Physics Special with Emily Duden

<INTRO MUSIC>

All

Hello, howdy, sup?

Lori

This is a very special Hugo, Girl! the podcast. Where normally we read Hugo award winning novels and we have read The Forever War by Joe Haldeman. And it has a lot of time stuff. So we thought let's get a time stuff expert, also known as a physicist!

Haley

We phoned a friend.

Amy

We did phone a friend. But what we really did was Skype a scientist.

Lori

Yes! Which is a really cool program and <dreamy harp music to indicate a flashback in time> Okay, Hi, Emily!

Emily

Hello, how are you guys?

Lori

Good. Thank you so much for joining us today for a session of Skype of scientist. And you're going to teach us all of physics today, right?

Emily

Yeah. We're gonna cover everything.

Lori

I mean, we have, we are self taught scientists. Most of our education is through speculation, rank speculation after we read a science fiction novel. So I think we're going to pick it up pretty quickly.

Emily

Yeah. Soyou pretty much know everything.

Haley

Yeah. Yeah, and also three former English majors. <laughter>

Lori

So you have a lot to work with. So why don't we would you want to go ahead and just introduce yourself? And if there's anything you want to say about Skype a scientist, like please go ahead and do that.

Emily

Yeah. All right. Well, my name is Emily. I am a first year graduate student at Brandeis University. I'm studying particle physics, and I'm working on the ATLAS experiment. So Atlas is a really cool particle physics experiment at the LHC in Switzerland, and we are investigating all sorts of super interesting questions like, What is dark matter? And why is there more matter in the universe than anti matter? And what are the fundamental building blocks of matter? So I am here because of Skype of scientist, which is a cool program that allows classrooms and groups that just want to learn more about science, talk to scientists. So if you have a group that wants to talk to a scientist, you should definitely check that out. And you'll get matched with someone who can tell you all about it.

Lori

Thank you, this was so exciting. I was looking at my email, like every second, and when we got matched, I was like yayyy! I was so excited. And I want to let people know too, that Skype a scientist is free, donations are encouraged and we're excited to be able to make a donation. After we finish our conversation today, we're definitely going to do that. But just want to let people know that it is a very accessible program. So if you have questions, or have a group that has questions, this is something that's accessible to everybody.

Emily

Yeah, awesome.

Lori

Um, okay. So that matter and anti matter thing sounds awesome. So I might like want to do a follow up session on that. So the, the reason, the thing that prompted me to try to sign up for this, and I heard about it on Ologies podcast with Alie Ward, which it's like, probably anybody who listens to podcasts listens to or like, knows about. It's funny for me to tell our like, dozen listeners, hey, podcast called Ologies. But anyway, we heard about it there. And so one of our listeners, Emmanuel asked, or gave us like a topic to discuss in the context of our current read, which is The Forever War by Joe Haldeman. And he asked, you know, what do you think about the impact on relationships, how they're affected by relativity and time dilation? So, in that context, I thought, maybe I should understand those things better. So that's sort of the theme of the conversation today.

Emily

All right, well, sounds good. We can talk all about time dilation, I do particle physics and time dilation is something that is very relevant to what we're doing. So it's a super interesting topic. And it's, I think, crazy to think about that it's real. And it's not just science fiction.

Lori

So is there like a simple definition of time dilation?

Emily

So without understanding why it's happening, you can understand what's happening pretty easily and that is that time is moving slower for someone who is moving really fast at speeds close to the speed of light.

Amy

Nope! What?! <laughter>

Lori

Go Amy, go!

Amy

Say that one more time, slowly.

Emily

If you are standing still and you have someone who is going really fast, that constant velocity, you'll see that if they have a clock and you have a clock, their clock is moving slower than your clock is. So you could reunite and then you would find that you may have aged more than that person who was moving has aged.

Amy

Okay, so can I ask you about that clock? That hypothetical clock that they're holding? Okay, so clocks are a thing we have on Earth. And I don't know what they measure. <laughter> And I'm wondering if so you're talking about the, the clocks that they're holding? Like, okay, what do clocks measure? And why is what clocks measuring going to be different for the person going really fast?

Emily

Yeah. So what you're asking me is, what is time <laughter>

Amy

One time Haley did a really deep dive on Wikipedia about time, or I think or maybe that was me. I can't remember. And I thought we learned something, but I guess we didn't.

Haley

The Wikipedia for time is one of my favorite entries, it is - it's fascinating.

Emily

Wow, well, so you're already an expert, so I should let you take over here. <laughter>

Lori

I need the help though, so please, please go ahead.

Emily

So a clock basically measures just how many times something happens, our definition of a second is just a number of times that a cesium atom oscillates and energy.

Amy

Oh my god, wait, what?!

Emily

So we're just counting how many times things happen.

Lori

I didn't know that. I had no idea that a second was actually tied to like, some observable thing I thought we just like decided, like, let's just divide, it will divide into 60. Because 60 is a hard number to use, unlike a 10 or 100. Like I've really I - okay!

Lori

Wow.

Emily

So I'm not sure how the history of that came about, I'm sure what happened was they wanted to divide they like knew what a year was in a day was, and they wanted to divide that up into some other units. So they basically had a human version of a second. And then scientists went and wanted to define that and something more quantifiable. So they defined it as however many oscillations of a cesium atom

Amy

So the day the year is our earth is relative to our Earth, right. So like it has to do with the sun and the earth. <Emily: Yes. Right.> Okay. So yeah, when we're deciding that people are, so we're talking about time dilation, and deciding that time works faster for some people than others. Is there a way to define that without resort to like how we define a year in a day? Because that's different than the rest of space? Right? I don't know if that makes sense.

Emily

Yeah, absolutely. So that this all goes back to the to the principle of relativity. So relativity describes why time dilation is happening, describe some other things like length contraction, all the goofy things that happen when things move really fast. And the principle of relativity is that we cannot detect our own uniform motion, relative to empty space. From that one statement, we get all of these great things like the fact that the speed of light is constant in any reference frame. So I can explain to you guys, if you're interested, how that comes from that. And then how from there we get time dilation?

Lori

Yes, please.

Emily

It takes no math. But you know, sometimes it's a little hard to wrap your head around.

Amy

Wait, let me pause you for one second. So the whole concept of relativity is that you can only know the speed of something relative to something else.

Emily

Yes, so if you're flying on a plane, you don't feel that you're flying. It just feels like you're staying still to you. It could just be that all the fields and things that you see below you are moving. From your perspective, it doesn't really, it doesn't really you don't feel that as a physical thing.

Amy

Right.

Emily

So, yeah, everything's moving relative to other things.

Amy

Just depending on what your vantage point is, yeah. Okay.

Emily

Yes. So I have a picture that I could show you guys, but I know your listeners can't see it. But maybe it would help you ask some questions. Am I able to paste this in the chat or something?

Lori

I'm not sure. We can definitely put the picture up on our social media when we post that episode.

Haley

I remember seeing something once where like, if you were going at the speed of light, then you turn on a flashlight. Nothing can go faster than that too, right?

Emily

Yes, nothing can go faster than the speed of light, not even information.

Lori

So your flashlight would be useless?

Emily

Yeah, I suppose so. It would not. Am I able to email this to you with that? I'm sending two pictures right now. All right, you ready for your physics lesson? Yes, we're ready. Alright, so this is this first picture is explaining why the speed of light is constant. So you can imagine that you want to measure a wave traveling through a slinky. So the first, the left hand side of the picture is showing a person holding up the slinky, they push in the end of the slinky, and they send a wave down that slinky, we have another person that is holding a meter stick up to the slinky. And they're using that meter stick to measure how long it takes the wave to travel one meter. So as that compression in the slinky reaches the front end of the meter stick, they're pressing go on their stopwatch, and as it's leaving the back end, they're pressing stop on their stopwatch, and then they know how long it takes the wave to travel a meter. But in the image below, we're thinking about what happens if you're running towards the person who sent the wave down. So what if you're moving at a constant velocity? Well, if you're moving, then the time it takes for the wave to get to from the front end of the meter stick to the back end of the meter stick is less. So you would measure a faster velocity of that wave if you are moving. The thing that is maybe not so intuitive is that this is not what happens when we look at light. So on the right end of this picture, we have a person who's holding a meter stick. And at that, either end of the meter stick we have a photocell, so the photocell is going to tell us when light hits it. So let's say we send a pulse of light through those two photo cells. That will tell us, it'll trigger the first photo cell when it hits that and then it will trigger the next one. And a little bit of time later. And we'll be able to tell how fast the light traveled through that meter stick. But if the person is running towards the person who sent the light through, what happens? Well, if it's the same as a slinky example, the light should be measured to be going faster. But that's not actually what we find, we find that the the light is going at the same speed when we measure this experimentally. And the reason that is it all goes back to the principle of relativity, it's that the the wave in the slinky is traveling through the slinky. So we can tell the velocity relative to the slinky. But the light is just traveling through empty space. So we can't tell when we're moving relative to empty space. So that was a lot that I just threw at you. How do you feel about that?

Haley

Is it just because the speed of light is the cosmic speed limit? Like nothing can go faster to it? Or is it?

Emily

Yeah, I mean, that that is why the the speed of light is the cosmic speed limit.

Haley

What if the man was moving at the speed of light in the opposite direction? So wouldn't matter?

Emily

The the person who was holding the meter stick? Yeah, then the light would never reach the meter stick. So

Lori

Oh, yeah. Because they'd be traveling at the same speed.

Haley

If it was going towards the guy holding the laser, and the laser was going towards the meter stick?

Emily

Yeah, you would still measure the same speed of light. Crazy how that works. So that's not really something that we can intuit because we never get close to the speed of light. So we wouldn't know that things happen. So things are so weird when you move at the speed of light.

Haley

Is it proportional too? So like, if you go at half the speed of light? Is there half the effect? Or is it?

Emily

Yeah, so the the constant that you're multiplying by is the square root of one minus v squared over c squared. So c squared is the speed of light squared, and v squared is your velocity squared. So if you're moving close to the speed of light, you have one minus a number that is about one. So you have a bigger effect. If you're just multiplying something by one, you get the same number back but the closer V is to the speed of light, the bigger the effect.

Haley

Cool.

Emily

So have I convinced you that the speed of light is constant? No matter how you're moving?

Lori

Oh, I just believe you. <laughter>

Haley

Yeah, I think the speed of light constant thing is just like, based on what we know about physics now, like, if you look at, like what we knew about physics 600 years ago, like, how much different could it be in 600 years from now? Like, but that won't change?

Emily

Yeah. Now, we didn't even know what light was 600 years?

Haley

Yeah. So I think that's just like, it's just like the agnostic, English major part of our brains are like, Well, is it really?

Emily

Yeah, well, I definitely when I first learned about this, I was like, I'll just accept it, the speed is constant, no matter how you're moving.

Lori

That's where I'm at. I'm like, just, I believe you. I believe it!

Haley

That's all you really can do.

Emily

Well, the the next part of this, the the fact that time dilation happens is I think a bit easier to understand, just using the fact that we accept that the speed of light is constant. If you have a clock that is moving through space, if a clock is moving, it has to take longer to click. So that is what the next, the next image is explaining. So I can briefly talk about that.

Lori

Sure.

Emily

So we talked to, we talked about what time was before, and how it's just a measure of how many times something happened. And that's our unit of time. So we can make a clock, like the image on the left, that is just a plate on the bottom, a plate on the top, and a beam of light that is traveling between those two plates. And we'll say one unit of time is when the the light travels from the bottom plate to the top plate back to the bottom plate. So that is our clock. Then if you're in space, but you're not moving, you're just kind of sitting there chilling in space, and you have an astronaut that's flying past you at a constant velocity, you both have this clock, and they're synced up, you can see that as the astronaut is moving, the light needs to travel a greater distance to tick off one unit of time, it has to not only go up and down, but it has to go in the direction of motion of the astronaut. So our one unit of time is going to take longer to happen for the astronaut than it is for us. So time is moving slower for the astronaut.

Lori

Oh my god, that was so helpful! <laughter>

Amy

So how does that relate to how your body ages though, right? So you have time is measured? I understand why the measure of time would take longer, but given that image, so but how does that relate to why you wouldn't age?

Emily

So this yeah, so our clock is a time clock. But a clock can be anything it could be us and how we progress through our lives. It could be a wristwatch. So say like we have a different time measuring device, maybe it's a watch, maybe it's just us and our aging selves. We can kind of think of this as a proof by contradiction. So if we did age differently, we end up violating the principle of relativity. So let me explain that. So say you have another clock, that's just your regular gear clock, and the astronaut is displaying that clock right on their window alongside their light clock. So we just talked about that we know that the light clock has to move slower from the viewpoint of someone who is not moving. If they can also see the regular clock, and that clock hasn't changed, that clock is synced up with their own clock, then they're seeing that the light clock is moving slower than the regular clock. And so the astronaut must be seeing this too, that they have a light clock that is moving slower than the normal clock. But they were synced up at the beginning of this thought experiment. So what happens? Suddenly the light clock started moving slower for the astronaut, all the astronaut has done has moved is has moved in a constant velocity. And what we know from the principle of relativity is the astronaut should not be able to tell that they are moving at a constant velocity. So the two clocks becoming out of sync would violate that principle. So all the everything that happens is slower, not just this light clock

Haley

So that would count if your clock was bouncing a basketball, just up and down like that, because of how you're moving through space. Hitting the floor hitting your hand it's going to travel. It's gonna travel so much because of how fast you're moving, that it's gonna affect the way that time is perceived, or not perceived just is. Yeah.

Emily

From your perspective, if you're the astronaut who's moving it, you won't be able to tell that anything's weird. But from someone looking at you, yes, it would be the same thing no matter what your clock is, whether it be a basketball or light. Oh, yeah, crazy.

Lori

So are there real world examples of this? Like, for example, I think there's like, there's like the atomic clock on the space station is like, yeah, itty bitty bit off from what it would be on Earth, right?

Emily

Yeah. So we've, we've done this, we've measured this a famous experiment was the Hafele-Keating experiment, which I'm probably butchering the name. And that's where some people had some atomic clocks. And they were all synced up, they threw a couple of them in a plane, and they flew the plane around the world, and then went and compare the clocks. And they found that at the end of the day, they were different. The clocks were different.

Lori

So even a plane. Wow!

Emily

Yeah, so it was a difference of like, probably microseconds, but with an atomic clock, you can measure that small difference.

Lori

That's so interesting, because we do you know, what science fiction and movies and things like I think we tend to think of this and only really considered on an enormous scale. Like if I'm way out by Jupiter or something, you know, using that as an example, because I just watched interstellar the other day. But yeah, like to think of that phenomenon occurring observably on on Earth, like all within Earth is so interesting on something as mundane as a airplane ride.

Emily

I know, I know, it's so crazy to think about that. I mean, it's a difference that we would never be able to feel. But it's there all the same. And these big cosmological things that we're thinking of can be measured, if you can think of a clever way to do it.

Lori

So if I travel around the earth a bunch of times on a plane, then I will not age,

Emily

You'll age, maybe microsecond, less than the people -

Amy

What if I just keep doing it?

Lori

Just stick with moisturizers, Amy.

Amy

Am I gonna pull Mary gay and just keep being in the plane?

Haley

So the speed makes sense, because of the what we've just talked about? Can we talk about how gravity and like big mass affects time? Because that's where I get more confused, I think.

Emily

Okay, so the experiment that we did, where we put some clocks in a plane and flew them around, it's not so simple as the case that I just explained to you because there's other factors coming into play there. So I explained special relativity to you. But there's also something called general relativity, which is a lot more complicated and takes into the fact takes into account that we have a time dilation associated with big gravitational fields. And we also have time dilation associated with accelerating reference frames. So the fact that the plane had to accelerate to take off and decelerate to land, and the fact that it was not experiencing as much gravity when it was in the atmosphere, also play into that. So when we were comparing the clocks to prediction, we had to account for both of these things.

Emily

I was just gonna say that so if you're really close to a giant gravitational object, you will also experience time dilation, so time will move slower for you than someone who is further away from that object.

Lori

Oh, that happens in Interstellar.

Haley

Yeah, I was gonna ask. So I think we all learn in school, at least I did. Like gravity is like things falling to Earth. But it's more than that. So could you give like a better definition of gravity?

Emily

Gravity. Gravity is a force. Well, there's the gravitational force. So there's some fundamental constants in the universe. One of them is the speed of light, which we just talked about, and the other one is this gravitational constant. So massive bodies are always attracted to each other. And this goes into what we think of as space time, which I'm not sure if I can really do justice to that but very massive objects warp space time. And that's what causes this general relativity and time dilation due to gravity.

Haley

Hmm. Are there any theories as to why? Or just like, just because?

Emily

You know, there's theories that explain it. I don't know how philosophical they get I mean, doesn't it all go down to like, why are the laws of the universe what they are? They just are. And yeah, if you go beyond that, I think it's more of a philosophical question. But interesting to think about.

Lori

So I want to pose another question from one of our listeners, Ronni on Instagram wanted us to ask you, are there any kind of pop culture treatments of this issue that sort of make you roll your eyes or that you're like, Nah, that's not real. Anything that you want to debunk that we see all the time in movies or anything like that?

Emily

You know, with time dilation specifically, I feel like it's already kind of wacky enough that it fits into science fiction pretty well. There's definitely, I mean, I'm always watching popular movies and TV shows and thinking, Okay, well, maybe you should have gotten a physicist on board for that one. Interstellar specifically, I've never seen it. But I have kind of gathered what happens from other people. And I've talked to a lot of physicists about what they think of it. And you know, physicists generally enjoy that movie, I've heard that the, the visuals are really accurate. Although the ending sucks. From a physics perspective, I, I'm pretty sure Matthew McConaughey somehow leaves a black hole. And that's a little bit iffy. But you know, the rest of the movie, my undergraduate advisor gave that movie a C in terms of physics accuracy, which is pretty decent.

Lori

That is better than I would do on an exam on physics, so Interstellar is doing better than me. <laughted> Yeah, I read that they, they definitely did a lot of consultation and research with actual physicists in the production of the movie. So you know, I had seen it several years ago and didn't remember it that well. And then somebody was, I think, pretty much asking about that movie, I decided to rewatch it. And then I found out that it was like, fairly well researched. And then, I guess, like you said, that time dilation has room for some artistic space to play, I guess.

Emily

Yeah, I mean, there's a reason it's so popular in science fiction, it's just kind of a fun concept and fun to try to wrap your head around it.

Lori

It is and it really sets up a opportunity for like, it's kind of the tragedy of space travel, like you are leaving behind everyone you knew you are potentially leaving behind your whole family and possibly coming back to a world that you won't recognize, which is what happens in The Forever War that we're going to talk about, for our December podcast episode. And that's exactly what happens there - is the main character leaves to go off and fight a space war. And then by the time he comes back, Earth Society doesn't look much like what he remembers.

Emily

And that is what is so compelling. Anything can happen when you're going near the speed of light? I mean, not anything.

Haley

Yeah that scene in Interstellar, I think it's, it's, it's in the middle of the movie. And yeah, the ending is weird. And love is not a dimension, whatever. But like, they decide to go down to this planet that's being influenced by a black hole. And there's huge waves. And for the purpose of them, for the purposes of the movie, they're like, every hour on this planet is going to be like seven years in, like real life or whatever. And so they go down, and they get in trouble. And it's like three or four years, and then they get back on the spaceship. And they left a man alone there for 20 years. And then Matthew McConaughey checks his answering machine and there's like, 30 years of like, life updates from his kids and grandkids and it's wild.

Emily

I mean, yeah, that's, that's why the human aspect - we're always so drawn to the human aspects. So when the science and the humanity can intersect, that's what the stories are all about.

Amy

I haven't seen that movie, but I feel really bad for the guy. They left on the spaceship.

Haley

Oh, yeah, he makes it a little bit better cuz he goes into hibernation, but like he's, he's aged at least 15 years.

Amy

Okay so he doesn't just wander around the spaceship for 20 years.

Lori

Yeah he was working too. He didn't fully go into hibernation. He does some of the time because he's like, gone from a young looking man to quite gray when they get back on the when they get back on the ship. So he spent a lot of time like doing math by himself. And he seemed sad about it.

Lori

I was gonna say, well, Emily, I think that these are our 30 minutes. We don't want to keep you any extra time.

Emily

I wouldn't worry about it. Ask your questions! <laughter>

Lori

Well, we had, like we had other questions in our list that stem from The Forever War like I'm betting that this is a question that Amy put in there that says what would 23 G's do to your soft parts. <laughter>

Emily

Oh yeah! That's a fun one. That's a fun one.

Lori

Have you read the Forever War, Emily?

Emily

I have not. I looked at the Wikipedia so that I can at least understand what kind of physics they're using in it?

Lori

Yeah, so when they travel, the narrator tells us a lot about how many G's they're doing. And then if they're over a certain amount they get in these uh, what do they call them acceleration couches or something. And they're like, zipped into a pouch, a life support pouch and filled with goo. And I guess the goo was supposed to absorb the pressure. And sometimes, sometimes the suits go awry, and you will absorb the pressure.

Amy

Which apparently, by the way, apparently, in real life, what would happen if you are an Air Force pilot, and you're going really fast in your plane, and there was a crease in your suit? It would tear and do weird things to you. So that was like a real thing that happens.

Emily

Yeah, so fighter pilots are trained to withstand more G's than us normal people can. And sometimes they wear special suits to try to account for that. So we can talk about how many G's is normal. So yeah, GS is just a unit of acceleration. So one G is the acceleration due to gravity on Earth. And we can measure any acceleration in terms of that just as multiples of the acceleration we have on Earth.

Amy

So one G is Earth's gravity?

Emily

How much acceleration. Yes, one G is Earth's gravity. We can only really withstand about six G's before we just pass out. A roller coaster usually has four to six G's. But fighter pilots can withstand eight to nine G's, but only for a couple of seconds. The problem here is not that you get squished and the force, it's that the blood in your heart can't travel to your brain and you just pass out and die. 23 G's is doable. There are people who have experienced that for a couple of seconds and survived. But it that depends on the orientation of your body compared to the acceleration. We're better at experiencing accelerations that are perpendicular to our spine. So eyeballs out or eyeballs in is the term that people use when they describe that. <laughter>

Lori

What's the context of someone having survived 23 G's for a couple seconds?

Emily

Um, you know, I do not recall I remember I was looking this up and there were some people who survived car crashes. Especially like NASCAR. They have but, uh, yeah, that was it was for a very brief amount of time.

Lori

So if you were going very fast and slammed into another vehicle or a wall or something, then that would cause you to experience increased Gs?

Emily

Yes. So G is just acceleration. So if you're going really fast, and then you immediately stop, then you've experienced a lot of acceleration. Acceleration is a change in velocity. So if you're speeding up or slowing down, you're accelerating.

Amy

So if you if you fall from a plane and you're plummeting towards the Earth, you would you only experience one G?

Emily

Yeah, only one G. The, the force of impact is quite a bit more than one. So when you go from moving really fast, so you won't accelerate indefinitely, because of air resistance, you'll reach a terminal velocity. But when you go from that terminal velocity to hitting the ground, you accelerate very quickly from going very fast to not going at all and that is the force that kills you.

Lori

That's like the joke. It's not the fall that kills you. It's the stop at the end.

Emily

Exactly. <laughter>

Lori

Let's see, Amy, what did you put this video about the 10th dimension in the Google doc? I remember you talked about it when we read the Three-Body Problem.

Amy

You can ignore that, it's tangential. It doesn't really, I decided after I put that in there that doesn't really have anything to what we're talking about.

Lori

I did watch the first part. And once they got to five dimensions, I was like, "Well, alright." <laughter>

Emily

I watched it. It was a pretty good video. I mean, it was a good way to visualize some of this stuff, although they bring quantum mechanics into it at some point, and then they got a little iffy, but it was pretty good.

Haley

That might be a good segue. So they travel, basically via wormholes, I think in this book, but they call them collapsars. So yeah, could you talk a little bit about wormholes? Are they a theory? Are they something that might really happen or what's the state of the art of wormholes right now?

Emily

So you were you asked me before about science fiction treatments of this that make me angry. But it doesn't really make me angry. But wormholes are definitely stretched in science fiction, they are theoretical - theoretically possible. They very well could exist. If they do exist, they're very tiny. And they are unstable. So if anything tried to enter them, it would destroy them. We have been thinking about ways that we could make a stable wormhole, theoretically, could we make one? And the answer is not with any of the physics that we know right now, it would require some exotic matter that we haven't heard of yet. So maybe someday we'll discover that matter and can make a stable wormhole.

Amy

Is the concept behind a wormhole just like a tunnel through some sort of space/time? Like as if space/time was a thing?

Emily

A good way to think about it is using that video, that was the 10 dimension video. So that video explained how we have three dimensions. And the way that we get from one point in our three dimensions to another point is by traveling through the fourth dimension: time. So it's kind of like, okay, we're in our three dimensional space. And we could fold through this other dimension, and get to another point in it without actually having to travel through all of that space.

Amy

So it's a shortcut?

Emily

So it's just a link between two points in space. Yeah, it's a shortcut.

Lori

That's like a tesseract and A Wrinkle in Time. Anybody's read that that was one of my favorite books as a kid. That's what it is. It's A Wrinkle in Time. You just fold the time!

Emily

I've definitely heard black holes - or, not black holes - wormholes described as A Wrinkle in Time before.

Lori

So wormhole and black hole, not the same thing?

Emily

No, a black hole, though, is. So it's one of the ways that we think that maybe a wormhole could be created. Black holes are just collapsed stars. So I saw the word collapsar when I was looking up the Forever War. A collapsar is just a collapsed star. But I think what you specifically need is a collapsed star that has turned into a black hole.

Lori

Oh, why is it called a wormhole? Is that a science fiction name?

Emily

You know, that is probably an interesting piece of history that I don't know.

Lori

I guess since it's made up, it probably doesn't come up in your field of study.

Emily

I mean, I I've heard physicists use the word.

Lori

Really?

Emily

Yes. It's not the technical term. But you know, colloquially.

Haley

I think it's because if you look in dirt like worms actually leave holes between two discrete locations, so it might be just based on farming. <laughter>

Amy

The first Google result says that wormhole is from the 1590s. It's a real thing, a hole made by burrowing insects but the astrophysics sense of it is attested from 1957. Hmm.

Emily

Interesting. We're learning today.

Lori

Yeah. So do you think, Emily that this thing in The Forever War where they are in like a goo filled bag? Would that protect someone from one from the acceleration that they described in the book or with a goo filled bag have no, no protective properties?

Emily

I mean, definitely, if you were in a capsule that somehow had an opposite force that would counteract the acceleration that could protect you, maybe, somehow the inertia of the of the goo keeps you from accelerating so fast. I mean, immediately, off the top of my head, to me, that sounds like it wouldn't protect you, you need something a bit more complicated. But, you know, maybe it helps.

Amy

The there was a explanation from Haldeman on a Reddit Q&A that I read where he said that part of what happens in the tanks is that they're trying to pressurize people, so that they are equivalent, basically, to the outside pressure, so they didn't mush up. Does that make sense?

Emily

Physically, I guess I would like a little bit more context before I could comment.

Haley

Maybe biochemistry, I don't know.

Lori

I mean, it definitely makes like sense to a reader. Right? Like I can imagine like, if you wrap me in a big foam, rubber bubble and drop me the foam is gonna like insulate me from the impact of the ground. So I think it's like the same, the same kind of thing. It's just like it to sort of ridiculous extent, which is what all of science fiction really does is it takes something that's like plausible and carries it out to maybe ridiculous isn't the right word, but to an extreme. So it makes some sense as a reader.

Emily

Yeah, I mean, suspend your disbelief. That's what I always do.

Haley

Yeah, he also spends I think too much time talking about like, I, he could have not brought it up and I would just fine. <laughter>

Emily

That tells me that he researched it. And he wanted you to know that he researched it.

Lori

So interesting!

Haley

It was kind of like people saying, like, well, if you just, if an elevator is falling, and you jump at the last second, you'll be fine. Like it was that kind of energy?

Emily

Yeah, I mean, it probably would have an effect. I can't imagine it protecting you from 23 G's, but perhaps.

Haley

Alright, I've got a theoretical question about traveling at the speed of light. So you could travel at the speed of light for a long time? Would it be possible to get to the end of time? Like, could you get to the the end bang, if you keep going forever?

Lori

This is a yes or no question. Yes, you can get to the end of time, or no, you can't.

Emily

No. <laughter> Well, you're traveling through time, right? Like any of us, if we wait long enough, I guess. We'll live to see the end of time.

Haley

Well because at one point, they're talking about if they go off in the wrong direction, they could come back 140,000 years later, so I was like, well, but eventually maybe the universe won't exist. I don't know. But like it just when you start talking about like these big chunks of time, I was like, Well, shit, where does it end?

Emily

Yeah, I mean, that's another philosophical question. So we we know that the the end of the universe or how physicists think it will end is a heat death everything will just expand. And you know, all that energy will just kind of even out throughout the universe and it will just be big nothing expanse of space, the universe is expanding.

Amy

Emily, please go get your PhD in philosophy.

Emily

Okay, will do!

Lori

So there's a couple places in The Forever War, that I really could not wrap my head around. So the premise is that humans are at war with this alien species called the Taurans. And nobody really understands why, and that's kind of part of the commentary since Haldeman was a Vietnam veteran. But there are there places where the narrator tells us, well, we don't know which Taurans we're going to get. I think I said Terrans, I meant Taurans. We don't know which Taurans we're going to get. They could be the ones who show up for this skirmish could be future Taurans. And so they have technology we couldn't have anticipated, or they can be past Taurans and they've got like the equivalent of sticks and rocks compared to us. And that is something I had a very hard time wrapping my head around that they could physically encounter each other, but be from different points in time. So is there any theory underpinning that that makes that I mean, obviously, it's not real. But is there any, like, scientific theory behind that?

Emily

I guess the the Taurans that you would encounter would just depend on how they are moving relative to you. So how much time dilation has happened? That's my immediate thought. When I think of that, so maybe there's different groups of Taurans that are moving at different speeds. And that maybe just explains it.

Lori

Yeah, that makes sense, I guess is if they're, they're just sort of sitting on a planet waiting for the Taurans to arrive. And they're there with the static technology that they had and Taurans are flying around in space, and I guess they - I don't know! That one was one that just really, I sat with it and thought and thought and thought and I was like, Okay, I'm just not gonna get it.

Haley

Yeah, sometimes if I watch time travel movies too much, I get a headache, but I kind of like that headache. So.

Emily

Yeah, I am always, whenever there's time travel in any piece of media, I'm always like, Okay, how is this a paradox? How can I poke holes in it?

Lori

So I love Doctor Who with that, the doctor always says, paradoxes by and large resolve themselves, and they just always says that and it's like, okay, that's fine.

Emily

Yeah, I'm okay with that.

Lori

Yeah, I honestly find that a lot more fun than trying to make something that will work because I don't think you can do that in like a 40 minute television program.

Emily

When you try to make it logical, then your viewer is also going to try to make it logical. And then if they can find holes in your logic, it kind of ruins the experience. So I do like it when they just say, Yep, this is what it is. And I say Okay.

Lori

Anything else you guys?

Amy

I am thoroughly confused. I'm good to go.

Lori

Yeah, I feel like yeah, I feel like I fully understand all physics now.

Emily

Great! That was the goal.

Lori

Well, Emily, I wanted to ask you, do you want to talk a little about how you got interested in this field and how you started working on what you're working on?

Emily

Oh, boy. I mean, that is a question that I should really know the answer to. <laughter> The, I guess the answer is it just really worked out this way. And I'm glad that it did. I was interested in science in high school. And then I thought, oh, we'll give physics a try in college. And I just really loved my classes. And I really loved my professors. And I think a lot of it had to do with the environment and the culture that I was in at my school. And then I just didn't want to stop learning about it. So I went to grad school, and here I am. And I'll be learning about it for a while.

Lori

I love that. I think that's a great story. Because the thing that comes up for me when I hear that is like, just stay curious and stay open to things.

Emily

Yeah, you start learning about it, and you realize that there is just so much that you don't know, and I'm just not satisfied yet. I need to, you know, at least get some of these things worked out in my head.

Lori

Yeah, you can well, you can probably keep going until the end of time, right. And there's interesting stuff to learn.

Emily

Yeah, it will never end. I will always be like, Oh, I should just, you know, take this class,

Amy

I will learn until the galactic heat death.

Emily

Exactly.

Lori

There are definitely worse ways to spend your time, you know? All right. Anybody have any other questions?

Amy & Haley

No, thank you so much.

Haley

Thank you so much.

Emily

Yeah, thank you guys. Feel free to send me an email if you want to straighten any of this out. I know, the first pass usually, the first pass doesn't stay. You know, go over it a couple times.

Amy

I'd like to just keep you on retainer.

Emily

I'll be available for comments.

Lori

We can just make like a monthly donation to Skype a Scientist and then check in with you.

Emily

Sure. Sure.

Lori

Emily, what's going on here? Do you want join us for five minutes? <laughter> Well, thank you. This has been so fun and super helpful. And we're really grateful to you for sharing your time, especially when you've got time off from school and work and everything that you've got going on that you gave us an hour of your time. So thank you again!

Emily

Yeah, no problem! It was fun. <dreamy harp music indicating return to the present day conversation of Lori, Haley, and Amy>

Amy

So while you were listening to that 30 years past on Earth,

Haley

Something like that. I keep reading about time dilation. I've been watching more videos, and I'm more confused than I was.

Lori

I feel sort of outraged when I think about it too much.

Haley

Part of it's just like, Okay, so a clock slows down. I get that because distance, but like, why is time slowing?

Lori

I don't know. I still I mean, it made so much sense when she explained it. But I still don't. I'm still outraged by it.

Haley

It doesn't seem right. And it doesn't seem fair.

Amy

No, it's insulting.

Lori

<singing> It isn't right, it isn't fair.

Haley

Well, and it goes back to what you said about, are we sure it's the cosmic speed limit. And I think right now it is, for what we know. But 600 years ago, we knew jack shit about anything. But hubris, I guess.

Amy

Well as long as we don't think we know everything, then maybe we can avoid?

Haley

That's where I think this comes from, is like how do you know what's the cosmic speed limit?

Lori

Well, she was very upfront, like we don't. But for anything we can measure.

Haley

That's true. That's true.

Lori

It works. And we can't - there's nothing else we've observed.

Amy

I have to admit that I did not understand that just, she was talking about how the person in the plane can tell that his clock is slower. And since he can tell his clock or can't tell us clock is slower -

Lori

It would not be something that is meaningfully noticeable, it wouldn't be something noticeable, but when they use like an atomic clock, they can tell that there's like, you know, out like eight decimal places or something, there's a difference that can be measured by very, very, very sensitive instruments. But you would never notice the difference.

Amy

And so when we asked why the person wouldn't age correctly, like I get the clock thing, but like the person aging still throws me because it's like -

Lori

The light clock was a simple function, the light bounces up or down or the light has to bounce effectively in like a Z or an M or something. like that makes sense. Cellular function? I don't understand. But I mean, is everything just movement? I don't know, everything. All all atoms are vibrating all the time.

Haley

Oh, I had a breakthrough about gravitational time dilation, I get it. I can't explain it to you. But I understand that in my mind. Okay, so there's videos online and like, when you see like the pictures of space time curved, it's like, you know, see it like that. Yeah, the green and black netting? Yeah, yeah. I think what space time is is just like a blank slate. And then everything that has mass like everything in the universe gets superimposed on that and that's what creates gravity.

Amy

Do check our Instagram for the images that Emily shared with us during the conversation.

Haley

I did find them helpful for sure. I was dubious at first one and then I was like, okay, good. All right.

Lori

She did a great job explaining it!

Amy

Thanks, Emily!

Lori

And if you enjoyed this episode, you can donate to Skype a scientist. And if you need a scientist in your life, you can sign up for Skype a scientist!

Amy

It's apparently great for teachers!

Haley

So nice that exists!

Lori

I think most of what they do is talk to classrooms. And if you have a group or you want representation for a specific underrepresented demographic, you can note that and they'll try to match you with somebody who matches the demographic interest of your group. Like we've specifically asked for a woman scientist. And so they matched us with a woman scientist. So that was cool. And there are a variety of groups, underrepresented groups that you can ask for.

Haley

Maybe one day someone will invite us to talk about The Terror to a class.

Amy

We're experts on so many things. Having read the Three Body Problem, having talked to Emily and having read the Forever War, we've got quantum mechanics, we've got computer programming, we've got time dilation.

Lori

We've got western maritime exploration. We've got both poles, and New England whaling -

All

Horses, horses, horses! Star Wars.

Lori

Amy, you got birds, you know.

Haley

You do know a lot about birds. The law. If you need metal, you can talk to Kevin

Amy

That's right. Watches. Watches are kind of related.

Haley

When I was going down a Wikipedia wormhole, pun intended, last night, it gets into chronometry, which is like the you know, the art of measuring time.

Lori

Kevin, I did wish that you were on there when she was talking about the light clock in space I thought you would be really interested, and when she said a second is actually the physical measurement of the vibration of a cesium atom. I was like, pardon?!

Haley

My whole mind was blown. So like, but also like a, like a Kmart clock? Time can be measured with a basketball.

Amy

I guess we've just all agreed what a second is now and so you can make a clock do with it.

Haley

There's a lot of time that's been based on like the Earth, you know, but then to like even everything standardized with science. So like a meter is like how far light travels and like one 9,000,000th of a second or something like so everything has a way to be measured. But we don't think about that. In real life. It's just one second.

Lori

I didn't know that about a meter.

Amy

Say that about a meter again.

Haley

So. How, like the the SI, like the scientific standard unit of a meter like how they describe it is not just like 36 inches or whatever, or 100 centimeters. It's the distance that light travels in a certain period of time. It's really small.

Lori

That seems so extra, doesn't it?!

Amy

Now they're just being silly.

Haley

Well, so that's what I liked when she was like, she's like, do you like about science? Or do you want to talk about philosophy? And I was like, this stuff's more fun.

Amy

It seems hard to talk about one without the other really? I think when you too far down into science becomes some philosophy.

Haley

Wellexactly, that's what I like but like, if you keep it surface level, it's like well, a second is just this and then like a pound is really whatever this is.

Amy

Well, they could have picked anything to make a second I mean to make that unit of measure. But why cesium? Yeah, that's what seems maybe that fit nicely into the units they needed to create a day. Yeah, or an hour or whatever.

Lori

Well, I bet if you look up a second on Wikipedia, it'll tell you.

Haley

Again, I'm gonna really get back to it. I reread the time Wikipedia article. It gets very granular.

Amy

Emily did say we could reach out to her.

Lori

I don't want to abuse that. I'm like a little like, I think once I pop I can't stop.

Haley

It's weird to slide into someone's DMS about space. Hey, you up?

Amy

Hey girl, what're you doin? I got this question about horology.

Lori

You got time for time?

Lori

All right, is that I think that's our outro.

Amy
See you later, everyone! Okay, bye, listener!

<OUTRO MUSIC>