just take this number, and multiply by that.

And you get 3 times 10 to the 8th intelligence alien species, or 300 million alien species that are intelligent. So this very simple. Yes, question?

AUDIENCE: What would you consider intelligent [? life? ?]

NICHOLAS DIBELLA: Yeah, so that's a good question. So what defines intelligent life? They should be able to solve problems.

Basically, do the things that we can do. I mean, what kind of things can we do? We can build stuff. There are a bunch of chairs here.

AUDIENCE: Beavers can build stuff.

NICHOLAS DIBELLA: What's that? Yeah, OK, build complicated stuff. For the purpose of our discussion, let's just say a species is intelligent if it can, essentially, do all the stuff that we can do. I mean, it's a hard question, how you define intelligent.

AUDIENCE: It's just like, where [INAUDIBLE] finding intelligence [INAUDIBLE]

NICHOLAS DIBELLA: Right, right.

AUDIENCE: There could be something that could be even more intelligent than us. And then we'd have to [INAUDIBLE]

NICHOLAS DIBELLA: Yeah, yeah, so there could be something-- so by our standards, maybe a super intelligent civilization would not be judged as intelligent by us, just because we have no idea how to judge them. Yeah, that's certainly possible. That's a hard question.

That would lead to an entire other discussion of this whole business. For now, we can define intelligent in kind of an operational way, in terms of what they do, rather than in terms of how they think. So if they can build vehicles that can travel long distances, if they can build computers that can compute, if they can build rocket ships, if they can figure out science, if they can do science, that's probably another important characteristic of things that are intelligent. Yeah?

AUDIENCE: Can you give an accurate estimate on how many intelligent species of life on this galaxy?

NICHOLAS DIBELLA: In this galaxy? Well, let's assume--

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: In your star galaxy-- yes, so there are about 10 to the 11 galaxies in the observed universe. So we can approximate them all as being about the same. So 300 million in all-- with this really low probability of intelligence arising, 300 million in all.

And then you divide that by 10 of the 11th. So that gives you about 1 in 1,000. So 1 intelligent species for every 1,000 galaxies, that's with this low estimate of intelligent life arising. With this larger estimate, you get 3 to the 16th, divided by 10 of the 11th. So that's 3, times 10 to the 5. So 300,000 intelligent--

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: So, yeah, there's an important question. With some estimates, you get a high number of intelligent species. With other estimates of this number, you get a smaller number of intelligent species. But in both cases, there's still a lot of intelligent features that we would expect to see in the universe. And, yet, we don't seem to see any of them. So there's the big question. Where is everybody?

Where is everybody? And this is called the Fermi Paradox. Who first explicitly asked the question, where is everybody, when he was referring to the expected number of alien civilizations that there should be, and that we should observe.

Enrico Fermi was one of the great physicists of the 20th century. It was named after-- I don't think he started it. But it was named after him, Fermi Lab. He was an Italian physicist, originally from Italy.

And he was one of the very few physicists that was both a brilliant theoretical physicist and a brilliant experimental physicist. Those are very hard to come by. And in today's world of physics, that's even rarer, because now the fields have diversified so much that it's really hard to be an expert in one field and an expert in the other field.

But Fermi was both of them. So he was really like the uber physicist. So, yeah, where is everybody? Does anybody have an explanation?

AUDIENCE: [INAUDIBLE]

NICHOLAS DIBELLA: So your explanation is that they're there. But we just have a hard time seeing them. We just can't see them, essentially. Yes?

AUDIENCE: Maybe they all died.

NICHOLAS DIBELLA: Maybe they all died. That's possible. Yes?

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: Maybe they haven't reached our level of technology. Yeah, maybe we're the super race. Maybe they're too advanced for us to detect. Like, maybe they are omitting some kind of signals. But we just can't understand it. Yeah.

AUDIENCE: This is kind of weird, but have you ever considered that they have found us but don't want to talk to us?

NICHOLAS The aliens have found us. But they don't want to talk to us. Like, maybe they're observing us.

DIBELLA: But they're not going to talk to us.

AUDIENCE: [INAUDIBLE]

NICHOLAS DIBELLA: Yeah, that's another possibility. I guess they kind of look down on us. They don't want to contact us. And they prevent us from being able to contact them.

Yeah, that's another possibility. Any other explanations? So there are essentially three explanations that people tend to give for this paradox. A paradox is just a contradiction between-- an apparent contradiction.

You expect to see one thing. But you actually see another thing. There should be some reason behind it. That's just where the paradox is.

And there are essentially three explanations that people seem to give for the paradox. The first is that they are here. The aliens are here.

There are a lot of people that believe that we have been visited by alien spacecraft, and they're meddling in our affairs. In fact, you can look at the polls. Something like 3/4 of Americans-- that was terrestrial in nature, not extraterrestrial.

Something like 3/4 of Americans, or even more, believe that we have been visited by aliens. And they are currently meddling in our affairs, you know, freaking us out, doing all this crazy stuff that we can't explain. Yeah?

AUDIENCE: [INAUDIBLE]

NICHOLAS DIBELLA: What if they what?

AUDIENCE: [INAUDIBLE]

NICHOLAS DIBELLA: Maybe they live in the ocean. Yeah, maybe. Yes?

AUDIENCE: [INAUDIBLE]

NICHOLAS DIBELLA: What if we were sucked into a black hole and we can't hear them because of that?

AUDIENCE: [INAUDIBLE]

NICHOLAS DIBELLA: Yes, and this is another excellent explanation. So maybe they got sucked into a black hole. And they were trying to contact us. But the light couldn't escape the black hole. Nothing can escape a black hole.

Yeah, that's another conceivable equation. I guess that would go under the disaster scenario, something for one reason or another, they get effectively destroyed. I mean, not really destroyed, but effectively destroyed. Yeah?

AUDIENCE: If you put a bomb in a black hole, would the bomb explode [INAUDIBLE]

NICHOLAS DIBELLA: The bomb would explode in a sort of way, in the black hole. So anything inside a black hole is being constantly attracted to the center. And so you can imagine-- you can kind of imagine throwing a bomb off a plane, and looking at the explosion like that. It's falling down. Although I don't--

AUDIENCE: But you would never see it explode if you were outside the black hole.

NICHOLAS DIBELLA: Yeah, if you're outside the block hole, you wouldn't see that. But, anyway--

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: Yeah, then they could see it if you're inside the black hole. But what we're talking about with aliens today. Black holes will have to wait, probably next week, next week. So the first time exploration that people give is they exist. And they are here.

Now, we've all heard stories of people talking about reported sightings of UFOs that they think are flying saucers. And maybe we even hear stories where people are abducted by-- I was about to black holes-- people were abducted by aliens. We've all heard these stories.

I won't really spend a whole lot of time on this first explanation, because, fortunately or unfortunately, most of these stories, most of these pieces of evidence that people claim are due to are extraterrestrials can be easily explained away. They can be reproducible.

For example, maybe you see some kind of a weird light in the sky, some kind of a weird shape moving in a weird sort of way. And they said, well, hey, maybe that's an extraterrestrial. It's just visiting us doing something.

That's certainly possible. But we should try to first make simple explanations in trying to explain the things that we observe. Explanations of things that we know exist, things that we can reliably use to explain. It could certainly be that on that day there were unusual atmospheric conditions, for example, and you had light from the headlight of a car being refracted in a weird sort of way to produce some kind of a weird light in the sky.

That's certainly possible. It could also be that the person was observing some kind of plane, or some kind of a weather balloon, or something like that. A lot of these sightings are very easy to explain on the basis of terrestrial intelligence, as opposed to extraterrestrial intelligence, or even terrestrial non-intelligence.

They could be naturally created. Photos and videos, those are easy to duplicate. And definitely with today's' technology, with Photoshop and all that, it's very easy to fool even an expert on-- you present an expert with a video, and say, I want you to test the validity of this.

See if this is valid. See if this is a valid UFO sighting. Well, UFO just stands for unidentified flying object. So anything you see in the sky that's flying that's an object that you just can't identify, you just don't know what it is, that's a UFO. Whether it's a flying saucer, is another piece of business.

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: What do you call an unidentified person?

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: An unidentified un-flying object. I don't know. You can call it whenever you want.

I mean, before I met you, you were an unidentified non-flying object. So, anyway, so it's very easy to duplicate a lot of these findings, a lot of these sightings that people have. I guess not so much for the alien abductions that people claim to have, but we have mental institutions for a reason.

No offense, no offense, if I hurt anybody's feelings in here. So it's really easy to duplicate these findings. Almost all of UFO sightings that people claim to have seen throughout the year can be duplicated or understood in some sort of way.

But at the end of the year, there's still some small portion of cases that go unexplained. But why should-- OK, maybe you want an explanation for everything. But I personally think that's a little bit unreasonable.

There are many things in the world that we don't have an explanation for. But we're pretty sure that if we spent the time and effort working on it that we would have an explanation for it. For example, if you look at the back of the classroom, the shades, something happened to them.

Who knows what happened to them? I could try to get funding to research why that's the case. Maybe that could be a research project that I engage in.

But do you think that would be worth it? Do you think maybe I should try to really understand what happened there, or work on something else, like trying to understand the nature of reality? Maybe you're odd, or statistically abnormal, to think that I should try to figure that out.

There are a lot of things in the world that we just don't have explanations for. I mean, police they don't solve every single murder mystery they come across every year. There are some things that they just can't explain.

They don't know who did it. They don't know who pulled the trigger. Some people demand for an explanation.

But a lot of times we just don't get explanations. I mean, we don't think that it was some kind of an extraterrestrial intelligence that was responsible for the death of the parrots, or whatever. A lot of things just go unexplained.

The world is just so big and so complex that life is too short to try to figure out what happened. Why did this happen? We're able to explain almost all of the things we observe, at least with the UFOs.

And so it's reasonable to think that if we spent the time, and the effort, and the money, that we could figure things out. I think that's a reasonable position to take. But you should think about yourself.

If you want, you should check out check out the files of UFO sightings. And see for yourself if it really tells a consistent story, if the data indicates it must be an extraterrestrial origin. So form your own opinions is what I'm trying to say.

Any questions about what I think about? I have to admit, that's my own bias that I have kind of formed in regard to terrestrial sightings of extraterrestrial things. But you're free to have other opinions.

Maybe you have very emotional experiences, and very vivid experiences. OK, so I won't be spending much more time on this first type of explanation, they exist and they are here. But I think there's a lot more to be learned.

And there's a much more interesting type of explanation, which is that they exist. But they're not here. They exist, not here. Or let's say, they exist, but they haven't communicated. I should add in parentheses, yet, seemingly.

So there are really two different observations in the Fermi paradox. One is that they don't seem to be here. I don't think anyone in this audience is an alien. You don't look like an alien.

They don't seem to be here. But they also don't seem to be there in the stars, in the sky. So we need some kind of an explanation.

So, first, let's try to understand why if they exist, why they're not here. So it's possible-- it's conceivable that an explanation is that it's simply impossible to travel the great distances to get here. Maybe it's physically impossible to get from one star system to a very far away other star system.

Maybe that's the case. But it's probably not the case. Sorry?

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: Maybe they can exist in our atmosphere. Maybe that's another possibility. I would think that if they're advanced enough to figure out how to get there, they could probably figure out how to get inside our atmosphere, or least tell us, hey we're here. Come outside the planet. Let's play in space.

There's nothing in the laws of physics that forbid interstellar travel. I mean, in principle we could do it today, with the rocket ships that we have now. But it would take a long time. To get to the nearest star, it would take something like 100,000 years.

But there's nothing, in principle, that forbids interstellar travel. The laws of physics definitely allow it. It's more of an engineering problem to get to a far away star system in a short amount of time.

So maybe the reason they're not here is not that it's impossible to get here, but just that they haven't had time to get here. That seems like a reasonable explanation. Certainly, if they have technology like our own, 100,000 years it would take to get here, that's a long amount of time.

At least it seems like it, when we think about it at first. But let's figure this out. Let's think about it more closely.

So the galaxy is about-- OK, so let me backtrack a little bit. So we as a species, homo sapiens, sapiens, we've been around for about a million years, give or take a million years. And that's just the blink of an eye on a cosmic timescale.

Compared with the age of the universe, compared with 14 billion years, it's less than 1,000th of that time. It's a very small amount of time. Also compared with the age of the galaxy, the galaxy is about the age of the universe, maybe a little less. Maybe it's 10 billion years old or so.

Compared with the age of the galaxy, the time span of our existence is also very small. Now, there doesn't seem to be anything special about the time that we came into existence. We certainly needed time to develop from the things present in the very early Earth.

It takes a long time for evolution to happen, and to produce intelligent species like our own. For example we have very good evidence that indicates that the earth is about 4.5 billion years old. So it took about 4.5 billion years for humans to eventually form. But there doesn't seem to be anything special about the time when Earth formed.

There doesn't seem to be anything special about 4.5 billion years ago. It seems perfectly plausible to speculate that before 4.5 billion years ago, other planets formed, other Earth-like planets formed, and other human-like species came into being.

So let's assume that one extraterrestrial species of intelligent life formed a billion years before Earth came into being, let's say. Or let's say intelligent beings came into existence a billion years ago, so I guess 900 million years before humans came into being.

So let's say there's one extraterrestrial, at least one extraterrestrial civilization-- intelligent, very important-- originates 1 billion years ago. And then-- civilization, civilization. Have I removed all the spoonerisms?

OK, that's an example of a spoonerism. Yeah, I think so. It's one of those weird linguistic things. So let's assume that one intelligent extraterrestrial civilization originated one billion years ago.

Now, it's conceivable that the civilization will want to expand once it has the ability to. They might want to colonize the galaxy, say. Now, I'm not going to claim to know anything about alien psychology. I have no idea how aliens think.

I have hard enough time trying to figure out how humans think. Even our experts, we don't know how humans think. So we have no idea how aliens might think.

But it's conceivable to think that maybe, eventually, they'd want to leave their own star system, maybe for reasons of curiosity, maybe because they have to. Maybe there's an overpopulation problem, and they just have to expand outwards, they have to disburse.

Maybe their own star, their own sun, runs out of fuel. And they have to find another sun. Who knows?

It's totally conceivable to think that, eventually, an extraterrestrial civilization will want to colonize the galaxy, at least one. It's totally conceivable to think at least one extraterrestrial civilization will want to colonize.

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: Well, that depends. So that depends on the numbers that you put inside. Nobody knows what these two probabilities are.

But you can speculate that maybe this is a significant number of civilizations in the galaxy. This is just another hypothesis. This is just one type of explanation to the Fermi paradox.

So let's assume that there's one extraterrestrial civilization that's intelligent that originated a billion years ago. And then once they had sufficient technology, they decided to start colonizing the galaxy.

So let's suppose that the way they do this is they-- let's say this is the galaxy. It doesn't look like that. But let's assume that's the galaxy.

Let's say they started here, their original star system. They're are a bunch of other stars. Take this number, multiply by approximately 10 billion.

And so then we can imagine what happened is that you start sending colonies outwards. So you have one group, one fleet maybe, one fleet that goes to this star. And then maybe they go to there.

And at the same time, you have another fleet going here, which goes to there, and goes to there. This goes to there. This takes care of that guy, so on, and so forth.

So there's a wave of colonization that happens, some kind of a wave that eventually gets the whole galaxy, eventually covers everything. Now, you can calculate how long it should take to colonize the galaxy. You can just feed in some numbers, and get an answer.

So I said with our current technology, the best we can-- the fastest that we can accelerate rocket ships is about a percent of a percent of the speed of light, which is not very fast. But it's totally conceivable that in the future we'll be able to accelerate rocket ships much faster than that, maybe 1% of the speed of light. That would be a significant improvement.

With current technology, we definitely can't do anything like that. But with the known laws of physics that we have, we can definitely hypothesize certain types of methods that people would use to get things going that fast. One attractive possibility that people talk about is to use some kind of an anti-matter fuel.

So there are two kinds of things. At least, there are two kinds of things in the universe. There is matter, and there's anti-matter. For example, you have an electron, you have an anti-electron.

An anti-electron is exactly like an electron every way, except that it has the opposite electric charge. So an electron has negative electric charge. An anti-electron has positive electric charge.

And for every kind of particle of matter that you talk about, there is an associated anti-particle. And what happens when you take a particle with its anti-particle, you put them together, what happens is that they annihilate. And they give out a lot of energy.

And so you might want to use this energy as a thrust in your rocket. And it turns out that you can get pretty high speeds with an anti-matter rocket. Yes?

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: So would the rocket eventually consume itself? You have to be careful. If you have a rocket built out of matter, make sure that the anti-matter doesn't leak onto the rocket. Or if you built the rocket out of anti-matter, make sure that the matter doesn't leak on to the rocket. So you have to be careful the way that it uses fuel.

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: Eventually, we'll be so smart we'll work out the kinks. You might also want to use some kind of a fusion thrust. For example, between all the stars and all the galaxies, it's mostly empty space, but not completely empty space.

There is some matter. In fact, there's about one hydrogen atom per cubic meter. And so there's a little bit of matter.

And you can imagine scooping up the hydrogen as you travel through space. And if you have fusion technology, then you can take these hydrogen atoms that you pick up, fuse them together, cause fusion to occur. And it's going to give off a lot of energy.

And you can use that energy to propel yourself. So there are a lot of different ways that people have thought of to get things going at a very high speed. We're not good enough engineers to figure out how to do it yet.

I mean, we figured out how to do it. We know the science. But it's really an engineering problem. We don't know how to do it yet. But it's totally conceivable that in a million years we'll be able to do it, if we're still alive. That's something conceivable, right?

A million years-- maybe not 100 years, maybe not 200 years, but a million years. So maybe these intelligent extraterrestrials got to our intelligence at a billion years ago, and then it took them another million years to get up to 1% of the speed of light. That was startling.

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: What?

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: The loud noise just startled me. I wasn't expecting it. So let's say that after-- so takes them a million years to get to this point of intelligence where they can travel at 0.01 times the speed of light, 1% the speed of light.

So, eventually, they're able to travel at 1% of the speed of light. And so this wave front, this wave of colonization, eventually goes upwards at about 0.01 times the speed of light, about 1% the speed of light. So let's assume that the colonies, they travel-- not the colonies, the fleets. I'll call them fleets.

The fleets travel at 1% of the speed of light. And if they only take short breaks before reaching one star system before moving into the next, let's say it's very short, then the amount of time it would take them to get across the entire galaxy is just this distance, divided by that speed.

Whoops, I forgot to write down a distance. So the galaxy is about 100,000 light years across. That's important to know-- our galaxy, the Milky Way galaxy.

So if you take this distance, divided by this speed, then how long would it take? What does that give? How long would it take to get across the whole galaxy? So 10 million years.

And 10 million years certainly sounds like a long amount of time. But on a galactic time scale, in a cosmic time scale, it's really nothing. This is supposed to happen-- so they originated billion years ago.

And then we said it took them 1 million years to get this technology, and then 10 more million years to colonize a galaxy. So all of this happened. They colonized the entire galaxy.

How long would that be-- 1 million 11 years, so 989 million years ago, the entire galaxy was colonized, if these assumptions are right. But where are they? Our galaxy, the Milky Way galaxy.

But we don't seem to see them anywhere here. So let's look at our assumptions again. This seems plausible.

It seems plausible to think that-- the galaxy is very big. And it seems like there would be a chance for intelligent life to arise a billion years ago, as opposed to a million years ago. This seems plausible.

The fleets travel at 1% of the speed of light. Eventually, we'll probably be able to do that. The galaxy is 100,000 light years across. We've measured that.

And I didn't write it down. But I assume that the colonizers, they don't spend a lot of time before quickly moving on. So they don't spend time to rest. They don't spend time to do anything else.

So maybe that assumption is flawed. So let's say that between each voyage, they rest for the amount of time that the voyage takes. So that would effectively double the whole time to do the whole trip.

So if they did that, if they rested the amount of time each voyage takes, that would lead to 20 million years to colonize the galaxy. And that was 969 million years ago. That was still a long time ago.

Where are they? So maybe that assumption is still flawed. It seems like that's possibly the most flawed assumption, in addition to how they would travel.

Maybe it takes them a really long time before they can really colonize, and really settle, on a planetary system. Maybe it takes a long time. It takes a really long time for them to settle, and then eventually get all the stuff, and leave.

Maybe they only send a few people to each star system. Then they let it get it to a certain population. See if they wait a certain number of generations before the next wave of colonization gets sent down.

If you make the colonization process sufficiently slow, then obviously you can get a number much larger than 10 million or 20 million years. In fact, you can get a number as large as you want. So maybe that's the explanation.

Extraterrestrial intelligence does exist. But they haven't had time to reach us. Not because they lack the technology, but because it takes long to colonize. Maybe that's the explanation.

But it's also conceivable that they don't even want to colonize the galaxy. They might not be interested in our system, or our solar system. We think it's interesting. We think they want to visit us.

I mean, we're intelligent. We're smart. But maybe they don't maybe they don't see any value in visiting. Maybe it's too expensive.

That's another possibility. Maybe it's too expensive to do this large scale kind of a colonization. But this would have to be true for every single intelligent civilization that formed in our galaxy's past.

I mean, if it's impossible for one, it might be possible for another. They might not take as long colonizing it. They might not take as long getting settled on the planets before they move outward again.

This would have to be true for every single civilization that formed in the galaxy. None of them were able to reach us in time. Who knows? Nobody really knows.

We have a hard time understanding how our intelligence works. We have a hard time understanding how an extraterrestrial intelligence. So we must have a really hard time understanding how all extraterrestrial intelligence works.

So maybe it's actually impossible for them to get here in time. It seems possible for them to get here in principle. But maybe they just don't have the amount of time to get here. So we don't see them here.

So that would explain the first part of why they're not here. It just takes too long to get here. That would explain that part. But it doesn't explain why we don't seem to see them.

There's been an industry of searching for signs of infinite intelligence now that's been going on for over 40 years. We've been pointing our telescopes in the sky. We've been trying to look for signals that might indicate that some signs of intelligent life besides our own exists out there in the universe-- the observed universe. We can't see the whole universe.

And so this search has been going on for a long time. Definitely the most well known search that has been going on is known as SETI, which stands for Search for Extraterrestrial Intelligence, SETI. That's been going on for a long time.

But they've never found any clear signs of extraterrestrial intelligence. So now, we need to explain, well, why don't we seem to hear from them? We need to explain that now. Does anybody have an explanation for why we don't seem to hear from them?

AUDIENCE: [INAUDIBLE].

NICHOLAS The way of talking to us, the way of sending signals to us, is not restricted to just answering

DIBELLA: our calls. They could be signaling us before we even have the technology to signal them.

They don't have to wait for us. They could have been sending stuff for millions of years, for all we know. Yes?

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: Maybe they're surrounded by mini black holes that prevent them from reaching us. Maybe, but I don't think there's much observational evidence for a whole slew of mini black holes permeating through the whole galaxy eating civilizations, not much evidence for that. Yes?

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: Oh yeah, so that's a valid criticism against the program. So the way we've been trying to search for these signals has been through electromagnetic waves. We've been trying to find signals in electromagnetic waves-- so radio waves, microwaves, visible light, things, red, blue, gamma rays, x-rays.

These are all electromagnetic waves. And we've primarily been looking into radio waves. We've also looked in optical, visible light.

But we haven't seen any clear signs from these signals. We haven't seen any signals in these electromagnetic waves that we've been receiving. And we've been looking for a long time.

So it's possible that maybe-- well, maybe we're not even looking at them the right way. Maybe they don't send signals in the form of electromagnetic waves. There are other possibilities.

Electromagnetic waves seem like the natural choice of sending signals to us. Electromagnetic waves travel at the speed of light, which is theoretically the fastest you can go. But maybe they don't use electromagnetic waves.

Maybe they use gravitational waves. Gravitational waves are similar to electromagnetic waves. They also travel at the speed of light.

But they're also very different. The way to produce a gravitational wave is to take a mass, and basically to shake it. And that produces gravitational waves.

The problem with that is that gravitational waves are extremely weak. In fact, to date nobody has ever-- we as a civilization, we have never directly detected gravitational waves. They're just so weak.

People are certainly trying. And we may very well detect the first gravitational wave in five years or so. It's definitely possible.

But we haven't to date. We've indirectly observed gravitational waves. We are pretty sure they exist. We're very sure they exist.

There are consequences of Einstein's general theory of relativity. But we've never directly observed one. So it's possible that aliens, for one reason or another, are sending signals encoded in gravitational waves. And we just have no chance of seeing those signals at all, because we can't detect them.

So maybe the aliens, they prefer to use gravitational waves, because they only want to communicate with civilizations that are elite enough to have developed the technology to detect gravitational waves. I don't know. Who knows? Yes?

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: So what physical conditions can produce detectable gravitational waves, is your question? Well, it certainly won't detect this.

Only the most violent disturbances in matter can you really detect, at least today do we have any chance of hoping to detect. I don't know a whole lot about it. But I think we might be able to detect collisions between black holes.

I'm not sure. I don't really know too much about it. But they have to be the most violent disturbances in matter, definitely nothing that we can create right now. So that's another thing about the extraterrestrial intelligence.

They would have to be able to create very strong disturbances in gravitational fields to produce detectable gravitational waves. Although, maybe they purposely choose not to produce very strong gravitational waves, and just want to give us a hard time. They want to give us a challenge.

So only if they are advanced enough to take these gravitational waves this weak will we communicate with them. Who knows? But they might be using these gravitational waves to communicate with us.

AUDIENCE: How weak are gravitational waves? Say, you smashed two planets together.

NICHOLAS DIBELLA: Smashed two flames together-- planets. I don't think that would produce detectable-- I mean, I always forget the numbers. But if you sent a gravitational wave of reasonable strength through maybe it's like a million-- I don't know, like 100 light years of lead, then it would only be like 50% diminished.

I don't have the numbers offhand. But they're so weak that they're very, very, very, very, slightly interact with matter that it's just so hard to detect them. And there's actually another means of communication that they might use, which is similarly weak.

They might use neutrinos. Neutrinos are these very, very light particles. They travel very fast, not as fast as the speed of light, slightly less.

But they travel very fast. And they're very light. And they're very weakly interacting.

I do have the numbers for the neutrinos. So these are written somewhere. Yeah, so if you sent some neutrinos through 1,000 light years of lead-- it would take about 1,000 light years of lead to have a significant chance of stopping a neutrino.

That's how weak neutrinos are. And gravitational waves are even weaker than that. We have detected neutrinos.

Now, we have neutrino detectors, where we essentially make the neutrinos travel through a lot of matter before we can detect them is essentially what we do. But we are able to detect neutrinos now.

We have neutrino telescopes. But we probably wouldn't be able to detect any neutrino signals if they send any. So it's totally possible that we're not looking at the sky the right way.

We're just looking at electromagnetic waves. We're not looking at gravitational waves, or neutrinos. Or maybe they use tachyons. Tachyons are hypothetical particles that actually travel faster than light, which might exist.

We've never detected them. According to relativity, strictly speaking, you can't take a particle and accelerate it up to the speed of light, and then past the speed of light. It would take an infinite amount of energy.

But you can have particles-- I mean, special relativity doesn't forbid it. You could have particles that always travel faster than the speed of light. They're called tachyons.

We've never detected a tachyon. We have no evidence at all that tachyons exist. But you can think, maybe they do.

We have no idea of manipulating them, because we don't even know they exist. But maybe they do exist, and aliens know how to manipulate them. And that would certainly be a much more efficient way of communicating, because they can travel faster than light and get to us in a quicker amount of time. Who knows?

But it's certainly possible that we're looking at the sky in the wrong way. It could also be that we're looking at the sky in the right way. Maybe aliens are sending electromagnetic signals. But we're looking at the wrong frequencies.

And the electromagnetic spectrum spans a wide range of frequencies, from the very short wavelength gamma rays, x-rays, to microwaves, to optical lights, to infrared, to radio waves. It forms a very vast spectrum.

And, mainly, we've been looking at the radio waves. We've also been looking in the optical, and I think maybe also gamma. But we haven't been looking at that many different frequencies.

There are certain frequencies that we look at that seem natural. For example, it seems reasonable to think that an intelligent civilization will have discovered that there's a very prominent wavelength that gets emitted from hydrogen throughout the universe. It's called the 21 centimeter line.

You would think that they know about that. So maybe they would try to send something related to that frequency, something related to that wavelength, 21 centimeters. Maybe they do twice that, or three times that, or pi times that. Presumably, they know about pi. Who knows?

So we've really been looking at a handful of frequencies. And we haven't seen anything. So maybe that means we're not looking in the right frequencies. Maybe we need to broaden our horizons, maybe.

It could also be that our search technology is just not sensitive enough. The universe is a big place. And there are a lot of things going on in the universe. And so there's a lot of noise.

And we need, somehow, to distinguish the noise from the signal. We want to see the signals that they're sending, not the noise. Maybe the signal is just mushed up with the noise somewhere that we can't distinguish it.

Maybe that's the problem, and we need to increase our sensitivities. So it's entirely possible that they are communicating, they're trying to communicate with us. Or maybe they're just inadvertently communicating with us by sending signals.

We're just not observing them, because we're not looking at the right frequencies. Or we're not even looking at the right kind of thing. We're not looking at electromagnetic waves. And we're not looking at the right kind of thing. It could be graviational waves, et cetera.

It could also be that we're not doing sensitive enough searches. So over the years, people have gradually increased sensitivity, gradually increased number of frequencies. And this continues to expand, as the years go on.

And the people in SETI, they're really hopeful that eventually we'll see something. And so they keep expanding, expanding, expanding their sensitivities and their ranges. It could also be that the aliens are there, and they're just not sending signals.

Maybe they're trying to conceal themselves. Maybe they don't want their presence to be known. That's also possible.

Or maybe we're just not looking in the right place. Maybe they're not there, but they're over there. That's also possible. We just don't know. So these other explanations of the Fermi paradox. We don't know.

So we look at two general types of explanations to the Fermi paradox. Where is everybody? We looked at two different explanations. One is that, they do exist, and they're here.

The evidence for that's a little shoddy, a little skimpy. But the second possibility is more intriguing, more interesting in my opinion. It's that they exist, but they haven't communicated with us yet, seemingly.

Maybe it takes too long for them to get here, and they just haven't gotten here yet. Maybe it's too expensive. Maybe they don't want to come here. Who knows?

That would explain why they're not here. We would also like to explain why we don't see them in the sky, why they haven't communicated with us. And we don't know that for sure. We don't know if they haven't communicated with us.

It could just be that we haven't been searching for them in the right way. We've been searching for them electromagnetically. They could be using some other kind of signals.

And we've only been searching in a small window. And it's totally conceivable that they would try to contact us in another kind of window, a different kind of frequency range. It's also possible that they're just hard to distinguish from the noise that we observe.

There's one final possibility. And it's probably the darkest one, and the gloomiest. It's that they don't exist.

This would certainly explain why we don't see them, and why we don't seem to hear from them. But, admittedly, it's probably the saddest one. But it's a very real possibility that we have to consider.

And it's not only the final possibility to consider. And so we might want it by process of elimination. But there are a lot of reasons for thinking that we are actually alone in the galaxy, or we are actually alone in the observed universe.

It could be that life is just-- intelligent life is just very, very rare. Our current understanding of the way life formed, our current modern understanding, is through evolution. So a long time ago, there existed a bunch of stuff on the Earth.

The Earth existed. There's a bunch of molecules. And, occasionally, some of these molecules would interact in a favorable way. They're all moving around in random directions, interacting with each other in random ways.

But, eventually, a fluke will occur, a statistical fluctuation will occur. And the molecules will interact in a certain way to produce something that today we would classify as being a meaningful sort of molecule, an ingredient of life. Eventually, for example, amino acids formed through these random interactions of molecules.

Now, it's very unlikely that it does occur. But, remember, if you try doing something many, many times, if you wait long enough, then eventually it's going to happen, regardless of how small the possibility is. It might be extremely small probability that the amino acids do form. But if you wait long enough, they do.

And once you get things like amino acids, you can start getting more complex things. Our current understanding is that eventually, very simple cells forms, very primitive kinds of bacteria. And then from bacteria, you had eukaryotic cells.

These are cells that have nuclei. Then from eukaryotic cells, you get multicellular organisms, things that are more complex. And you wait long enough, you let this process go on for 4.6 billion years, a vast amount of time, it's an insane amount of time you, let this process go on, you let these random processes occur for a vast amount of time, and eventually you get this.

You get the wide diversity in life that you see today. And, in particular, you get intelligent life. At least for us, we got intelligent life. But it could be that the way it happened here is vastly improbable.

I mean, there are a number of steps that have to occur for the evolution of intelligent life to happen. One of them is you have to get life from non-life, some sort of way. You let these random collisions happen for a long enough time, they eventually get a cellular type of thing from a non-cellular type of thing.

You get life from non-life. And it could be that that's just very, very unlikely to happen. And we're the only place in the whole galaxy where it did happen, perhaps the only place in the whole observed universe where it did happen. Yes?

AUDIENCE: Isn't what we were talking about last week with the type of multiverse, doesn't that kind of prove that there's other life out there?

NICHOLAS DIBELLA: Well, certainly, if the universe is infinite, definitely there's other intelligent life out there. But we don't observe the whole infinite universe. We only observe a small, finite portion of it.

It's actually very large. I threw some numbers out before. But we don't observe the whole universe. So we might effectively be the only intelligent life in the universe. At least our universe, we're the only intelligent life.

Or at least in our galaxy, that might be the case. So there could be some kind of a-- yes, it's raining. There might be some kind of a really improbable step that occurred in the sequence of steps that had to occur for life to form.

Maybe it was getting life from non-life. Maybe it is getting multicellular from single-celled organisms. Maybe it was getting big brains that was hard to occur, that was very unlikely.

So it's reasonable to postulate that there was some kind of a great filter that acted on the development of our species, that one or more steps had to be extremely improbable for it to happen. And it's so improbable that we're the only intelligent life in the whole observed universe, or the whole galaxy. And if that's the case, that would very easily, very elegantly, explain why we don't see anyone else.

That would explain why there's nobody else, because we're the only ones. We're here. So it is possible for intelligent to form. But it might be so improbable that we're the only ones in the whole observed universe.

Maybe you only get one intelligent life form in the volume that's equivalent to the volume of our observed universe. Maybe that's what happens. Yes? Did you have a question?

AUDIENCE: [INAUDIBLE].

NICHOLAS DIBELLA: Yeah, so there are a number of other explanations. That might be part of the great filter. The civilizations, they would have to survive a whole bunch of possible natural catastrophes.

Maybe meteors were common. They would have to survive that. Or they would have to have to keep developing so that a meteor hasn't struck yet, or a supervolcano hasn't erupted yet.

Or probably the most interesting case of a kind of a natural catastrophe is what's known as gamma ray bursts. So these are the most energetic things that we see in the entire universe. They're called gamma ray bursts.

They're these burst of energy, primarily gamma rays. And they only last for a short amount of time. But they're so energetic.

The amount of energy that a gamma ray burst puts out in just a few seconds is equal to the amount of energy that the sun produces in its entire lifetime, billions of years. That's how energetic these things are. Now, we've only seen gamma ray bursts outside of our galaxy.

We've only seem them very far away. But it's quite possible that any day, a gamma ray burst might happen inside our galaxy. We don't really know a whole lot about these things.

It could happen tomorrow. A gamma ray burst happens, and completely annihilates us. So it could be that intelligent life started to form in a number of cases, but got quickly killed away by some kind of a natural catastrophe. That's certainly possible.

It's also possible that once intelligence reaches a certain point, then the civilization inevitably destroys itself. That's a very real possibility. I mean, certainly-- I mean, we only have one data point to look at, our own civilization.

And we have the potential to destroy ourselves many times over. I mean, we have the toys. We have the weapons to destroy ourselves many times.

And maybe most or all sufficiently advanced civilizations inevitably destroy themselves before they can communicate with other civilizations, or before they can try to travel to see us, to see other civilizations. So this might be another step in the great filter. It could be that the main part of the great filter is actually after intelligent life forms. It could be that most intelligent life destroys itself after discovering weapons, for example. Or they destroy their ecosystem, or something like that.

So I was actually reading an interesting paper recently by a philosopher named Nick Bostrom, where he hopes that our search for life on Mars, for example, finds nothing, because the more-- so suppose we found life on Mars. Or maybe we found relics of life from the past.

Maybe we found simple bacterial type of life on Mars. That would seem to indicate that it's pretty easy for simple life forms to emerge. And so that would seem to indicate that the great filter doesn't happen at the beginning, but it would happen after life is formed already.

So maybe it's multi-cellular. Maybe that's the stage that's very unlikely. Maybe that's the main part of the great filter.

But suppose we found bones on Mars. Suppose we found bones that looked like human bones, or human type bones. That would be awful new for the future of humanity, because that would seem to indicate that it's not very hard to get to the stage where you have intelligent life.

And if you find bones on Mars, you don't find actual living life, you find dead life, then that would seem to be evidence that once intelligent life forms, then it gets destroyed for one reason or another. So that would seem to say a little bit about our future. And so it would be very bad news for us.

The article goes on to say, if we found bones on Mars, or even if we found any kind of life on

Mars, the more complex life we find on Mars or anywhere else, would probably lead to a lower chance of survival for us in the future. And that would be bad news, because we'd like to live for a long time.

So I guess the main lesson to take away from all of this, is that the Fermi paradox, it's a real problem. And it's a hard one. I feel the question of whether we're alone in the universe is an extremely important one.

And it's one that we've probably all wondered in our lives. We certainly don't know the answer now. And we may well never know the answer. But searching for the answer is certainly a fun journey. And I'll end with that. I'll see you next week.