LQ28

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Jorge: [00:00:00] Hey, Daniel. I've got a question for you. Oh, let's

Daniel: hear it. I love questions.

Jorge: Nah, I'm not sure you like this one. I've seen you cringe every time people ask

Daniel: you this. All right. Now I'm curious. Let's hear the

Jorge: question. All right. Are you still actively doing research? Oh,

Daniel: you're right. I used to hate that question, but actually now I've learned to love

Jorge: it.

Oh yeah. You have what. You actually started doing research

Daniel: well, instead of grinding my teeth at the suggestion that it's not possible to do outreach and research, I just take it as another chance to talk about my research and Hey, I love smashing stuff together. So I love talking about it. Wonder

Jorge: if people assume podcasting takes a long

Daniel: time.

If only they knew.[00:01:00]

Jorge: Hi, I'm jhan cartoonist and the creator of PhD comics.

Daniel: Hi, I'm Daniel. I'm a particle physicist and an active researcher at UC Irvine. And I love smashing together podcasts with my cartoonist

Jorge: friend. Sounded like you say, you're an actor researcher. I thought, whoa, that's pretty cool. You do

Daniel: acting as well? I do my own math stunts, unlike Leonard de capo.

Jorge: I didn't know Leonardo needed a

Daniel: stuntman. Oh yeah. He couldn't write the equations himself on the board for don't look up. So they had to hire somebody to do his math for him. But me, I. I live that danger, man. I take those risks every day with my body. Did you

Jorge: audition to be Leonard de capos? You know, wrist

Daniel: standing?

I didn't even know that was a thing, but if I had known it was a thing, I definitely would've signed up for it. Absolutely. Yeah. You live

Jorge: right next to Hollywood. Why not? You could be Robert Downey JRS. Wrist. You could be

Daniel: I think I look a little bit more like Robert Downey Jr. Than Leonard de capo. Anyway, [00:02:00] but I don't think I look much like either of them

Jorge: yes.

I can say . I mean, not, not to say anything about how you look, but you know, you just don't look like Robert Downey Jr. Or Leonard de capo. Mm-hmm mm-hmm you look like a handsome Daniel.

Daniel: Like if Woody Allen needed a math double, then I would be his math double .

Jorge: Oh lot. I don't think he won a double for Woody Allen on any set.

Daniel: No, that's true. He's off the list, but

Jorge: anyways, welcome to our podcast, Daniel and Jorge, explain the universe, a production of iHeartRadio in which we

Daniel: take all the risks by diving deep into the unanswered questions about the universe. We don't shy away from the dangerous math and the difficult questions.

We ask them straight up and wonder what the answers are. How big is the universe? How old is it? What's happened to it? What is it made out of and most important? Can we explain it to you?

Jorge: Yeah, because it is a very perplexing universe full of things to wonder about. And we like to take you right up to the edge where scientists are taking all the [00:03:00] creative and scientific risk, trying to figure out how everything works.

This makes it sound like science is kind of risky. Daniel, do you have insurance for doing science? Is there science, insurance?

Daniel: I spent three years on this paper and it turned into nothing pay me. Oh, I wish. I would have so many payouts

Jorge: I think it's called tenure. that's pretty good insurance,

Daniel: right? That's pretty good safety net.

Although, you know, tenure doesn't guarantee you funding, you could have a job, but no money to do any actual work. Mm. But you still get paid. You do get paid as long as you still do teaching. That's true. But there are sort of intellectual risks involved in science. What we do is research. It's a sort of exploration.

We don't know that there will be interesting answers until we go out and look the same way. You don't know, what's waiting for you when you first land on the surface of some alien planet. Is it filled with all sorts of incredible creatures or is it just a desert of rubble? You don't know until you go and look, and sometimes you hit the jackpot and sometimes you come home with dust.

Jorge: Mm. I mean, it's not like a casino. Like a science, like [00:04:00] a nature casino. you just a bunch of, uh, scientists pulling the lever on the slot machine of the universe.

Daniel: There's an enormous element of luck. Absolutely. In making a discovery, you know, there are people who are really clever and have good ideas about where to look for the next big thing in the universe.

And then there are folks who just stumble across it.

Jorge: Mm, well, I'm an artist and a cartoon, so I don't know anything about risky or risky. Yeah. There you go at all. You know, what are you talking about? I'll take 10 years. Sure.

Daniel: yeah. You left one risky career for the ultimate risky career. Absolutely.

Jorge: Well, I do have insurance.

Yeah. Actually I have cartoons

Daniel: insurance. Yeah. You've insured your right hand against injury. ,

Jorge: it's called marrying someone with a stable job. Mm.

Daniel: Patronage. I think they call that patronage. Yeah.

Jorge: patronage. patronage actually, maybe. But anyways, uh, scientists ask a lot of questions about the universe, cuz we're trying to figure out how the universe works, but they're not the only ones who have questions about the things around them.

All of

Daniel: [00:05:00] humanity is trying to push forward the envelope of knowledge and understanding and mystery just by looking around us and wondering how things work. It's not just those of us with a tenured job who can take naps in the afternoon. It's everybody who wants to know how the universe works. And everybody out there asks questions about the.

Jorge: Yeah, and it's not like only the scientists ask really cool and interesting and valid questions. Everybody can ask these amazing questions. And in fact, there's a huge amount of overlap between the questions people have every day. And the questions that scientists at the forefront are

Daniel: asking, because we're a lot more ignorant about the nature of the universe than you might expect from the fact that you can rely on technology and fly and airplanes and all that.

There are some pretty basic questions that we just dunno how to grapple with. So we mostly avoid them and work on other stuff that's E easier to tackle . So sometimes you ask us a really hard, basic question, like, what is space? How does time work? And you get a blank stare because it's the kind of thing we just don't know the answer

Jorge: to makes you wanna know what you're [00:06:00] doing to earn that

Daniel: tenure, Daniel, you know, sometimes I get great ideas while napping,

Jorge: while napping.

Interesting. And then you wake up and you forget 'em .

Daniel: I keep a pad of paper actually next to the couch. And sometimes I wake up and I look at the scribbles. I'm like, I have no idea what that says. And other times I'm like, Hmm, that seems like a good idea. I'm gonna go try. That sounds like

Jorge: there's an episode of Seinfeld where he has the same thing and he spends the whole episode trying to figure out what he wrote down on that path.

Daniel: and so don't leave us in suspense. Did he get a great science idea? Did he launch a new experiment and win a Nobel prize? Yeah.

Jorge: Yeah, that was the season fan , but uh, everybody has questions and they're all awesome questions. And sometimes we get those questions here on the podcast. People write to us or contact us through.

Social media or they hang out at our discord and that's where they ask the questions. That's

Daniel: right. We welcome all of your questions. If you are curious about the universe or there's a science concept, you haven't heard, explained to your satisfaction. Please write to us two questions@danielandjorge.com.

Everybody deserves to understand the universe or at least understand [00:07:00] how little we know about the. So

Jorge: to be on the podcast, we'll be tackling listener questions. Number 28, the annihilation. Confabulation special

Daniel: that didn't quite work out. That's what a lot of these questions have to do with smashing stuff together, blowing things up for science, which in the end is something I love to do.

Jorge: Mm. You like blowing things up for science or you like smashing things for science.

I thought we had this conversation. Daniel. It's not the same thing unless you blow up the entire world, in which case , um, please don't do that. And I guess it won't matter anyways, you know, I

Daniel: think it's an artificial dichotomy. I think there's a spectrum. Between smashing stuff together and blowing stuff up.

And you're just trying to force an artificial separation between them

Jorge: and I think you're, I think you're wrong.

Daniel: I think there's a spectrum between right and wrong, actually.

Jorge: I wonder what the, um, legal authorities say about that.

Daniel: Yeah. You either go to jail [00:08:00] or you don't, so that's definitely a quantum distinction

Jorge: rights discrete that either smash things or you explode things , or you can smash things that then explode, but it's a then sequential.

It's not like. Quantum superposition,

Daniel: but to continue our argument from the blast episode, that's exactly why we smash stuff, because then, then explode and we look at what comes out. So yeah, absolutely. Wait, did

Jorge: you say, and then it explodes.

Daniel: Yeah. Protons. We smash 'em together and then they explode .

Jorge: Oh boy.

Well, I guess we came to an agreement. It's not the same thing. It happens one after the other. I think it's what you just admitted to. Yes.

Daniel: Time flows forward. I do agree.

Jorge: right. Anyways, we are answering listener questions once again, and this is our 28th episode, uh, which is amazing. And this one has a theme of annihilation, I guess that's in on everyone's

mind

Daniel: these days.

Yeah. Everybody's thinking about blowing stuff up or smashing stuff together or something on the spectrum between. Yeah. Or

Jorge: something in Europe causing everyone to blow ourselves [00:09:00] up. So we have some awesome questions here about, uh, electrons, annihilating with muons about Daniel, uh, annihilating, I guess his career, uh, prospects maybe, and also maybe an alien civilization coming to annihilate us.

So some pretty grim and interesting question.

Daniel: Yeah. So thanks everybody who submitted these, please don't be shy. If you'd like to submit questions for answering on the podcast, please write to us two questions@danielandjorge.com or come join us on the discord or join my office hours or write to us on Twitter any way you like it.

We love interacting with our listeners. Okay.

Jorge: So our first question comes from David Smith and he has a question about, um, I guess, shaking hands with himself. Hi, Daniel and Jorge. I

Daniel: recently listened to the episode about particles and their antiparticles. And I was a little surprised by the statement that Daniel made that generation two particles won't cancel with generation one particles.

In other words, you can't have a cancellation or an annihilation between a positon and a [00:10:00] move on. It made me wonder. Say hypothetically, there was a stable object that was made from generation two anti-matter and these objects came into contact with normal matter, with the opposite Valent shell charges.

Cause the objects to tend to stick together. If so, how strongly would that attraction be? For example, if I shake my generation two anti-matter doppelgangers hand, would I be able to pull it apart afterwards?

Jorge: Thank you. Whoa. Pretty interesting question here from David. There's a lot to unpack here. I think there's anti-matter and also multi-generational particles here to unpack.

Yeah. He's

Daniel: responding to a conversation we had about annihilation of matter and anti-matter and we talked about how electrons, for example, can annihilate with their opposite particle Tron to turn into things like photo. That's something people are familiar with, but we commented that a positron can't for example, annihilate with a muon, which is like the heavier version of the electron.

We called it a [00:11:00] second generation particle electrons are the first generation muons are the second generation. And so while an electron can annihilate with a positron, Aon cannot annihilate with a

Jorge: paiton. Well, let's take it one step at a time. So an electron. Has an anti versions of itself called the anti electron, but you guys give it another name, you call it Tron.

So Tron is just an anti electron mm-hmm

Daniel: most of the anti matter particles, we just call anti-whatever. But Tron, because it was the first one discovered got a special name.

Jorge: Mm. Okay. So then, and it's the same as the electron, except it has one charge flipped or all of the charges flipped.

Daniel: I forget it has all of its gauge charges.

Flipp. And so the weak hyper charge and everything else, all of that is flipped for the Tron relative to the electron. Most important is the electromagnetic charge, which goes from minus one to plus one. So the positron has plus one electric charge.

Jorge: Well, there's only three forests, right? So it has three charges flipped the [00:12:00] electromagnetic charge, the strong, the color.

Daniel: And something else, right? So it has all of its charges flipped the electric charge. Obviously the electron also feels the weak force. So it has its weak quantum numbers flipped, the electron doesn't feel the strong force. It doesn't have color. And so the Tron also doesn't have

Jorge: color. Mm, okay. So if I take an electron and I.

Mash it up with an anti electron it annihilates, right? It turns into like pure energy, meaning like photo. Yeah.

Daniel: It can turn into a photon. It can actually also turn into something like a Z Boze on. But yeah, the point is that that electrons matter no longer exists. It's not like you've taken the components of the electron and the Tron and you rearrange them like some sort of.

Chemical reaction where you move atoms from one place to another. The matter that made up the electron and the Tron does not exist anymore in the universe, it's converted into a photon, which has no mass.

Jorge: And also there's the idea that particles have, uh, sort of heavier versions or [00:13:00] cousins or generations.

So the electron has in, uh, heavier kind of twin version of itself, right called Theon, which is exactly the same, same charges as the electron. Just more mass.

Daniel: Yeah. And this is something we don't understand why these particles exist, but you see, there are all these symmetries and reflections in particle physics.

You know, one is like a particle has an antiparticle and now we're talking about a different sort of direction in which particles have reflections of themselves. So every particle has a heavy version of itself. Electron is the heavier version. The muon even the quirks have heavier versions. So there are three of these generations generation one, two and three.

The electron is the first generation muon is in the second generation. And then the even heavier version is called the

Jorge: towel. Right? Well, I guess the mystery then is that I, cuz I think, you know, the electrons matches with deposit Tron because they have opposite charges and so they can attract each other.

And so they get really close to each other and that's when they annihilate. Wouldn't the same thing happen if like an electron [00:14:00] met with its. Anti heavier cousin wouldn't they have the opposite charge and still attract

Daniel: each other. That's exactly what Dave's asking. And you would expect that that might work because it does satisfy the principle that they have the opposite charges, but to David's surprise, that's not allowed in particle physics, AAN, and a positron cannot turn into a photon because while that.

Does respect conservation of charge. It doesn't respect all of the rules of particle physics and there's kind of a lot of them. Oh yeah. What are these rules? One of the rules of course is conservation of charge. And so just stepping through the reaction here, you start out with like Aon, which is minus one charge and a Tron, which is plus one charge.

So that adds up to zero total charge. So there's no problem. Then turning that into a photon, cuz the photon also has zero total. So you've conserved the charge. That's cool. But there's another rule. And that rule is that you have to conserve the number of El. Like electrons cannot just be created and destroyed [00:15:00] willynilly you can't change the number of electrons in the universe.

That's one of the

Jorge: rules. So somehow, like the number of electrons in the universe has to be the same.

Daniel: That's right. And that seems weird because like, hold on a second. What happens when you annihilate an electron and a positron? Aren't you destroying an electron? Yes, but the reason that works is that positrons count as negative one electrons.

So in that reaction, the number of electrons is plus one from the electron minus one from the Tron. So in total zero electrons. Then when you make the photon, you still have zero electrons. The problem, when you try to do the muon and positron reaction is that that reaction starts out with minus one electrons from the positron and ends up with zero electron.

Because you just have a photon. So it violates this rule. You have to have the same number of total electron.

Jorge: Right. But I think maybe what's probably confusing to David is that Aon is pretty much it's it's it is like an electron, right. It's like an El heavier electron. So why can't it count as like a plus two you know what I mean?

Like. [00:16:00] Why can it be, or, uh, count as, as an electron, just with extra energy.

Daniel: The answer is, we don't know, this is what we observe for some reason, there's an important difference to the universe between electrons and muons, that's basically what makes Aon Aon, and not just an electron with more mass. This is Theon ness of Theon because the universe doesn't just count the number of.

And as a separate count for the number of muons and the same rule applies there, you can't just create and destroy muons willy-nilly. So the answer is we don't know why this seems to be important, but we think it's a clue, you know, in particle physics all the time, we're looking for things that are served, what are the rules that the universe follows, and then try to back that out, to figure out what that means about the nature of.

In this case, we don't yet know.

Jorge: Mm, well, I feel like you're telling me that an electron can't and ILA with an antimon, because we've never observed. Kind of right. But have you actually like

Daniel: looked you're right. We have never observed it, but we are looking very, very carefully and there are dedicated experiments [00:17:00] looking just for this.

They shoot a bunch of muons and electrons or equivalently. They look to see Ifans can decay directly to electrons. Without producing any neutrinos. And so these are very careful, very high precision experiments, and nobody has ever seen this kind of reaction.

Jorge: So the answer could still be yes, that an electron couldn't anhilate with an antimon, maybe

Daniel: that's right.

The answer could be, yes, it might be possible for it to happen. And in fact, there is a little wrinkle here, which is that neutrinos. Count in the sort of number of electrons and number of nuances category, for example, an electron neutrino counts in the electron category, which is why, for example, like a w decay into an electron and a neutrino what's really interesting is that we have seen neutrinos violate this rule.

We've seen neutrinos change from likeon neutrinos to electron neutrinos or town neutrinos. So we know this rule is very, very strong, but not a hundred percent absolute. We know neutrinos break this [00:18:00] rule. We've never seen electrons and muons break it, but we suspect that it might be breakable.

Jorge: Wait, what do you mean that neutrinos break it?

How do they break it? Well, we have

Daniel: this rule that you can't just change the number of electrons in the universe, or we can't just change the number of nuances in the universe. Neutrinos count in those same categories. That's what it means to say. We have three different kinds of neutrino. There's an electro neutrino, a muon neutrino, a town neutrino.

Right. And we do the same kind of account. For neutrinos as we do for electrons and for muons. So we don't seeans decay to electrons. We don't seeans annihilate with anti. But we do see neutrinos jump from generation to generation. You can have Aon neutrino, which then just changes its flavor to an electron neutrino as it flies through space, which seems to break this rule, that the number of electrons, the number of muons can't change.

Jorge: I guess it's confusing because you're saying the heavier neutrinos called the electron Nutri. We don't know what

Daniel: the masses of these particles are, but there's a first generation neutrino, which is the electron neutrino and a second generation [00:19:00] neutrino, which is the muon neutrino and a third generation neutrino, which is the town neutrino.

We don't yet know exactly what the masses of those neutrinos are. And if they follow the rule that the first generation is lightest and the third generation is heaviest. We don't yet know.

Jorge: Oh, I see. But do you know that the Neu Nutri jumps between generations? So maybe that's not a hard and fast rule for

Daniel: everybody.

Exactly. In fact, that sort of proves that this rule is not like deep and fundamental to the universe. Like it almost is even neutrino. Oscillation is pretty rare. So it's something the universe likes to do to keep these categories and to keep these numbers in balance. But it's not absolute. The way for example, conservation of momentum is, or conservation of electric charge seems to be absolute.

We've never seen any violate. Of conservation of electric charge.

Jorge: All right. Well, to get back to David's question then is what would happen if he met a version of himself, but where all the electrons are somehow made up of heavier electrons, nuance, it'd be like a heavier version of him, but also an anti wait, an anti [00:20:00] heavier version of him.

That's a lot of caveats there. So, uh, it's like you can make atoms out of anti. Particles. Right. And you can also maybe make them out of the heavier particles. So what would happen if you met an anti heavier version of you?

Daniel: it's a super awesome question. And I love that you thought about this. My first concern though, if we're being like hyper realistic about this is that second generation matter, like nuances is not stable, right.

And electron can last forever. It can orbit the nucleus. Be here for billions of years, but Aon is heavy and heavy particles like to decay. So Aon will decay into a Neu Trino and a w which then turns into an electron and another Neu Trino. And so neutrinos only last four microseconds. So Theon version of you is gonna very quickly decay to the electronic version of you, plus a bunch of energy.

Jorge: So you get, say hi really

Daniel: quick. okay. So let's imagine that you say hi, super quick. You high five, the anti muon version of

Jorge: you in a fraction of a second

Daniel: Uhhuh. It's not gonna be the typical [00:21:00] annihilation you expect from like, highfiving the anti-matter version of you. It's just like hitting another kind of matter, I suppose.

So

Jorge: basically nothing would happen. You would high Highfive your, your anti heavier version of

Daniel: you? Yeah. I think the anti N U could successfully Highfive you in the brief microseconds that they exist. Well,

Jorge: again, that's, um, maybe right? Like it's possible. They could an island. You, you haven't observed that,

Daniel: right.

That's right. It's possible. They couldn't island, but if they do, it would be at a very low level, you know, like one in 10 to the 40 anti ones might annihilate with your electrons. So that's pretty small, but a tiny fraction of you might go up and.

Jorge: Well, no, a tiny fraction of the antimon self with an eyelid, but maybe all of you would an eye Eileen, right?

Cuz you're in the minority.

Daniel: Uh, how are you in the minority? Isn't there one of you and one anti-me on you?

Jorge: Well, the antimon you version is much heavier.

Daniel: That's true, but that doesn't matter. It's still, it's a particle to particle annihilation cuz heavier particles and lighter particles can come together in Anni.

Jorge: Mm. All right. So, [00:22:00] um, some fraction of you would, might annihilate maybe in either case maybe just don't try it. that would be the safest thing.

Daniel: Ask this person, how did you end up being so MEIC that would be a fascinating question to answer. .

Jorge: Well, you, you only have a fraction of a second to ask them, Daniel, are you gonna waste it ti fiving, your antimon self or asking them boring

Daniel: physics questions.

Oh, maybe we should ask them the difference between smashing stuff and blowing stuff. Well, they

Jorge: would, they would probably just take the anti position. It would be fruitless discussion. All right. Well, I think that answers David question. And so let's get into our two other awesome questions about annihilation, but first let's take a quick break.

All right. We are answering listener questions here today. We answered a great one about antimon and meeting your antimon self. Now we have a question here from [00:23:00] Bob who has a, a kind of a personal question for Daniel. Hi, Daniel.

Daniel: My name's Bob. I'm a longtime fan of your podcast on occasion. You interview other scientists about their work, but I and I, and other fans were in the dark about your research.

Would you consider doing a podcast to talk about your major research? You could be the guest speaker in Jorge could interview. I could try to read your research, but for sure that's a lost. For us listeners, you could bring your ideas and findings to a layman's level. Like you always do. I think that would be informative and a lot of fun.

And I hope you

Jorge: think so, too. All right. Got some fans out there, Daniel at least

Daniel: somebody's trying to read my papers.

Jorge: even if they can't. Well, you write a lot of papers, right? Like 10 or 20 a year or something.

Daniel: Yeah. It varies a little bit, but my research group and I, we put out like 10 or 20 papers every year.

Yeah. Yeah.

Jorge: So it'd be hard to keep up. I guess

Daniel: it's a lot of fun. I have a group of like eight grad students and a few postdocs and some undergrad researchers and I collaborate with lots of. Really [00:24:00] fun and smart people around the world. So I have a good time thinking about these questions about the universe and how to use clever techniques to try to make crazy discoveries or use artificial intelligence, to try to help us sort through these crazy data

Jorge: that we collect.

Well, break it down for us, I guess Daniel, cuz I know you do some machine learning and you also do some dark matter stuff and also some particle physics stuff. Maybe, um, step us through from the beginning. Like what did you do for your.

Daniel: That's an interesting question. When I was a grad student in the late nineties, the most exciting thing in particle physics was the top core because we had just discovered it in 1995, we'd seen the top core after 20 years of looking for it.

Remember they had built like two different accelerators, specifically aimed at finding the top core, neither of which found it because it was so much heavier than they expected. So it was finally discovered at firm lab in 95. So when I started particle physics a few years later, the name of the game was understand this particle measure its properties and see, is it the top co that we [00:25:00] expected or is it something new and weird?

So for my PhD, I looked at some particular decays of the top core. When it turns it in lighter particles and try to understand if it was looking the way that we expected it to look.

Jorge: Mm. So you were getting your degree at Berkeley, but you were working in Chicago.

Daniel: Yeah. In particle physics. You're in nomad.

You just follow the biggest accelerator around. So I spent two years taking classes at Berkeley and then I shipped out to Chicago to do my research at the accelerator.

Jorge: And the, the top core, how do you make a top co yes,

Daniel: smash two protons together and they blow up. now at the Tevatron we smash protons and antiprotons together and they come together with a lot of energy and sometimes they annihilate into gluons and then those gluons can make a pair of top cos a top cork and an anti top co.

Mm.

Jorge: And then just so you measured like the remains of the annihilation and then what, what did that tell you about the top co?

Daniel: So we measured how often the top co was made, and then we calculated, how often did we expect it to be made? Like how likely [00:26:00] is that process to happen? How often do you expect to get top Coks.

And what we found is that it's made it exactly the level that we expected, which is why I didn't win a Nobel prize for my P thesis.

Jorge: wasn't the top qu the one that people, that it was like heavier than people expected or something, or not as heavy as people expected. Were you part of that or was that before you,

Daniel: that was just before my time, the theorist predicted that the top cork would be like about as heavy as the bottom cork, which is like five protons in weight.

So they built a Collider in Japan just to look for that and didn't see. So then they thought maybe they would discover it at CERN and they didn't see it there. So finally at the Tevatron in firm lab, they did see it. And it came out to be about 175 times the mass of the proton. So the theorists were way off in their initial predictions.

And so the advice there, the lesson learned is. Don't listen to the theorists, just go out there and look for stuff and you'll find surprises. Right.

Jorge: Right. Well, but you went looking for stuff and, and just kinda confirm what they had found [00:27:00] before. Was that enough for a thesis or did you have to come up with something like a, a new

Daniel: idea?

It's a great question. You ask. And it really goes to the heart of something of a conflict within particle physics. A lot of folks who are doing research these days. Are answering questions posed by theorists theorists say, I think the top core will be produced at this level. Go and check. And then experimentalists go and check.

And you might ask, is that enough for a thesis? Well, you know, it's a lot of work to get an accelerator to run and to build the detector, to capture these collisions and to make that detector work and calibrate it and analyze the data and do all the St. It's definitely a thesis level work, but I think that there's something else that experimentalists could do, which is not just look for the things that the theorists predict, but go out and see if there's something else out there that they didn't predict actually be explorers the sort of a pendulum in the field, which swings between the theory leading the field and the experiments leading the field.

And right now I think the theory is leading the field. They have big ideas about what we should look for. And I'd like the experiments to lead the field a little bit more. I'd like us to be sort of [00:28:00] exploration driven.

Jorge: Mm. Well, I guess it's kind of hard though, right? Because in particle physics, I mean, there's so much stuff that comes out of these coalitions.

You sort of need a theoretical basis just to kinda make sense or to find things in, in these, in all that data. Right. Like you, you have to look for deviations. You can't just look for like random things. That's

Daniel: right. Because there's so much data. If you just look for something weird, you're guaranteed to find it.

And so you do have to be a little bit careful about how you phrase the question. And so you can't just look for, like, is there something strange you have to think about what kind of strange thing could we discover, you know, and you have to put a little bit of a box around the kind of things that you're looking for.

And the useful analogy is like, say you land on an alien planet and you're looking for. What kind of things are you gonna look for? Are you only gonna look for cats and dogs and roses? You're pretty sure not gonna find that. So you gotta broaden it a little bit and think about, well, what kinds of life am I looking for?

What are the essential signatures that I'm searching for? And so in the particle physics context, what my group is trying to [00:29:00] do is think about what are the kinds of discoveries that we could make. That maybe wouldn't be anticipated. What are the things that we're not looking for, but that we could discover and would pretty clearly be a new.

That was the question we asked about 10 years ago when we started working on this project.

Jorge: Mm. So I guess you did that for your thesis. Do you remember the title of your

Daniel: thesis? Oh, the title of my thesis was something really boring, like measurement of the production of the top core in the EMU channel or something like that.

Jorge: he sounds so excited. . Well, I'm sure it was awesome. Um, and would make great reading and you did a postoc. And did you also work on that for your postdoc? For my postdoc,

Daniel: I doubled down on that. Exactly. And I measured the mass of the top co using a fancy new statistical technique, and we got the most precise measurement of the top co mass in that kind of data.

That anybody had ever had before, which is a lot of fun. And, you know, as a postdoc, you have to sort of like take one swing and hit a home run. You have like three years to demonstrate that [00:30:00] you're a good young scientist with smart ideas and you can turn those ideas and your energy into science. So you can't take like a risk.

That's gonna take 10 years to develop. You have to do something that you know how to do, and they will immediately pay benefits so you can get the faculty

Jorge: job. Right. Right. Which you did, you went to UC Irvine. And then did you switch focus or did you sort of continue on that track? Cause then that's when you joined the LHC right.

You switched from firm lab to the LHC and they were doing other things. Did you also have to. From the top cork to other things

Daniel: I did. I moved away from the top cork because I wanted to not just study the things that the theorists were predicting. I wanted to go out there and find new stuff that wasn't being looked for.

I figured that was the exciting thing about the large Hadron Collider. You had new high energy collisions that nobody had ever seen before. And so when you turn that thing on, all sorts of crazy stuff could come. And it could be what the theorists predicted, but I felt like more likely the discoveries would be something that they hadn't even thought of something crazy, something unanticipated.

And that was my [00:31:00] scientific fantas is to discover something weird and new that made everybody go, huh? That can't be right.

Jorge: Mm. And so maybe talk to me about this idea about like, how do you look for things that you don't know are there, because you know, there's so much data coming out and so many different kinds of explosions.

You sort of need to know what you're looking for so that you can look for deviations. That's kind of how particle physics usually works. How do you even look for things that you don't know? Are there.

Daniel: You're right. You need to know what to look for, but our idea was that you only need to know sort of the category of things to look for and the kind of things you should look for are the kind of things that you're good at seeing.

And so the large Hadron Collider is really good at seeing heavy particles that then decay into lighter particles. For example, the top cork is a heavy particle and it decays into electrons and muons and corks, all of which we can see. And when we measure those particles and put them together, we can see, oh, there was a heavy particle that was made.

It shows up as like a spike in your data. So all you need to do then is look for heavy particles decaying [00:32:00] into lighter particles in ways you didn't expect. There are some people out there who predicted heavy particles decaying into pairs of electrons. Pairs of nuances, for example, and people are looking for those and those are good ideas, but I thought, what about heavy particles decaying into weird pairs of objects?

Like what about a heavy particle decaying into a Higgs and an electron or something weird like that? Why aren't we looking for those things? Because we'd be good at finding them. And if we looked in our data, they would be pretty.

Jorge: Right, but you still need some theory behind it, right? Like you have to have a theory that says how often you should expect to see those kinds of weird things.

Or were you thinking about like totally unexpected, not even in the theory things

Daniel: I was thinking totally unexpected, not even theoretically anticipated actually took this idea to a theorist at UC Santa Barbara. And I said, what do you think about looking for these? And he said, it's impossible. You will never find these things.

I have three reasons why quantum mechanically it's impossible for that particle to ever be. I thought. Hmm. Well, that's cool because then I [00:33:00] could discover it. I'm gonna also blow up quantum mechanics.

Jorge: that's kind of, that's kind of risky Daniel though. Isn't it? It's like, I think unicorns exist. I'm gonna spend the rest of my life looking for unicorns, even though people tell you it's impossible. And then , you might not find it. Yeah. But

Daniel: you wanna take a little bit of risk with your science career. And one thing that motivates me is that we know so little about the universe.

We know there are big surprises out there and we're scratching our heads. About how the universe works. It's gonna take somebody thinking outside the box to stumble into something new and interesting. And, you know, I saw that same theorist a week later at a different conference. And he said, you know, I was thinking about that idea of yours.

And actually I now have five different theories that could all predict that particle. So you should go ahead and look for it. And the lesson I took from that is. The reason nobody's predicting these weird particles is not because they don't think they exist. It's because they just haven't bothered to think about them because, you know, the theory community, they're all very smart, but they tend to sort of follow a certain mainstream and all sort of think in the same [00:34:00] direction.

And so I think that experimentalists have this job, this opportunity to think outside the box and, you know, be open to the universe's surprises by looking for stuff that maybe other people think is. Mm.

Jorge: So is that something you're doing right now is looking for these unicorns?

Daniel: Absolutely. Yeah. We are looking for unicorns.

My plan for the next 20 years is to one by one, look for these things because then either you'll find them and you'll say, wow, look, I found this thing. Nobody expected to king into this weird pair of particles, or at least you'll rule them out. And you can say conclusively, like. There are no weird resonances produced at the LHC.

Even that negative statement is some knowledge about the universe. Mm,

Jorge: cool. Well, I, I hope you find that unicorn. Uh, and also one thing that's interesting about your research is you use machine learning or

Daniel: AI. Yeah. My background actually is in physics and computer science as an undergrad. I'm really interested in machine learning and artificial intelligence.

My brother is a professor of artificial inte. So it's something I've really been interested for a long time. And we have a lot of data that's [00:35:00] produced by our colliders. It's like petabytes of data every day. And every collision we get like hundreds of millions of pieces of information. And the way you can tell the difference between like, oh, this was a unicorn or was not a unicorn is sometimes very subtle correlations between those measurements.

And artificial intelligence is very good at handling very high dimensional data and summarizing it for you, boiling down the crucial information, helping you make decisions,

Jorge: right. It's also good at making fake Tom cruises for TikTok videos which is, which blows my mind. But you're saying you can actually use AI to kind of replace physicists almost to analyze, uh, the data from curi.

Daniel: Almost 10 years ago. Now I went over to the computer science department here at UC Irvine. And I said, our networks are kind of dumb. We were using neural networks already, but they weren't very smart. We found that if you gave the same problem to a physicist, they could usually do better at finding new particles or understanding what was going on.

And so they took on the challenge and they said, well, your networks just aren't [00:36:00] deep enough. And at the time there was this revolution in neural network. People have probably heard about called deep learning, where basically you just make your networks have more layers so they can learn more complex functions.

And they had deeper networks and their networks were actually smarter than our physicists. So they did a better job than we were doing at pulling this information out of our data. And that was kind of a big breakthrough in particle physics. People realized that we should be using deep learning because these colliders are expensive.

It costs billions of dollars to collect this data. So we might as well get as much as we

Jorge: can out of it. Wait, do you actually feed it like the raw data from the Collider or the post filtered data or just, just like the. The numbers that a physicist would look at.

Daniel: So these networks can't handle like the actual ocean of raw data, like drinking straight from the fire hose.

But what we were able to do was give them sort of more raw data than the physicists usually take, like at a lower level, higher dimensionality than physicists usually analyze. And they were able to reverse engineer a lot of the quantities that physicists use [00:37:00] to analyze these.

Jorge: What do you mean? Like can detect the Higgs bows on from the data for, for the Higgs bow on discovery, without

Daniel: saying, Hey, here's the calculation you should do on these photons.

You just sort of give it all the information from the event and it figures out it learned how to discriminate between Higgs boons and non-G bosons. And if you peer inside a little bit, you can sort of tell what it's doing. And it's found a lot of the same kinds of calculations that physicists do when they think about these problem.

Jorge: Right. Right. And the advantage is it doesn't drink as much coffee as a post and it works

Daniel: all night.

Jorge: yeah, you can enslave. Until in flavors, you Daniel. But

Daniel: one of the challenges of course, is understanding what it's doing. There's lots of examples of neural networks being trained to solve a problem. And then it turns out it's solving it.

Not exactly in the way you expected. You may have heard about this case when. They trained a neural network to tell the difference between wolves and dogs from pictures. And they did really, really well, but then they discovered that what it was actually learning was that the pictures of wolves had [00:38:00] snow in the background and the pictures of dogs had grass in the background.

So if there was snow in the background, it called it a Wolf. And that's not exactly very interesting. Right. This didn't tell you anything about the difference between dogs and wolves. So we are trying to understand what our networks are doing to make sure. That, what it's learning is really physics is not just some nonsense about the data, like whether it was snowing

Jorge: that day.

All right. Pretty interesting. Uh, it sounds like you're gonna put up a lot of, um, physicists who don't yet have tenure outta a job. Maybe

Daniel: I collaborate with a lot of young physicists. They're great folks. Uh, lots of really fun ideas. And, uh, have a good time.

Jorge: he totally just avoided that comment. All right.

Well, um, hopefully that explains what you do for, uh, your research Daniel, and I guess if people wanna find out more, do you have anything, like, do you write this up anywhere in a more accessible way or is it all just scientific paper? Well, I guess one thing I find is you can usually read the introduction to papers and that usually get, and the conclusion, and that gives you kind of a pretty decent overview of things without having to get into the nitty gritty.

Daniel: Is that how you [00:39:00] read papers? Jorge? Are we now learning? You never actually read papers. You just read the abstracts

Jorge: well, it depends, right? Like if I just need to know what. Going on. I'm not gonna read all the

Daniel: details. I'm taking that as a yes, no, I haven't written anything accessible at this level about my research.

It's mostly, uh, heavy duty science writing and then this kind of accessible writing, but I haven't really bridged that gap. Well,

Jorge: as the, as you said earlier, you have office hours and you can actually talk to Daniel in our discord channel. So, um, go ask him questions. If you wanna know the difference between a Wolf and a dog, I guess

Daniel: well, thanks Bob, for asking about my research.

I appreciate it.

Jorge: All right. Let's get to our last question here. And this one is a, it's a doozy it's about aliens and multidimensional weapons. So let's get into that. But first let's take another quick break.

All right. We are answering [00:40:00] listener questions here and they all seem to have a theme of annihilation, like blowing things up or blowing Daniel's career up. I, I guess, yeah. How did you, why did you love the one about you in this annihilation team?

Daniel: because that is my job. I'm annihilating protons all the time.

All day long. Oh, I

Jorge: see. You're not annihilating young researchers' career by inventing AI. That does

your

Daniel: job. no, no facilitating their careers, right? Absolutely. I'm giving them new tools to do the job better.

Jorge: Giving them more nap time. Right? Well, we have, uh, one more question here for today and this one is pretty interesting and it comes from Chris, from Chicago.

Hi, Daniel and Jorge.

Daniel: Thanks for taking my question. It concerns a scenario in the book deaths end, which is the final book in the three body problem trilogy. In this book, it's noted that supremely advanced civilizations

Jorge: used dimensional weapons against

Daniel: potential threats in the universe to eradicate them, meaning that in the beginning of the universe, it started out as an 11 dimensional universe, but over [00:41:00] time civilizations that were able to make themselves into lower and lower dimensional beings used a weapon.

To drop a dimensional bomb on a particular part of space to effectively end their existence. It would be akin to someone setting off a two dimensional bomb in our a space. And then from the point of the explosion, 3d space collapsed into 2d space infinitely from the point of origin, a. So my question is could an advanced civilization as described in this scenario, use a weapon that sets off a quote unquote lower dimensional bomb to collapse, dimensional space, time to the next lowest dimension.

Thanks for making science accessible and helping me and my kids understand and explore the

Jorge: universe. Cool. Thank you, Chris. Great question. And it's awesome. He listens with this. Yeah,

Daniel: exactly. I wonder if he reads books called death's end with his kids also

Jorge: but, uh, death's end. It's actually a positive thing, isn't it?

Daniel: Mm. Yeah, I suppose so. The end of death. Life's the beginning. , [00:42:00] there's lots of alien invasion and catastrophe for humanity in this book

Jorge: though. Mm. Well, you just described most Marvel movies. Um, so, and people let their kids watch that all the time. So sounds like we've moved past that

Daniel: point. Didn't you?

Welcome to the parenting podcast with Daniel, Jorge .

Jorge: Yeah. Do not listen to parenting advice from, uh, cartoon and physicist. But anyways, so his question, I guess, is there that there's a scenario in this book in the third book of this famous and best selling trilogy of science fiction books. What's the trilogy called the first

Daniel: book in the series is called the three body problem.

I think it's

Jorge: called like the three body trilogy, right? Or that's what they call it. Yeah,

Daniel: you're right. The whole series is sort of called the three body problem trilogy. This says three books, the three body problem, the dark forest, and then deaths end death's end is the last one. Wow. Key titles. yeah, so they're super bestsellers and they were translated into English by Ken Lou.

Who's also an excellent award-winning science fiction writer and, uh, hugely [00:43:00] popular. I've heard them described as. Chinese star wars. .

Jorge: Whoa, I don't know if that's a good way to describe things or not.

Daniel: Well, in the sense of like, you know, the cultural impact, I think, I mean, if you wrote something and they described it as the new star wars, I think you'd be pretty happy about that.

Jorge: Mm, interesting. Well, uh, so in the, I guess in the third chapter of the, of this trilogy, uh, death end, there's something that happens with aliens. Like they try to kill us, I

Daniel: guess. Yeah. So the first book sets this up because we discover distant aliens that live around this world that has multiple sons. And that's why it's called the three body problem.

And then the next two books are all about how you deal with aliens, aliens, attacking. We actually did an episode recently about this idea of the dark forest that maybe the universe is filled with dangerous civilizations. And it's not a good idea to get in touch with folks, cuz then they'll try to come and kill you.

So death's end is the fly max and that's when like the aliens come and they invade and their solar system is attacked. Wow.

Jorge: And then that's where the lightsabers come in or . [00:44:00]

Daniel: These are Chinese light savers. So I don't know how that translates. I see

Jorge: fireworks, maybe they're fireworks. That's right. Yes.

They're um, light fireworks. but then somehow the concept here is about multi-dimensionality. So you mentioned in this question that in this universe of the book, I guess we know that the universe started with more dimensions and slowly they've been collapsing or what? So the idea

Daniel: in this book is that they have some.

Which can collapse space from a certain number of dimensions to one fewer. So you take space, that's three dimensional, like our space and you collapse it to two dimensions. So things then have to live like on a surface instead of living in a volume. And the idea in the book would be that this would be an effective weapon.

Because you're smashing anything that used to be in 3d. You're smashing it now down to 2d, which makes it pretty hard to survive. And so in the long arc of the history in this book, the universe started out like 10 dimensional and there were these beings that were fighting each other. And one way they would fight is that they would make themselves nine dimensional and then would collapse the universe from 10 dimension sound to [00:45:00] nine before their enemies could adapt, then crushing their.

Wow.

Jorge: That sounds like the most complicated way to do, um, which war here, but I guess maybe step us through a little bit what a dimension is. I guess a lot of people, you know, as we talk about in our books, a lot of people maybe think of dimension as like another realm or like a doorway into something else, but really physicists, just think of it as another way to, to move.

Yeah.

Daniel: Dimension has been co-opted to mean like a parallel universe or another realm or something like that. It's not another place. It's an aspect of our universe. You say, it's a way that we can move. So our space, we think has three spatial dimensions, which means you can move in three different directions, like up, down forward, backward left, and right.

Those are three different dimensions. And if space was four dimensional, there'd be like another direction that was perpendicular to all three of those, right. That didn't overlap. That was like a unique way that you could move. So our space, we think is three [00:46:00] dimensional. Plus then there's the one dimension of time, which people sometimes fold together in two space time.

But that's what a dimension is. Right.

Jorge: And actually string theory thinks that there are maybe dozens or if not, hundreds of dimensions that, but they're just so small. We can't feel them or see them. Yeah. Lots

Daniel: of theories of physics make more sense. If space has additional dimensions, more than the three that we can see and some string theories like 11 dimensions, some 26, there are arbitrary number dimensions in other theories.

They're all there because the math makes more sense in those dimensions. Not because we have any evidence in our universe. That those dimensions exist, but just as you're putting the theory together, it works better if space has more

Jorge: dimensions. Right. So then, um, in this book, um, I guess there are many, or there were many other dimensions, but they're not small, I guess they're assuming that in these.

Other dimensions in the book, they weren't like small or little loops. There were like actual other directions you could move around in and grow in, be

Daniel: in, yeah. When theories develop ideas [00:47:00] about our universe, they have to try to match our experience. And so they're gonna have a theory with 11 dimensions.

They can't make those other dimensions the same as our dimensions, they have to be weird or different. So as you say, maybe our kind of matter, doesn't move along those dimensions, or maybe those dimensions aren't infinite the way X, Y, and Z are. They're like weird little loop. But in this book, it seems like these aliens used to move and live in these other dimensions.

So probably they were infinite dimensions. You imagine like an 11 dimensional universe with 11 different directions. You could move as far as you

Jorge: wanted. I guess somehow in this universe that the book is in or describes aliens, figured out how to like collapse themselves to a smaller number of dimens.

Daniel: They've like adapted to living in a smaller number of dimensions. Like if you could make yourself a thin sheet of paper and still somehow have all of your biology and all of your synapses work, if you could do that, then you could safely collapse the universe down to 2d and you would survive. And anybody who wasn't prepared would not survive.

Like [00:48:00]

Jorge: you could just shed a dimension or something, but that would be weird, right? Like it seems almost unthinkable. Like how could we somehow adapt to being just 2d? Like our, all of our organs are 3d. Um, if you just smash 'em together, they wouldn't quite work the same way. Yeah. I

Daniel: think it would be a pretty big engineering project.

Right. You have to think about how things flow, you know, like how fluids flow in your body and you know, the tangle of arteries you have, you can't just like lay that stuff out. I dunno if you've ever seen that exhibit in a museum. Plasticized human bodies. You can see the incredible tangle of organs and the neurons.

And it's definitely a 3d setup. So you can't just like lay it flat. You'd have to definitely reorganize it. It would look more like a circuit board, right? A circuit board is like a 2d representation of relationships between things so that you try not to cross things.

Jorge: And so somehow these aliens can do that.

And somehow they also figured out a weapon, I guess, that can destroy dimensions or

Daniel: collapse them. Mm-hmm collapse. Dimensions. Yeah. And they use it on the solar system and like Jupiter is [00:49:00] flattened into a disc. It's pretty dramatic stuff.

Jorge: but how does it work? Like you, you know, you shoot it or you like aim it or you send like a plane that somehow absorbs dimension.

Like, do they talk about how that works? Yeah.

Daniel: They take a two dimensional plane and they shoot it into the solar system. And anything, it touches gets converted into two dimensional matter. Whoa.

Jorge: Sort of like the Phantom zone in the Superman original movie. right. Is that what you mean? It's like a, like a mirror that float around in space and if it touches you, you're now trapped inside the mirror.

Yeah.

Daniel: I'm not exactly clear on how big this 2d plane was that they shot into the solar system, but it touched Saturn. For example, before touch Uranus, cuz Uranus was on the other side of the sun. When this thing came into the solar. So, yeah, it's definitely like you get touched and then you get collapsed.

Oh,

Jorge: I see. And I guess the premise is that somehow these aliens have this technology and I guess they can go from any dimension to a lower dimension. Right. And so, because we are in 3d, they send [00:50:00] us a 2d fire.

Daniel: Exactly. They smash us down to two dimensions. They

Jorge: flatten us but they're, they're a 3d too, or they used to be higher.

D it's

Daniel: not clear to me in this book, what dimensions those aliens are. They definitely used to be higher dimensional. Like they started out 10 dimensions and it's pretty hard to imagine, like reengineering, a 10 dimensional being. Down one dimension. Now imagine reengineering it down. Eight dimensions to two dimensions.

That seems impossible, but Hey, it's science fiction for a reason.

Jorge: yeah. All right. Well, I guess the question from Chris is whether this is possible, cuz he has could an advanced civilization set off a dimension weapon to collapse FaceTime. So I guess, um, Is there any kind of basis for that? Like, can you just collapse dimensions in, in space time?

Well, you know,

Daniel: the first caveat is we just really have no idea how space works, how many dimensions there are and what the rules are. We're just really beginning to discover, you know, what space is and the shape and structure of the [00:51:00] universe. So we're early days, but with our current understanding, that seems pretty flat out impossible.

You know, something that you can do with the universe is you can change, like how much space curves you could put mass in it, which bends it. You can change its shape, but changing its fundamental topology, like how it's connected and the dimensions. There's no way we know of that can do that. Like no amount of mass or energy can change the fundamental shape of the universe or the number of its dimensions.

I mean, you could make these dimensions bigger or smaller, but you can't rule them out entirely. Right?

Jorge: Well, I guess there's two questions. One is, I mean, technically it is possible to take something in our world that's 3d and make it 2d. Right. It's called squishing mm-hmm it's called squishing. She just like iron it, right?

Like you just, you squish it it'll become 2d. It'll be, I mean, it'll be super messy. But technically you, you could do that. You just wouldn't trap it to move in

Daniel: 2d mm-hmm and we did a fun podcast about whether there are 2d objects in our universe, and there's some fun systems where like, [00:52:00] electrons are trapped into a plane and they move around in new, weird ways following 2d, quantum mechanics, which it's pretty interesting.

So yeah, that's something you can do. You can't have 2d objects in a 3d world.

Jorge: Right, right. But I guess maybe. The question is, is it possible or would it maybe require like an infinite amount of energy to just get rid of a dimension?

Daniel: I think the most you could do if a dimension was curved, is that you could enhance its curvature.

Right? And so you could take a dimension which is like rolled up and you could make it basically have zero radius. So you could shrink it down to almost zero. The way you enhance the curvature in a dimension is you just add energy, right? Energy curves space. And so I guess in principle, if a dimension is not infinite, if it's already finite, then you could get it to collapse.

You could shrink it down by pouring in a lot of energy. I don't think you could change an infinite dimension, like our X, Y, and Z. I don't think you could collapse those cuz you can't bend an infinite sheet into a sphere.

Jorge: Right. Right. But I guess, you know, I think what you're saying is that, you [00:53:00] know, we know that space is expanding right now.

Like that the whole universe is expanding and so it could also contract. Right. Uh, I think maybe the concept might be like you collapse only one of the dimensions. Like somehow you figured out how. You know, space expansion works and you can somehow collapse one of the dimensions or maybe even expand it.

And so if I could do that in an area, then everything that was in that area would collapse into two dimensions or would it continue to be the same? It's just that to us, it would look squished in, in one dimension. Yeah. You could

Daniel: definitely use space to squish stuff, right? Like pour a lot of energy into, so.

Space will bend. And you could use that as a press, like a one dimensional black hole or something crazy like that. Yeah.

Jorge: One dimensional black hole. Yeah. That's what this kind of would be. Right. Well, I think

Daniel: that's a way you could compress stuff that wouldn't change the dimensionality of space itself.

However, Space would still have that higher dimensionality. It'd just be that you'd have created like a 2d object in a 3d [00:54:00] space that wouldn't actually compress space. Like if the universe is infinite and goes on forever, there's nothing you could do to remove one of those dimensions. If the universe, however, isn't infinite, if it like.

Loops around on itself. Like we've talked about maybe in the shape of a donut diverse sphere, then you could potentially collapse one of those dimensions to have a very small distance wouldn't actually technically be gone, but it might practically be gone. It might be infinitely small.

Jorge: Right? Right. Well, I remember in, in, um, when I took math classes and talked about like matrix transformations that, you know, certain transformations have, uh, something called a null space, right.

Where you essentially get rid of a dimension when you transform. Something by that matrix. Could you imagine something like that being done to the loss of

Daniel: the universe? Well, when we talk about transformations and we're talking about space, we're really just talking about looking at space from different points of view, like transform your point of view.

You transform your coordinate system. You don't usually transform space itself, though. We don't understand why or how it's just sort of born with certain [00:55:00] features. Those features are like the number of dimensions and also the shapes of those dimens. And we don't think that it is any way for energy or mass to change those things.

It could change the radius. It could like compress it or expand it, but it can change that fundamental nature as far as we know. But I do think it's a really creative thing to think about. Like, and that's the kind of thinking that's gonna make some theorists out there. Go. Hmm. Maybe there is a way actually I used to think that was impossible.

And then a week later I had five ideas. So it's a, it's a great creative thinking. And I think it's a really awesome part of this book. Not something I'd ever heard of

Jorge: before. All right. Well then to answer Chris's question, uh, the answers is to couldn't advance visualizations, uh, collapse, dimensions as a weapon.

Um, doesn't seem likely to Daniel, but maybe, I guess you're gonna think about it. check

Daniel: back with me in a week.

Jorge: We'll. And I guess another question is, are there E walks in this third installment of the star wars? the trilogy, there are two de walks. too many, too many E walks is what you're saying. Two D E walks is too [00:56:00] many E walks.

Daniel: I love the E walks man who hates E walks. Really? What kind of person you have to be to not like E walks. I just heard a

Jorge: theory that originally, maybe the EVOS were supposed to be woo. But somebody, it got changed at the end or something. Oh wow. Executive producers did their job. That might be just a fan theory though.

I don't know

Daniel: well, until then I think that Saturn and the rest of the solar system are safe from being collapsed into 2d objects. For

Jorge: now you still have, uh, some room to move around in. All right. Well that answers all of our listener questions. Thanks again to everyone who submitted questions. If you have questions about the universe, about anything we talked about here on the podcast, please let us know.

We'd be happy to answer them.

Daniel: Thanks very much to everyone who writes in and interacts with us. We love hearing your questions.

Jorge: We hope you enjoyed that. Thanks for joining us. See you next time.

Daniel: Thanks for listening. And remember that Daniel and Jorge explained the universe is a production of iHeartRadio or more [00:57:00] podcasts from iHeartRadio. Visit the iHeartRadio app, apple podcasts, or wherever you listen to your favorite shows.