Episode 257

Ryan: I like that Ben's nightmares are I might be slightly late for a podcast recording. Like, it's not...

Ben: Well...

Ryan: It's not going to school in my underwear

Music

Announcer: From Sciencesortof.com you're listening to Science sort of.

Ryan: Hello and welcome to Science sort of, you're listening to episode 257. I'm your host Ryan and joining me to talk about things that are science, things that are sort of science and things I wish they were science, centered around the theme of small moves, is my cohost Jacob.

Jacob: What's up Paleo punks.

Ryan: And my other co-host, Ben.

Ben: Good evening everybody.

Ryan: This week we are starting off talking about what happens when you're stuck in the magnetic field of a neutron star which I think is something we can all relate to. I think we've all been there and experienced the quantum weirdness that occurs therein. But a new discovery was made about just such a situation and Ben is going to tell us all about it.

Ben: All right. Okay, what is, does music start before the thing. Do we have to break...

Ryan: Do you want, no, do you want music in the background of you talking just so it sounds more...

Ben: Oh, yeah, no, I do, yeah. Let's Radiolab, Radiolab lab lab it, so when you fall into a neutron star...

Ryan: Star, star, star, star, star...

Ben: There's a bouncing. Bouncing. Bouncing.

Various sound effects being voiced in background

Ben: Okay, focus here. Ah, an international team of astronomers led by Roberto Magnani, Mignani, Roberto Mignani from Italy.

Ryan: Just say it like an over the top Italian accent and you're probably closer to being right.

Ben: Roberto Mignani from Italy. So there's a, just released their discovery. Okay, which was, so there was a neutron star and they saw an effect called vacuum birefringence. All right so let's talk about what this was and why it was important. As far as, as well as I can explain it. Okay,so the idea here is vacuum, there is an effect called birefringence. Have either of you ever heard of it?

Ryan: Nope

Jacob: I've heard of it in the context of polarization of light.

Ben: Yeah, so it's something that happens in crystals where, you know, if you look at something through some types of crystals with this optical property you will see two images. And the reason is that the crystal lattice will treat one polarization of light differently than the other. They will have two different indexes of refractions so they will be refracted to two different angles and you'll see this weird pattern because...

Ryan: Oh wait, I actually...

Ben: Yes.

Ryan: I actually do know about this because this happens with calcite which is a very common mineral. But if you get a piece of calcite that is clear enough to look through you see two images of the thing you are looking at.

Ben: See, I thought you would know it. Good.

Ryan: Yeah.

Ben: So that's called birefringence and it happens in some materials. What they're talking about here is, it is called vacuum birefringence. The idea is that as light travels from the neutron star to us through, well more or less empty space, you are seeing a similar sort of affect. The two different polarizations of lights are being treated differently and are propagating differently and so there is, there is a difference between them that they are measuring. And this is mad crazy and what's happening is that they are interacting with the magnetic field close to the neutron star. You dig?

Jacob: So the magnetic field is acting as the polarization gate, I guess is what they typically refer to, like, in a, you know polarized lens they call it and a gate phenomena. So it is like the magnetic field is the gate that the light is passing through that is causing the light to be polarized as it passes through the magnetic field but in this case it's also originating from the source of the magnetic field, so there's something even crazier, happening, is that close?

Ben: Yeah, okay, no, that's a great place to start. So first off, the types of, the type of neutron star that they are looking at is a type a very quiet neutron star. All of the radiation is being emitted from the very surface of it, which is important, which means that there is nothing funny going on about the radiation that is being emitted by the neutron star. It's all just thermal radiation off this fairly cool object. I guess it's pretty hot, I don't know, it's a neutron star, I don't want to touch it regardless of what temperature it is. But it is radiating thermal radiation and that is essentially what they're looking at.

4:57

But, what we are seeing here is a purely quantum mechanical phenomena and it's rare to see quantum mechanical phenomena existing at macroscopic levels. Right? I mean, we are at a macroscopic, length scales here, we are talking about stars and light being emitted from stars and light being observed. Usually quantum mechanical effects are not at play. And what's happening here is, usually, photons will travel right through a magnetic field if there is no material in between. So, if it's just, like, the Earth’s magnetic field, but outside of the atmosphere the, that magnetic field won't interact with the light passing through it at all, okay? But they are both, they are both types of electromagnetic field, okay? So the issue here is that the magnetic fields around neutron stars are crazy, crazy, crazy strong. And the magnetic field here is so strong that we can't talk about the light moving through it independently of the background magnetic field, right. So, it’s like there is just one big electromagnetic field, photons are trying to move threw it at this point in time the magnetic field is so strong that it no longer acts, just as kind of like a background that photons can pass through. So one way of describing this effect is a very visual way it’s to talk about virtual particles coming in and out of existence in the vacuum. So have you ever heard of that?

Jacob: Yeah.

Ryan: Yes, I have.

Jacob: Feynman diagrams will show...

Ben: Yeah, yeah Feynman diagrams.

Ryan: Is that, wait, Hawking radiation is the stuff that comes out of a black hole right?

Ben: Hawking radiation is something entirely different, yeah.

Ryan: Yeah, okay, okay.

Ben: So, ah...

Jacob: So it would probably help to give a quick description of virtual particles and virtual photons though because I doubt many people have heard of it.

Ben: Yeah, so, no…

Jacob: And I don’t have a strong understanding of it either.

Ben: Definitely, definitely, okay, so it is all about Feynman diagrams to be quite honest. Feynman diagrams are a way of calculating approximations of higher and higher order to essentially a great big super weird quantum phenomena. You start out with your quantum field equations and they are gross looking.

Ryan: Oh yeah, I have seen these diagrams before, sorry I just looked them up.

Ben: Yeah, so essentially, the one method for tackling these and parsing these quantum effects is that some of the quantum effects are going to be really large and some of them are going to be fairly small and subtle. And, you can rank them in terms of the order of how important or how easy to measure it is and those correspond to the complexity of the Feynman diagrams. So Feynman diagrams are a way of charting the paths of particles, in essence. Where you say okay, one particle comes in here and then there’s a probability that it will split into two particles and they will do their thing and they might turn into four and they might re-combine in someway and just, there is a whole host of things that could happen. Each Feynman diagram is, essentially, one possible outcome for particles. But one thing that you can do in these Feynman diagrams, is you can say, hey, first there is nothing. There is some energy density or something. And then two particles, a particle and an anti-particle, come into existence. So a proton and a positron, sorry, an electron and a positron, say, come into existence and then they immediately, a, re-merge together and disappear. And in that context the total energy before and after it happened is zero and the probability of it happening is often described in terms of the Heisenberg‘s uncertainty principle where are you can say that your uncertainty about how much energy in a, how much energy density there is in a certain region depends on the time scale you’re looking at. And so you can say well, if we are talking about small, fairly small time scales, that is a pretty small time uncertainty. And so that corresponds to a large enough energy uncertainty for two particles to briefly exist and then cancel each other out. So that’s the description of particles and anti-particles coming out of the vacuum. And it’s, it’s fun because usually you think about the vacuum as having nothing in it but in quantum field theory there are these effects can show up and there’s different mathematical formulas to deal with them but the moral of the story is, one way of describing this particular, the cause of this particular birefringence is that the magnetic fields around this are so high that these virtual particles come into and out of existence long enough to interact with the photons traveling off from the surface of the neutron star and that is what's causing the birefringence.

Jacob: So let me make sure that I understand something about light as well as I think that I understand it.

10:00

Light is electromagnetic radiation. It's perpendicular electrical fields and magnetic fields, that are constantly, you know in a wave pattern that are in balance. There's no charge to a photon at any point along it's path.

Ben: That's right. Yeah.

Jacob: So light cannot be affected by a magnetic field, typically, right? Like if I were to hold up a very strong magnet next to laserbeam it wouldn't bend the laser beam in the same way that we know that gravity bends light when it goes around, you know, a very dense star or a black hole or something like that. That effect doesn't happen with magnets.

Ben: Yeah, that's right.

Jacob: For all we know. But, in this case how are, I guess, maybe we don't know, because the details of the paper are kind of murky. But how would they be able to determine if there's, that it's the magnetic field that's causing this effect, I guess? Like, I guess, does it just conform with a certain theory of quantum mechanics, that thats the most likely explanation at this point. Is that the idea?

Ben: Yeah, as I understand it, this is a pretty old prediction that it would happen in this context. But it's, the nice thing about this is that we know that the light coming off these, these neutron stars is pretty boring and normal. And then the light we are detecting isn't and there's literally...

Jacob: Right.

Ben: ... nothing between us and the surface of the neutron star, but this crazy magnetic field.

Jacob: Gotcha.

Ben: Yeah.

Jacob: I understand that the key to the article is that they are saying this is one of the only circumstances where we have observed a quantum effect in a macro scale way, but is really hard to, it is really hard to communicate just how important that is.

Ben: Well...

Jacob: Are there other examples of where we have observed a quantum effect in a macro way that, that people would be more familiar with.

Ryan: That's a good question.

Ben: Um, so...

Jacob: That's the only kind I have Ryan.

Ben: Yeah, you often see them in, in astronomy because astronomical systems are fairly simple. Quantum effects are what's holding up a neutron star actually. It's neutron degeneracy pressure, so there's that. So even the existence of neutron stars is evidence of weird quantum mechanical effects. This is the first time you've seen things interacting with the vacuum I think at this scale. Usually vacuum interactions kind of, I think they can change the mass of electrons, I think that's at thing they do. They don't show up too much in the macro scopic. But that said, you know in like, like I just mentioned, in astronomy one does see quantum effects. I mean, you can see, you can see hydrogen transitions I think, that let you detect hydrogen gas clouds. And that is essentially just like a fine state transition between an electron, or hydrogen atom can have a, an orientation relative to us and then as an, electron, as a photon passes by it can flip, modifying the electron. We use those to detect hydrogen gas out in space, even though it's not radiating. So, it's not, I mean this, the article about this are a little bit on the dramatic side in that we haven't proved Einstein wrong. Ah, the calculation is, the prediction is, apparently, is a fairly old one. It is a fantastic discovery, right? That we have, that we have detected this, that it is consistent with the calculations and the predictions that were done. But, yeah, I'm not, I'm not sure how much, I don't feel, like anybody's apple cart has been upset over this discovery. If anything we are just like, well, isn't that great.

Ryan: So this is confirming that what should exist, not overturning what we didn't think existed.

Ben: Yeah.

Jacob: And it also doesn't mean that, that general relativity gets thrown out the window either.

Ben: No, I mean, yeah exactly. Precisely. If anything there is a lot of calculations that involve the vacuum in quantum field theory. And it might be the case that a lot of people are little bit uncertain as to whether those particular calculations have anything behind them or whether they are just kind of math that works and nobody knows why. But, certainly...

Jacob: Otherwise known as quantum mechanics.

Ben: Yeah, and this is certainly consistent with those.

Ryan: I do like that the theory, that the quantum theory describing these principles is called quantum electrodynamics which the acronym, or I guess the initials for is QED, which is literally the end of an argument.

15:00

Ben: That's right. Yeah.

Ryan: Like, QED, our theory is right step off, walk away.

Ben: Well, thanks Richard Feynman.

Ryan: He was a clever guy.

Ben: He was a kind of know it all, yeah.

Ryan: Yeah. I wish I could crack safes.

Ben: You know once I, once I did that.

Ryan: You cracked a safe one time?

Ben: No, no, having read that, that story, I was feeling particularly ingenious and I had a, I was working for, like, one of those, like private garbage companies one summer and somebody threw out a stethoscope and I was like here’s a perfectly good stethoscope. And I was like, you know, I bet I could use these to crack the lockers at our school because at the university they have this really old crummy lockers with very loud, old lock mechanisms on them. And so a friend of mine said, well if you can get into my locker there is a bottle of wine there that you can have and I said oh well let’s go try this out. Hey, I’m going to pull, I’m gonna pull a Richard Feynman. So I took out the stethoscope and I put it against the lock and it went (makes grinding sound), every time I turn the thing just because it was so full of crap. and so I was like well this isn’t gonna work, but then I said to myself, you know, every time I use one of these lockers, I don’t after I close the locker I don’t always turn it all the way. Usually I’ll like, you know, just turn it off a little bit off the number that opened it. So I took the locker, the lock mechanism, and I just turned it a little bit counterclockwise and then opened it. So yeah, he’d only turned it a quarter turn away from the last number and because these mechanisms look old and crappy you can just turn it back to the original position and try it again and it’ll open back up. So, I got the wine even though I didn’t crack the lock. But I didn’t tell anybody how I did it so they all think I’m smart.

Jacob: Nice. That's the key.

Ryan: They all think I'm smart. The tag line for this podcast.

Jacob: Make sure they don't see the magic that happens behind the scenes.

Ben: Yeah, that’s right. Me going, okay, well let's just assume that everybody's as lazy as I am.

Jacob: Hey, ah, under the assumption that no one understood anything that we've said in the past five minutes, what's a neutron star?

Ben: That's great, a neutron star is...

Ryan: Wait, no, Jacob, do you really not know or are you asking just to be fake dumb or...

Jacob: I'm half-way asking to be fake dumb. I know the, the, like, textbook definition of...

Ryan: Let's get, let's you and me try to answer this one and then Ben can correct us.

Ben: Ah, I love this idea. This is very entertaining.

Jacob: That is a good idea. Okay, so, a neutron star is a very, very, very super dense star that is a leftover of a super nova.

Ryan: Right, so a star that's run out of fuel and it's exploded and the remaining matter left over condenses into something, yeah, incredibly dense. I think the article we read, I'm not looking at this for exact reference, I'm just trying to remember, it said like, one teaspoon weighs a billion pounds or something like that.

Jacob: Uh huh, yeah, one teaspoon would weigh 1 billion tons.

Ryan: Oh, that's awesome. A billion tons, not a billion pounds but...

Jacob: I have no idea why it's called a neutron star.

Ryan: That's a good question.

Jacob: Like, what about, why, why would it be a neutron star instead of a proton star?

Ryan: Is it because it's the remnants of the nucleus of the star? Maybe it has to do with more with the innermost level of the star rather than the atomic particle of a neutron. Do you know Ben?

Ben: Yeah, of course I know. Sorry. I'm really excited about telling you guys about the drink I have and then so every time I look over at it I kind of get distracted. And I'm more distracted than I should be today because this drink is so much fun. Okay, now...

Ryan: We're just about to get to the drink segment, so just tell us what a neutron star is and then we'll move on.

Ben: You guys, neutron stars are absolutely crazy because if it weren't for quantum mechanics they couldn't exist. So stars are essentially a story of matter trying to resist it's own gravitational pull, okay? So you can have, you know, a cloud of space dust held aloft with thermal pressure but inevitably, it will collapse down into a star. And the reason stars don't collapse any farther is that in the core of the star there is nuclear fusion going on, right? And when nuclear...

Jacob: So that's pushing all the matter out while the gravity of the matter is trying to suck it all back in.

Ben: Well, yeah, kind of. It's like a hot air balloon. There's, photons are being made and when photons get made, you know gamma rays and stuff, they go, hey we are essentially heat, it's really hot in the middle of the star, let's go out into space where is cold, them pushing out to the surface is what buoys up the surface of the star. But the thing is...

Jacob: This is good for our upcoming, for our next story by the way, radiation pressure.

Ben: This is, it's a process that has an end. Which is to say, it ends when the, the, the photons, the combining nuclei together in the middle of a star no longer releases energy, no longer releases photons.

20:10

And you hit that, if it's a star that's heavy enough, you will hit that when it starts combining iron atoms together, iron nuclei together. After that you don't get any energy out, it is a net loss in terms of energy. So what happens, immediately...

Ryan: Yeah, iron is, iron is like the weird pivot point on the periodic table, right? Where above it things start to decay back down or below it things can be fused up to it.

Ben: Yea, yeah, yeah. Exactly. So, what happens is at that point in time there's no longer these photons to buoy out the center of the star and so it starts to collapse under its own weight. And literally at that point in time there is no nothing, nothing in terms of classical physics that can resist this collapse. You get a supernova there because in the process of this matter collapsing so many neutrinos get produced, I think it's neutrinos. We're going to do a show on this in the next couple months and I'll sort out the details. It's been like over a decade since I learned this, for sure. But you get, I think it's neutrino production and those neutrinos explode outwards and blast off the surface of the star. It's insane because neutrinos usually, you know one neutrino isn't enough to do anything. It's like being, it's like seeing a car getting carried down the street by rats or something. You're like whoa that takes a lot of rats to do that. Sooooo the end state of this collapse, this matter will keep on collapsing down until the material in it find some other means of resisting the force of the collapse. And there is a threshold past which there's nothing that can resist the force of the collapse because the denser the material gets, the closer to the center of mass it gets, and the stronger the gravitational field pulling it inwards is. So you can get runaway collapse. So that's how you get a black hole, in essence. But there is a slight threshold that you can reach before that happens where it won't happen and it comes from the Pauli exclusion principle. Do you remember the Pauli exclusion principle?

Ryan: I definitely know all of those words.

Jacob: Yeah, I've heard those words before.

Ben: Yeah, Pauli exclusion principle usually gets talked about in terms of atoms where one electron exists, only one electron can exist in each shell. Or rather only one electron can have a certain set of quantum numbers. So you can't have any two identical electrons. So one way to resist the collapse is electron degeneracy pressure, where, essentially you were piling so many electrons into this very small sphere that all of the electrons say hey we can't all the same number and that can resist the pressure a little bit. But, if you add more pressure to that you can smoosh the electrons inside the nucleuses and they'll start combining with the protons to make neutrons and then the thing will collapse even more. And the last stage of this is when it is held aloft by something called neutron degeneracy pressure which is essentially the same Pauli exclusion principle applying to neutrons. And, yeah, that's the last stand of matter against the compression of gravity. So a neutron star is a star held aloft by neutron degeneracy pressure. So they are very, very dense. They are essentially, it's a little bit more complicated than this, but they are essentially giant nuclei.

Jacob: Wow.

Ben: They are just made of neutrons and protons and some free-floating electrons. And it's a big complicated thing, and we did a show about them because as you go from the outside, around the outside it's kind of regular atom nuclei. But as you go down towards the middle, they get, the neutron density increases and the number of other different types of material, you know protons and electrons, decreases, and so they describe the mixture and the structures of electrons and protons and neutrons as you get towards the middle of a neutron star using pasta phases of matter and it's pretty fun. So, like out near the edges there's just lumps of neutrons, big clumps of neutrons together and they call that like gnocchi phase. And then if you get higher pressure all of the neutrons will form chains and it looks like spaghetti phase. And then you'll have, in a little bit further, you'll have like sheets of neutrons and then it is lasagna phase and then you go down further and you'll have only sheets of protons and that's the anti-lasagna phase or something like that. And then there's the anti-spaghetti phase where all that's left are strands of protons and then little dots of protons in the gnocchi phase and then it's just pure neutrons in the middle. So, it's a bananas thing. This thing only exists by virtue of quantum mechanics and the pressure that comes from neutrons pushing on each other.

25:06

Jacob: Yeah. And it's like matter's last, last throes against the formation of a black hole.

Ben: That's right. Once it's past that there's nothing that can keep you from collapsing into a black hole, as far as we know.

Jacob: It's like, it's like in the *Walking Dead* or some show like that were somebody's almost about to become a zombie and they're like please, just kill me. And that's what the neutron star is saying.

Ben: Yes. So, yeah, ah...

Jacob: Wait, wait, wait, so they stay like that forever?

Ben: Well, I mean, until, until, you know, you throw more mass down on it to exceed the threshold.

Jacob: Wait, so, so it's not, it's not consuming the fuel and eventually becoming a black hole.

Ben: Yeah.

Jacob: It's sitting there in a really tenuous equilibrium until something runs into it and turns it into a black hole.

Ben: Yeah, that's right.

Jacob: Wow, that's crazy.

Ben: Yeah, so ah...

Ryan: Very cool.

Ben: So, yeah, so they have ridiculously high, often they have ridiculously high angular momentum and often they'll have ridiculously high magnetic fields because...

Ryan: So, you're saying they spin really fast, were you saying about momentum?

Ben: Yeah, that's right. Ah because the core of the star is what turns into these things and the core of the star will have some, you know, elaborate magnetic field and that magnetic field is essentially locked in place because it's a plasma. So as the material crunches down and becomes a very small object, they are very, very small, all that magnetic field, all those magnetic field lines will be condensed into this one small object so it will be ridiculously dense and all that angular momentum of the core of the star will turn into the angular momentum of this tiny object so it will be spinning really, really fast.

Ryan: So, Ben, you probably already know this, but Jacob probably doesn't and that's the fact that at one point Superman unlocked his fortress of solitude with a neutron star key.

Ben: Sure.

Ryan: He had a key that he forged out of neutron star material because he was the only person strong enough on Earth to lift it to unlock his fortress.

Ben: Right.

Ryan: And if there's one thing Superman probably needed to do when he got to the fortress of solitude and had a moment to relax is have a drink and so let's talk about our drinks in the next segment, coming up next.

Ben: Oh yeah.

Music

Ryan: It would not be an episode of Science sort of if we didn't also talk about what we are drinking. Ben has been teasing us, he won't let us hear the end of it and he's always got something weird so Benjo, take it away.

Ben: Oh my gosh, you guys. I got this in September, it's now December and so it's a fine time, but we were in, we were at IKEA. So, you know how IKEA has that cafeteria.

Ryan: Yeah.

Ben: That's right. So this was in September and it's currently December and I found the best thing. I looked over at this bottle in with the other drinks, you know how like, you know, low alcohol pear drink and stuff, there was a bottle of pop that looked like Coke and it had Santa on it and it's called Dryck Julmust, Swedish festive drink. And it's literally got Santa Clause on it and it's brown and red and I'm so excited to drink it. So, this whole episode I've been looking at this, like, cartoon IKEA Santa, he's been staring back at me and I've been like, it's been months and I can't wait to drink it. Here's, to try, see if it's carbonated...

Ryan: It is.

Ben: Did you hear that pop? That's ah, sea level, alright, let's try it. I wonder if it's still good. It says, storage, store in a cool and dark place. Well, it doesn't taste off. But it doesn't taste like Coca Cola either. It tastes like...

Ryan: No, it's different, yeah, it's a different...

Ben: Are you familiar with this Ryan Haupt?

Ryan: I've had it on the show before.

Ben: Have you?!

Ryan: Yeah, episode 234, Dryck Julmust from IKEA. I put some rum in mine because I was told you're allow to spike it with alcohol.

30:09

Ben: This would be really good with rum. It tastes like it has rum in it but it doesn't.

Ryan: I know, right?

Ben: Yeah.

Ryan: You were on that episode Ben! You were on the episode where I had the Dryck Julmust.

Ben: That was probably on my mind when I saw it.

Ryan: Yeah.

Ben: But I'd forgotten. But it's fantastic.

Ryan: That's cool.

Ben: Way to go IKEA.

Ryan: Tis the season. Tis the season yet again so that's fine.

Ben: Alright. So, ah...

Ryan: Way to go buddy.

Ben: So, if it has botulism in it I will die and, on the show, and then we'll know. But if it doesn't then I won't.

Ryan: And our ratings will soar.

Ben: That's the nice thing about botulism is you find out real soon if you've got food poisoning.

Ryan: The concept about the nice thing about botulism.

Jacob: You know, the good thing about botulism is...

Ben: There's a couple good things about botulism, right? One of them is like Botox, right?

Ryan: Well, Jacob and I actually got to hang out and have some beers last week Ben. Where were you buddy?

Ben: In Canada.

Jacob: Yeah.

Ryan: Mmmmm. Typical.

Jacob: And Canadians don't celebrate Thanksgiving either Ryan.

Ryan: No, they celebrate it in October.

Ben: Actually, I did celebrate it, I celebrated Thanksgiving because my wife is American. So I made her a turkey dinner with all the fixins'.

Ryan: Well, Jacob and I did a post turkey day hike to burn off some of the Thanksgiving calories.

Jacob: Indeed.

Ryan: It was good. It felt really good and then we had beers afterwards to regain those calories immediately.

Jacob: And pizza and hot wings.

Ryan: Yeah, one of those hot wings I was surprised. Ah, so what are you having Jacob now that I can't directly see you or hear what you order.

Jacob: Yeah. Okay, so, I've got a nonalcoholic drink as well.

Ryan: Oh, well, then I'll go in the middle so we have, we're bracketing.

Jacob: Okay, okay, go ahead.

Ryan: Ah, Ben, I've got this one, I'm assuming it work out for the next time you were on the show...

Ben: Awesome.

Ryan: It is a Funkwerks which is a brewery down in Ft. Collins that specializes in saison style ales.

Ben: Okay.

Ryan: And this is a single hopped saison style ale and the single hop variety that they used is a hop called galaxy.

Ben: Nice. So, what's the name of this beer?

Ryan: It's just called, the name of the beer is Galaxy single hop saison style ale.

Ben: Fantastic.

Ryan: And it says pairs well with alien abductions.

Ben: Does it have a picture of Santa on it?

Ryan: It does not. It has a picture of a mouse in a lab coat with a beaker and an erlenmeyer flask and I don't know why.

Ben: That's almost as good as Santa.

Ryan: If somebody knows what that symbol means please tell me because I don't know. So, it's very nice, it's very, you know, they make a lot of really easy drinking session-able ales. This is a little hardier on the alcohol content than most session ales but in general their beers are just clean, easy drinkin' good time fun. It's one of my favorite breweries from Ft. Collins. I'm amazed that I haven't featured them on the show before, so, time to rectify that and with a space-themed name to boot.

Jacob: And apparently, I just looked this up, galaxy hops were first bred in 1994, so, they're not that old.

Ryan: Interesting.

Jacob: Yeah.

Ryan: Well, Jacob, what are you having?

Jacob: So, I've got a non-alcoholic drink that is kinda cool. It's called coffeeist. Have you heard of this?

Ryan: I have. It's the, um, Soylent drink.

Jacob: Yes, so there's this company called Soylent. You've probably seen their ads on Facebook and all over the place on the internet. For a few years now they've been iterating on a food product called Soylent that comes in a couple of different forms now but the basic idea is that it is nutritionally complete. So, one bottle of Soylent contains everything that you need to survive for everyday of your life, or, 20% of it. So if you drink, you know, five bottles of Soylent a day you would have all of the proper nutrition that you could ever possibly need. You could survive completely on just Soylent for your whole life and be a healthy individual. They've done a decent... go ahead.

Ben: I wonder how they manage to find some kind of thing to make it out of that has all of the different nutrients and building blocks that would go into a human body.

Jacob: Right.

Ben: It's the, it's a mystery...

Ryan: So, it's weird that they named it that. I mean...

Jacob: Let's, before we get into the science part of it...

Ryan: Elephant in the room...

Jacob: ... yes. The name Soylent is inspired by the old sci-fi movie, was it also a book? Was it a book? It was just a movie?

Ben: It was a book first.

Jacob: I'm not sure.

Ben: Yeah.

Jacob: Okay, it was a book.

Ryan: But people know it from the Charlton Heston movie *Soylent Green*.

Ben: Right.

Jacob: Right, right. *Soylent Green*. And the idea was that, ah, in future society, food is a very, very scarce commodity and so the government creates various food products for people to eat and Soylent Green was supposed to have been a food product that was derived from algae, I believe, in the story.

35:15

But one of the characters in the movie finds out that Soylent Green was actually made of people because they were also engaged in mass scale euthanasia of people. And so they would harvest all the dead people and turn them into Soylent Green and then you'd eat all the dead people.

Ben: Right.

Jacob: So, there's definitely a bit of tongue and cheek reference to Soylent Green going on with this company but they own the trademark now for Soylent and they've kind of...

Ryan: It's vegan, supposedly.

Jacob: It is vegan, so it's probably not human, probably doesn't have any humans.

Ryan: Unless, if you put a vegan human in it, does that, is it still vegan?

Jacob: Ah, I don't think so because it needs to have a soul. Although I don't know if vegans do have souls, so I don't know.

Ryan: Well, no we talked about this on an episode recently but...

Jacob: Oh, did you ?

Ryan: But according to the scientific perspective, none of us have souls. So the claim that a specific group doesn't have a soul is a pointless claim because none of us have them.

Jacob: In any case, the company, after, after you get over the fact that they do, they are playing with the name Soylent, ah, they do have a pretty decent, as far as I can tell, a pretty decent scientific basis for everything they are doing. One of the founders of the company posted, like, the first year or so, really regular updates to all of the research that they were doing to find all of those right vitamins and minerals and micronutrients and all that. And he, one of the founders, tested it out on himself. He had nothing but Soylent 1.0 everyday for, like, a year and a half and he did develop a nutritional deficiency at a certain point and he was getting regular, I might be a little bit wrong on this, it might not have been the founder but it was somebody with the company. So, he did end up getting a slight nutritional deficiency because he was getting regular doctor visits to check everything. And so then he released version 1.1 and then version 1.2 and version 1.3 and at each iteration of the drink, didn't necessarily correspond to a health issue that was found but a lot of it was making it taste better, making it dissolve in water better. Initially the product was a powder that you'd have to mix yourself. Ah, later versions could, you could mix a larger batch of it so it would stay good for longer, so they were able to add some things that were allowed to stay preserved for longer and then now they have a bottled version, Soylent 2.0 where it already comes in liquid form and has a shelf life of like five years. So you can just buy it already in the bottle. It's a little bit more expensive to buy it in the bottle, but it's, I think it's $3 per drink and each drink is 400 calories so if you consider $3 per meal, it's a, it's not terrible. It's not crazy expensive. Just recently they released a new product called Coffiest where it's basically just Soylent 2.0 plus coffee so it's 400 calories plus all the micronutrients and things that you need, some sugar and caffeine, 125mg of caffeine in each cup, or, each bottle. So, I've been using Soylent, I was curious, so I was like alright, I just want to try it out. Not that I'm the type of person that doesn't like to eat because I do like to eat. But, I just thought I'd try it out so I had gotten a box of Soylent awhile back and I thought it was pretty good. I was actually using it as a post workout drink. So, when I was doing long distance runs I would have it as my kind of protein shake afterwards because there's a decent amount of protein in each one of them as well as some key micronutrients that all workout powders have. They're all in Soylent so when I ran out I was like, alright, well, rather than buying a $50 jug of protein powder because that stuff is ridiculously overpriced I'll just try out Coffiest because I always need caffeine after my runs anyway, so I got a box of it and it actually, it taste even better than Soylent 2.0. Which, Soylent 2.0 tasted a lot like, a lot like the milk that's left over when you have a bowl of cereal. Which isn't, like, which isn't a bad flavor, especially when it's cold, you know. Like, it comes right out of the fridge, it's not bad. It, I've had other meal replacement drinks before that tasted a lot worse. So, I never had a problem with it. Coffiest tastes better, it does, it has a coffee flavor but it’s also got some, like, caramel and chocolate notes in there. But I will say this, it makes…

40:00

Ryan: I feel like you should have gotten us a sponsorship for how long you’ve been talking about it.

Jacob: I just, I think it’s pretty cool.

Ryan: It is cool, I just, I wish we were making money off of it.

Jacob: Me too, me too.

Ben: Okay, I have an honest question…

Jacob: Before you say that, I just want to note, it does make my breath stink really bad, so, be warned.

Ben: So, Dan Harmon, when he’s working on his shows, doesn’t like eating and stuff so he got on Soylent and he was talking about it and he acted like it wasn’t a big deal but it made him poop his pants a lot.

Jacob: What?!

Ryan: I’ve heard that same, I’ve heard that same outcome from an excess consumption of Soylent, that your, your incontinence increases.

Jacob: Ah, I guess I haven’t heard that but I suppose it, I suppose it would be possible. You know, because, like, one of the things that’s on the FAQ on the site is do you poop when you drink Soylent. And the answer is yes, you do poop. But I could, I suppose that if, if somebody’s drinking, there’s probably some weird assumptions that are being made about how people use Soylent that don’t correspond with how they actually use it. You know, like, if somebody’s going to drink five bottles a day of Soylent, then, then the makers are probably assuming that that's probably about the maximum amount of Soylent that you would drink in a day, Maybe five maybe seven at most.

Ben: Right.

Jacob: But, I would assume that they wouldn't, they wouldn't go so far as to say oh yeah somebody's going to drink 10 of these in one day, right? And so if that does happen I could see a situation where your body it's like I have no idea what to do with the shit that you just put in to me so I'm going to do something weird.

Ben: Yeah. Anyway. It put me off Soylent.

Jacob: And here's another thing to put you off of it. Maybe not to put you off of it but, so their latest version of the powder which they still make for people that want it and their newest release product it's actually an edible it's called Soylent, the Soylent Bar, it's a meal bar, you know.

Ben: Yeah, yeah, they are small, green kind of waxy looking, sure.

Jacob: I don't think it's green.

Ben: No, I saw, I saw them handing out, right before the scoops came, there was a riot and the scoops came, you haven't watched the *Soylent Green* movie. Right, you haven't watched the *Soylent Green* movie.

Jacob: No I haven't seen it.

Ben: You have no idea what I'm talking about.

Jacob: The food bar is like a brown, but anyway both the food bar and the latest version of the powder got recalled because they were contaminated and they had some stomach issues so.

Ben: People.

Jacob: Yeah.

Ben: So I heard that the guy who named it had named it after the book. He had read the book, he was a fan of the book, but had never seen the movie. And somehow had never engaged in pop culture. This is at least his defense of naming it Soylent, is that the book is called *Makeway! Makeway!* I think and it is, it's short stories about an over populated New York City or something, I haven't read it. But, so, Soylent is a contraction of soy and lentils which he figured are the only source of protein and carbohydrates in the far future. And then yeah, so, so the guy was like oh, well, I'll name my food after this and everybody was like, don't you know that's made of people. He was like what? I have no idea what you're talking about, well I've just spent all my money registering it and building the website.

Jacob: That sounds, that sounds unlikely.

Ben: Well, if you've never seen the movie and you knew that it was made of people I don't know what...

Jacob: Yeah, exactly, exactly. Oh there was one other thing I was going to say, oh, there is one thing that they do, they list on their website, like, vegan, lactose free, nut free, follows FDA guidelines. But then on the other side it says this is not organic, this is not GMO free and they have actually a whole page dedicated to explaining why GMO free is dumb. It is pretty...

Ryan: I mean it is dumb.

Jacob: It is actually a pretty long, little essay that they've written for the, the title of the essay is "Proudly made with GMOs".

Ryan: Well I mean, I think, we all agree more or less on what that means and why that's fine. But, just for old times sake, send your hate mail to jacob@sciencesortof.com.

Jacob: We judge GMO's with the same level of scrutiny that we judge natural products for health safety.

Ben: That's not great. Once my aunt sent me out to the garden for some basil or something and I was like which one is the basil? Is this the basil? And I, it looked like a basil or something, or whatever she sent me out there to get.

45:04

And I picked it and I put it in my mouth and I tasted it and I was like no that doesn't taste right. So I went in and I asked her and I told her the story and she looked at what I'd eaten and she was like that's poisonous. Oh no, why are you growing poisonous food next to your herb garden, I don't know.

Ryan: Anything is poisonous at the right dosage.

Ben: Well, these things were poisonous at the small dosage apparently.

Ryan: This has already been a very long drink segment so let's go ahead and just move right along to the next segment which is something Jacob is going to tell us about, I don't have a good transition, I don't know, like maybe you should've seen it coming if you had a radar.

Music

Ryan: All right so now that Jacob has finished advertising for Soylent, he wants to advertise for Google. Tell us what's going on Jacob.

Jacob: Yeah, yeah one of my other favorite companies, you'd think that I'd be talking about Elon Musk but I guess, I'll leave that for Joe to talk about.

Ryan: Yeah we had Joe do the Elon Musk happy hour the last time he was on.

Jacob: So, ah, Google, in all of their awesomeness, they like to find a lot of crazy projects, right. And so there is a crazy project that they just kind of pulled the lid off of, or at least made a video about, called project Soli, S-o-l-i. I don't know what that refers to, I am assuming it has something to do with radar because what it is is it's a new way to interact with your computer or your devices that uses radar to detect your hand or fingers and recognize gestures with your hands. So, in other words, if you've ever seen this device that's come out in the last couple of years called the Leap, it is a little puck that you put at the front of your computer and it uses LiDAR I believe, I think it uses light.

Ryan: What's the difference between LiDAR and radar?

Jacob: Oh good question, so, radar is a particular range of electromagnetic frequencies that do a really good job of bouncing off of solid objects, particularly metals. And so we tune in to that radio, to that electromagnetic frequency, we shoot it out from a transmitter. That radar bounces off of an object that it hits comes back and is received by a receiver we, using the transit time for that signal to go back-and-forth, we can make a calculation to say how far away that object is. When you have a large assembly of radar transmitters and receivers, you can actually start to form the shape of an object as well, and the size. So, early, radar was invented during World War II as a way to detect aircraft coming in. And, at the time what they, the only level of fidelity that they had was that they could detect an incoming aircraft as a blip, and that's what you see in the movies, little green green screen with the sweeping line that goes across the screen and they will see a boop, just one little dot. And if there were multiple aircraft you'd see multiple little dots.

Ryan: That's why, so, didn't, didn't we drop, like, slivers of aluminum foil or tinfoil from our aircraft to block that, to make it just like a cloud of metal reflecting the signals.

Jacob: Well there are lots of different things that happened after, after the use of radar was made public that were ways to try to combat against the effectiveness of radar. But for a long time the British were using radar before Germany, or the United States for that matter, knew it existed. There was a little story, I guess, there was an anecdote that the British officers told to the, their soldiers because at the time radar was still super duper classified. Where they had all of the soldiers eat carrots if they were working at night if they were manning an anti-aircraft gun at night, they would eat carrots and the officers told the soldiers that if you eat carrots you have a better night vision. And the funny thing is there is like a small sliver of truth to that, like carrots do affect your vision to a very, very small extent, but so do...

50:02

Ryan: Right, it's the beta carotene but you have to consume and amount of carrots that would, like, kill you.

Jacob: Yeah and also that same beta carotene is in like, broccoli and all sorts of other stuff. So, the story ended up spreading to Germany, you know they're mathematicians noticed that their aircraft were getting shot down with a lot more regularity and they looked for an explanation, the explanation that came back was the British are all eating carrots. And so the Germans started importing carrots and growing more carrots, but...

Ryan: Which, I mean, I definitely grew up with the idea that carrots helped your vision and I've only, as an adult, really recently as an adult, learned that that was propaganda.

Jacob: Yeah.

Ryan: And not actually true.

Jacob: Yeah. Yeah, yeah, yeah. And it's one of those things, it's like, I think the reason why it's persisted is because, so what, you know? If we get a couple more kids to eat some more carrots it's not a big deal.

Ryan: Yeah but carrots, but no, carrots are delicious, you shouldn't have to trick children into eating them.

Jacob: You shouldn't.

Ryan: They're one of the best vegetables out there. Are they my favorite vegetable? I'm not going to say but, you know, it's a great vegetable.

Jacob: Yeah. So yeah post World War II there were a lot of things done to try and combat against the effectiveness, actually even during the end of World War II, once the Germans found out what radar was and that we were using it, they started incorporating graphite into the paint of their aircraft and graphite absorbs radar so this was at, like, the very end of the war so had they done that earlier it might have changed the outcome of some of the significant battles. Because it really did work. The Germans really did make an effective stealth aircraft right at the end of the war and if they had made that earlier it really might have changed some things.

Ryan: Was that also one of their early jets because they also had some jet aircraft by the end.

Jacob: It was, it was and it wasn't, it wasn't just the graphite in the paint, it was also the shape of the aircraft it's very reminiscent of a B2 bomber, it's got smooth curves on the front of the aircraft...

Ryan: I've often heard that if they had developed that aircraft earlier in the war our aircraft would not have stood a chance.

Jacob: Now the argument against that is that one particular, that one off aircraft was so ridiculously expensive that there's no way that they would have been able to make it in scale and it also wasn't, probably wasn't structurally sound enough to be used multiple times. So it would have required a lot of...

Ryan: I love that. Single use airplane.

Jacob: Yeah.

Ryan: That's like Zack Weinersmith's single use monocle.

Jacob: Yeah. So, anyway, after World War II those sort of, those secrets were actually obtained by the United States government and classified so that other powers like Russia, wouldn't have access to the advancements that German scientists years prior. And so the radar blocking techniques that were developed by the kind of communist powers post World War II, included things like metal chaff being used to create a cloud of aluminum particles that would...

Ryan: Yeah, that's what I was saying, where they were drop just a bunch of slivers of tinfoil or aluminum foil....

Jacob: And so...

Ryan: ...make it confusing.

Jacob: The most effective thing that came out of it was that they were just jam the aircraft or just jam the radar so, that, they would put radar transmitters on an aircraft, they would shoot high energy radar radiation back at the transmitter and receiver and then you'd just get noise and you wouldn't be able to see anything. So, from that resulted in a new type of radar called phased electronically scanned array radar. Joe and I talked about this on Technically Speaking at one point but basically the difference is that it's a radar that doesn't use a fixed frequency band. It goes, it kinda, it oscillates. But it's smarter than that, at least the newer ones are smarter than that, where they not only do they not stay on the same frequency band, but the frequency band that they do use, changes constantly in a way that nobody would ever be able to match. You know, there's not like an algorithm that they could, that a jammer could figure out how to match and figure out how to jam that radar. So it's essentially un-jammable, but it also reduces the energy that is, that is emitted from the radar so that if somebody is detecting radar they only see it as a small spike in one particular frequency and then they'd have to look way over on a different part of the frequency band to see another small spike and then when add all those spikes up you realize, all crap, that's actually a radar signal and I just got detected. Really cool stuff and what's even cooler about it is that it is a single piece of like non-movable silicone chip. It's not, it's not like a dish. It's not you know a dish in a can like the old radar systems, this doesn't rotate around.

55:04

It's literally, it looks like if you look up a picture of the radar system, like, on the F-22 or one of the more recent ship-based radars, it looks like a giant version of those, like, computer chip pictures that you see from Intel where they are like this is what the chip looks like at 100 times magnification. But the radar looks like that full size because it's actually just a bunch of different silicone die chips that are able to emit and receive radar signals. So typically what you'll have on an aircraft or ship is hundreds, if not thousands of individual little, little tiny radar emitters and transceivers. I said transceiver is because that's the word for something that transmits and receives. So you'll have hundreds of them all in an array. And so that's what I was talking about before where you can start to determine the shape of the object by having a large array of radar. And what Google has done, getting back to this Google thing, is they took just one of those, one little tiny radar transceiver and they put it on a little tiny handheld chip and it's super duper low power radar, I mean if you were to put yourself in front of the radar dish on an F 22 or a modern aircraft and they turned it on, you'd die. It's powerful enough that you'd probably melt from the inside out. So, so, this particular one that Google's using, is very low power and it's designed to, it's tuned to bounce off of your skin rather than going through your skin or getting absorbed into your skin. And it comes back and is received by the chip and it's able to detect gestures that your hand makes So, if you were to kind of take your fingers and put them in a pinching gesture, like you were going to grab something with your thumb and your forefinger and then you were to rub your thumb and forefinger back and forth like you're, I don't know, like you're putting a pinch of salt on something, the radar that's in this device...

Ryan: You are betraying your lack of time in the kitchen Jacob if you're, if that's how pinches of salt are distributed...

Jacob: Okay, okay, whatever.

Ryan: No, no, it's like, it's like the thing you do when you make fun of somebody by playing the world's smallest violin...

Ben: I was going to say that!

Jacob: Yes, yes, playing the world's tiniest violin...

Ryan: Thanks, Ben, I'm glad you and I are on the same wavelength as opposed to Jacob's weird salt pinching.

Ben: No, I was like, tiniest violin, tiniest violin. As soon as he stops talking, tiniest violin.

Jacob: So, in any case, the processor that's attached to the radar transceiver, is able to take the signal that's being received by the radar and detect those sort of gestures. So, it knows when you're pulling your forefinger backwards or pushing your forefinger forwards, and it can then be used as the controls to a computer or a phone. So the idea is that, say you're holding your phone in your right hand or your left hand, and you've got your right hand and you hold it in a fist and you start moving your thumb on top of, the side of your forefinger, you could use that as like a joystick or like a scrollbar. And it's precise enough to be able to use, to be used in place of the touch, the touch screen on your phone. So, the examples that they give, there's only one tiny little clip inside of the video where it's an actual usage, all of the other ones are like CGI rendered sort of things. But there is one part where it shows an actual usage and it looks super, duper precise. All it is, is they've got a circle and a little ball that rides inside the circle, the lines in the circle, and so when you move your fingers, it moves the ball to the left or to the right in the circle and so you can make the ball go around the whole circle. And in the video you'll see that the tiniest little movement of the fingers results in a subsequently tiny movement of the ball but it looks really, really precise. And the really cool thing about all of this is that it's a very, very small little chip that would need to be added to our phones or to our computers that is something that could be hidden behind plastic, hidden behind glass, you know the radar can travel right through glass and plastic without a problem. You could put it, theoretically into a smart watch and totally change the control scheme of a lot of these different devices, especially touchscreen devices to be something that is not only precise and accurate but also intuitive in a way that other proposed control schemes aren't, I don't think. Like, the, there's, I have seen some where you can do some gesture recognition on your, on your skin, like, where the, it will use the electrical conductance of your skin, where you can just tap, like you know, use two finger taps to go up, one finger up, tap to go down.

1:00:09

That sort of stuff you have to remember but if you just have to move your thumb up in order to make the page scroll up or move your fingers in a pinching motion in order to make the picture become bigger then it's very similar to what we already do on the touchscreen. And so I think, I think there's some good, there's some good possibility behind it but I'm also just really excited about the usage of the technology because...

Ryan: It reminded me a lot of the way that Joaquin Phoenix's his character interacts with devices in *Her*.

Jacob: Yes, you are exactly right, that's what they do in that movie. I forgot about that.

Ryan: Hey Tim can you just take him saying I'm exactly right and just loop it. No, because the way he plays video games like you know he just seems to haptically throw the game from his Phone up onto the screen in his apartment and he's just playing with his hands in the air but whatever, you know, it's sort of next level connect but it's done with the fidelity and finesse that this sort of technology would enable.

Jacob: Yeah. Yeah, it definitely, I think you're right, that's probably the best, because I was trying to relate it...

Ryan: And Tim, can you replace him saying that I think you were right with you are definitely right?

Jacob: Because I was trying to relate it to *Minority Report* but *Minority Report* he wore gloves and the gloves...

Ryan: He wore gloves, but also...

Jacob: ...did all of the gesture recognition.

Ryan: ...you know so, I think what designers of next generation interface systems are learning is that people don't actually like that stuff.

Ben: No.

Ryan: Even Tom Cruise who, you know, enjoys running on film more than greyhounds, the man is just always exerting energy on film, even, according to what I've read about that movie and the filming of it, he would get tired doing those scenes and would need to take breaks. Because using computers like that is way less energy efficient for the human than just using a keyboard and mouse.

Ben: Yeah.

Jacob: Yeah.

Ryan: So, you have to come up with something for us lazy jerks to do that doesn't take so much energy that we get tired of doing it and just switch back to our normal interface.

Jacob: There's a lot of really good examples of that, even outside of control schemes, just, just general, like, business systems where people use inbox and outbox systems that are all paper driven, that are, there are examples of this in the aerospace industry and in a lot of manufacturing industries where simple paper-based systems are orders of magnitude more efficient than their computer-based analogues. And it's crazy that we kind of get ourselves into this, into this mindset where if we digitize it it will be better. But, unless it comes with a savings and efficiency or quality or usability, then it's not worth it to switch. Just keep using the old system. And in this case I think that Google may be onto something where they might be solving some of the problems of those glove based interactions by just making it easy to use.

Ryan: Do you remember the movie *The Wizard* with the power gloves scene?

Jacob: Yeah...

Ben: Sure.

Jacob: ...power gloves.

Ryan: Yeah, the power gloves, that's for only serious gamers, the power gloves.

Ben: Man, the power glove is so cool.

Jacob: What a terrible device.

Ben: No it wasn't.

Ryan: I never had one I could never afford one.

Ben: that's the thing right, I, I had to look it up because I was going to, where was I, I was helping Tim with his podcast and we had to talk about the power glove and I guess the original specs were really cool. They were fiber optic cables inside of the glove and, so if you bent your fingers it would cause those cables to bend and they wouldn't transmit light as efficiently...

Jacob: Yeah.

Ben: And then so it used that to determine how much your fingers were bent and there was, it was super, super sophisticated but when they had to design it to manufacture it, they like, cheeped out on all the components and so the result was something really crappy. But, I guess, in the original version of it, it was supposed to work as cool as it did in the advertisements. Yeah, power glove.

Ryan: It sounds like we are all in favor of this being a thing that exists.

Jacob: Well, I think it's one of those things where it remains to be seen as to how, how well it actually works in real life. Because you can imagine...

Ryan: One of the things they said was that they were excited to release this to the development community.

Jacob: Right.

Ryan: And so if that's true and their plan is to just be like, we developed this, now you guys figure out ways to use it, I expect will see some pretty cool stuff.

Ben: I think it's going to be bad.

Ryan: That's also probably true.

Jacob: Here's the pitfall in my, in my engineering opinion. These electronic, and I, I'm brain farting on the word but the silicon chip that emits, the transceiver for the radar, it can only shoot radar energy out, straight perpendicular and then some chips can go 5° in either direction.

1:05:13

So what that would mean is that if you're using it to control your phone, you have to point your phone at your fingers in order to get it to recognize the gestures. Either that or it would have to incorporate some other form of, of visual tracking of your fingers, like it uses the phone's camera to see where your fingers are, and then it actually mechanically rotates to the transceiver to point towards your fingers, which would be kind of ridiculous especially in our world of super thin phones. There's not room in there to rotate anything, you know? So I think that's going to be the real kicker is, are they going to be able to make it so that it can see your gestures without having to be really picky about how, where your fingers are relative to the device.

Ben: Can I add that, I might sound like an old man when saying this, but like, the nice thing about a button is that you know when you're pushing it and when you're not pushing it, right? Even with touchscreens you're like, oh, right, you put you are phone up to your ear and you accidentally hang up because, your ear touched the touchscreen in a weird way.

Jacob: Yeah.

Ben: This way you'll be like, I don't know, you'll be like twitching, or, you know, just like, scratching an itch on your finger, and you'll accidentally phone Norway, like, come on, buttons man…

Ryan: I'm so sick of phoning Norway.

Ben: … that you can press down on. There's a reason we haven't replaced, like, actual keyboards with just, like, projected keyboards where people tap on the surface.

Jacob: I don't know, I think you get some haptic feedback by touching your other finger. As long as the device is reliable enough to be accurate 100% of the time…

Ben: Do you know what this would be good in, it would be good in the car when you like, want to turn on the radio or futz with the radio. Instead of having to lean over and press some buttons that you can't quite see, if you could just kind of do a thing in the air.

Jacob: Ahh, by the time this is ready we're all going to have self driving cars anyway.

Ben: Oh, okay. Well, then what's the point?

Ryan: We'll all be happier because we will have self driving cars. It's gonna be a good thing Ben.

Ben: Man, I had to carpool because there was a transit strike in my city and I was like, at first I was like, this will be fun. I can sit in the backseat like when I was a kid. And then as I was sitting in the backseat of the car I was like, sitting in the backseat is boring and stupid. Like driving is annoying and then sitting in the backseat is annoying, there's nothing enjoyable about it, so… bblleeeeaaahhhhh.

Ryan: Yeah, I remember that *Top Gear* did an entire thing about how like most people don't ever really use their backseats for people. I think they're right, I very rarely have somebody actually sit in the backseat of my car.

Ben: Right.

Jacob: All right, I think, I think we tapped all there is to tap on this right now. It's a preliminary technology, they have, they have a prototype that's ready to be shared with the development community. It'll be interesting to see where it goes, I hope it's not a gimmick like the 3-D cameras have been so far, but, we'll see.

Ryan: Sounds good man.

Jacob: Yeah.

Ryan: Well, we'll also see what the listeners have to say and if they would like some sort of radar enabled haptic whatever it is and we'll find out about that in our next segment called, next and final segment, you guys, you are almost done listening to the show so congrats to you. And the final segment, the only one you have to get through is called the Paleo POW.

Music

Ryan: Paleo POW is the segment of the show where we tackle the feedback from the listeners because you guys give us a lot to tackle. Ah, I think Ben has to go first this time.

Ben: All right so our first Paleo POW is by a guy named Peter P. and he's donated some money. "Congratulations" he sent a message and it says "I wanted to donate to you all for your great work. Also Ben has an email from me as well." And indeed, Peter had sent an email. He is a Patreon supporter on *Titanium Physicists* and a cool guy. That's...

1:10:12

Ryan: Thanks Peter!

Ben: Thanks Peter!

Jacob: Can you read us the email he sent?

Ben: Well, I, well...

Ryan: It was just saying nice things about Ben's show it's pretty unnecessary.

Ben: Yeah.

Jacob: Before the show we were just talking about how Ryan can be so mean sometimes.

Ryan: No, no I only tease people that I like. Everybody, like I get emails, they're like you tease Jacob too much, you tease Abe too much. I'm like, I like them the best, that's why they get teased.

Ben: Peter asked if I was, was I really a gentleman named Peter. I thanked him as a gentleman named Peter at the end of one of the episodes. That is so cool. So he loves supporting our show and would and will most likely support even more in the future when he can afford more. Peter, you don't have to send us all your money, it's fine. Your support us enough, thank you. You're a great guy.

Ryan: Thanks Peter.

Ben: Thanks Peter.

Jacob: thanks Peter, you are the best.

Ryan: Peter is also active with us on Twitter, Twitter handle, @vituanpeterphan, and so I'll link to his Twitter profile in the show notes for people to go, if you want to be part of our online Twitter community which is a fun little community of like minded sciency people.

Ben: Right on.

Ryan: I feel like we, I don't care how much talk there's been about bubbles, we all need our like-minded community of fellow fans on the Internet.

Jacob: We need to get people that hate us to listen to our show.

Ben: And then review it...

Ryan: We try but then...

Jacob: We should advertise our show to the flat earthers.

Ryan: I'm not sure that they are, they're swallowing what we're selling.

Ben: Man.

Jacob: That's because nobody's ever tried.

Ryan: Okay.

Jay: We could be the pioneers in the anti-advertising...

Ryan: We'll start planning a flat earth episode.

Jacob: Yeah.

Ryan: To appeal to that demographic. But in the meantime, my, no actually Jacob you go next.

Jacob: Okay, all right, I have an email from Joe S in the PA, I am assuming that's in Pennsylvania although it could be, never mind.

Ryan: I was trying to think of another place that that could be and I also failed.

Jacob: I was like Papa... nope, nope, not Papua New Guinea. All right Joe says, "Hey there, a huge fan of the show, well the 120 episodes I've managed to listen to so far anyway. Hopefully I will catch up before Christmas of this year 2014..." So....

Ryan: We're a little behind.

Jacob: Sorry Joe.

Ryan: We are trying. We're a little bit late getting to this Paleo POW. That said...

Ryan: But we're caught up now so he'll here it right away.

Jacob: Yeah, he says, "That said, I just read this article", and he links to an article, "and my inner nerd goes yay, mysterious physics doing the impossible. But then my rational brain works and I'm not science smart enough to separate the wheat from the proverbial chaff on this one so I thought I would kick it to my favorite science guys to see if it was science, a thing that was sort of science or a thing that wished it was science. Lastly, a special beer request, I moved to the Northeast two years ago from Oregon and have been dry ever since. Please have a delicious Widmer hefeweizen for me as I can no longer partake. P.S. You rock and I still can't tell Charlie from Patrick still." That's really surprising to me, that anybody wouldn't be able to tell Charlie from Patrick but anyway the article that he links is a PBS article from 2014 talking about a certain type of electromagnetic thruster that appears to violate the known laws of physics. And if you've been paying attention to the science subReddit on Reddit or various science outlets over the past couple of years you've probably seen these stories pop up every once in a while. The one that he links to is a thruster called the Cannae Drive, C-a-n-n-a-e Drive. There's another one that's very popular right now called the EM Drive and both of them are a type of resonate cavity thruster. So the idea is this, you take a cone and you chop the top of it off so that you have a conical cylinder, like a cylinder with one end pinched and then you the top and the bottom how do you put a microwave emmiter inside. The microwaves bounces off the inside of the container and through asymmetrical radiation pressure, or a lot of different there's a lot of different theories for how this would work, it theoretically produces thrust without the use of any fuel and only using magnetic radiation which we can produce through a battery or any electrical source.

1:15:00

So the, the thing that makes this really exciting, if you believe it, is that it would be, it would be a thrust drive that we could use in space that wouldn't consume any fuel. So if you had a nuclear reactor on board or a solar panel that was able to generate enough power to power this thruster you could theoretically have infinite amounts of thrust, or, infinite amounts of thrust even though it would be very, very small. It's kind of sort of similar to the Ion propulsion drives that we have, that we use right now except that Ion propulsion drives take a very, very, very, very tiny amount of mass and they shoot it out the back at very high speeds and they use the property...

Ryan: It's what TIE fighters have.

Jacob: Ah, no. This is what...

Ryan: That's true. TIE is an acronym, it stands for twin ion engines.

Jacob: Oh, well I don't know if those are Ion propulsion engines in the sense that what we use is the same thing but...

Ryan: No, I mean, because obviously TIE fighters have faster acceleration than, like, an X-Wing.

Jacob: Yes, so a lot of satellites have Ion propulsion engines. Basically the gist is it uses a very small amount of fuel but the trade-off is you get a very, very, very small amount of thrust but you can keep that thrust going for a very long time so if you put an ion propulsion engine, an ion thruster on your back, and it started pushing you, it would, you would barely even feel it, you know. It would be such a small amount of thrust that your own, the muscles in your feet would counteract the force and you wouldn't feel it hardly at all. But when you put that...

Ryan: Well, eventually.

Jacob: Well, if you put it in space. Or if you sat down on a skateboard or sat down on an ice rink, eventually it would, it could, potentially overcome the friction in the wheels of the skateboard and start pushing you. But in space where there's no air pressure to go against, there's no reaction force, these very, very small amounts of thrust can eventually lead to a very high level, a high velocity. The acceleration stays very, very low but eventually, and we're talking on the scale of micronewton's, so, 25 milli, ah, micronewtons to, or, I guess, 250 millinewtons is probably one of the highest ones. I just looked it up. Ah, it's a hard, I'm trying to find a good one, change velocity by, none of the American audience is going to recognize this, but change velocity by 4.3 km per second while consuming less than 74 kilograms of xenon on the Deep Space One spacecraft.

Ryan: Because, you know, Americans just really don't know how xenon works.

Jacob: Or kilometers or kilograms.

Ryan: No, just the xenon, xenon is the only part that we fail on. Everything else is fine.

Jacob: To get back to the, to the Cannae Drive and the EM Drive, the idea behind these is that they could potentially be a way to generate thrust without fuel. The problem is they violate the law of conservation of momentum. There's no mass exchange happening, there's no, there doesn't appear to be a way for these devices to produce thrust based on our current understanding of physics that doesn't violate the conservation of mass and the conservation of energy.   Ben: Right. Okay, so, before we go on. When you say fuel you mean stuff being thrown out the back of the rocket and not something that has energy in it that we're harnessing to get, right?

Jacob: Correct, correct.

Ben: So, it's...

Jacob: I'm talking about, when I reference fuel, I'm talking about mass ejection.

Ben: Right. So, normal rockets, you throw stuff out the back of them, the total momentum is zero but you give the stuff going out the back some momentum in the opposite direction that you travel and the rest of your ship gets an equal and opposite amount of going forward.

Jacob: Right.

Ben: And so the issue with this is that nothing's going out the back.

Jacob: Correct.

Ben: Okay, so, but photons carry momentum, right? I mean, you can, you can shoot, if you had a laser pointer and you attached your laser pointer to a deep space probe...

Jacob: Yeah.

Ben: ...you could generate a very small amount of thrust that way.

Jacob: Right, and then that's how solar sails work but this is, this is operating on, theoretically, a different basis because the cavity in which the microwaves are emitted is a closed container. So, the emitter of the, the microwaves is on the spaceship, it's not somewhere else. And it, it sends microwave energy into this little cavity and the microwave waves bounce around inside that cavity but they never go out the back, they never, you know, they don't escape. They eventually get absorbed by the material I guess. But, the crazy thing about it is that since 2014, or, I guess since earlier than that, there have been numerous tests of these different devices by different space agencies.

1:20:06

We've had NASA do some tests, we've had the European Space Agency do some tests, I think China did some tests on it and every single time that it's been tested so far, there is a small amount of thrust produced. But there's always, within a couple months, somebody that points out experiment flaws in the design of the experiment. So, the way that, a lot of times, these sort of things are tested out is you create a pendulum from which you hang the device that you're testing to see if it produces thrust. And then you detect any movement of that pendulum as resulting from the thrust of that device. So, they did the first test with a simple pendulum and they were like, aw, crap, it actually did produce some thrust. But then they flipped it around and tested it in the other direction and for whatever reason it produced thrust in the same direction no matter which direction they pointed it. And so they realized that there was a mistake in their build, they had to ah, you know, say that the results were no good. Then somebody else tested it again with a higher precision pendulum, they did see some thrust that was observed to change directions when they changed it but then when they, people identifield an issue where potentially the air was being heated asymmetrically around the device and that was causing some thrust on the pendulum. So then the next test that happened they had to put it in a vacuum and so there was just a recent test that happened in 2016 by the NASA Eagle Works Laboratories where they've basically covered all their tracks. They used an extremely high sensitivity measurement device, it happened in a vacuum, they tested it backwards and forwards, they tested it on and off which was another thing that they found in some of the original experiments where they turned on the magnetron but they didn't open it up to be able to emit any microwave radiation into the cavity, they just turned it on and, kind of as a control I guess, right. And in that scenario no thrust was produced and so they were able to say we've got a pretty high level of certainty that there is something happening here. It's producing one millinewton of, of thrust per kilowatt of power input into the system. Which is a very, very low amount of thrust. Way lower than the amount of thrust produced by ion thrusters but it is still something. And, right now, so the scientific community, is still kind of trying to figure out what, if there were any, experimental errors in the most recent test. But they're really grasping at straws as to explain how it works. There's a, um,the one that was done by NASA Eagle Works, they proposed something called the pilot wave...

Ryan: Wait, when you say Eagle Works, not to interrupt, but, I've heard the term skunkworks as like, the place where you build experimental stuff. What’s Eagle Works?

Jacob: Um, it’s a NASA facility, let me see if I can look it up real quick. It’s part of the Advanced Propulsion Physics Laboratory at NASA’s Johnson Space Center. So, it’s a small research group investigating a variety of fringe theories regarding novel forms of space craft propulsion. So that’s what they specialize in. I believe they were the ones, one of the ones that tested the vasa mirror thruster that Joe and I covered a long time ago. Or that I covered with you guys when we were talking about super hero powers.

Ryan: Yeah, Jacob helped me out with the articles that I did for marvel.com about the Iron Man suit. Ben helped out as well.

Jacob: Yeah.

Ryan: That was one of the things.

Jacob: And so they are proposing that there is something, there is like, kind of a discredited theory in quantum mechanics called the pilot wave hypothesis. Have you ever heard of that Ben?

Ben: Yeah, yeah, sure. Is it discredited? I don't know. I'm not sure it is.

Jacob: I don't know if it's discredited, let me see. I guess the way that I read it was that, it was, it was kind of fringe or non...

Ben: Yeah, yeah, it's fringe. Nobody really takes it seriously but as, but, nobody takes many worlds seriously either, so, I mean it's, it's just one of those things.

Jacob: So, so, right now the paper that was released by Eagleworks, they didn't really try to provide a detailed explanation of how it works because they're still just stumped. But they said that they were looking into the idea that it could be explained by pilot wave theory. And I have no idea how that would, how that would relate to it because I don't understand it all. But basically the next step for it, for this, is to put it space, to actually test it in not just a gravity, or, not just a vacuum but in zero gravity and see what happens out there. Because if it, if it works in the way that it appears to be working, it doesn't really matter if we don't understand how it works.

1:25:00

If it works we'll end up using it on satellites pretty quickly because ion thrusters aren't used for station keeping very much because they're really expensive. But this is a really cheap type of thruster that could be Jerry-rigged onto any satellite and just plugged into the solar panels and produce some amount of thrust that could keep it at orbital altitude. So, it's kinda cool but it's also kinda like everybody's skeptic brain is turning on and they're like you're violating the conservation of energy, how is this possible?

Ben: I mean, so, okay, honest talk. Do you think this is a real thing? Like, do you think, do you think that it's acutally new physics? Or do you think, like, it's entirely plausible that it's just radiation pressure?

Jacob: I, I don't, my, I guess my, and I really don't have good rational for why I think this but, I think that there is going to be some new physics that comes out of this. I do not think that it's going to be a functional thruster that results. I think that we're going to have a new understanding of, possibly, how microwaves are interacting with this type of situation but I don't think that it's going to be something that, that results in a net thrust once we get into zero gravity. I don't, I don't, if it, if it does, it's going to be so, I don't know, it's hard to make a judgement call on it because I don't understand what the hell's happening.

Ben: I mean, so, have you ever heard of the pioneer anomaly.

Jacob: Ah, I only just heard about it because I started reading the book *Nomad*.

Ben: Hey Ryan, have you ever heard of the pioneer anomaly?

Ryan: Yes, it's why the Pioneer probe was changing velocity outside of the solar system.

Ben: Yeah. So, I mean, the Pioneer probes, there's two of them and they're real far from the solar system now, they're really far from the sun. But there still is a little bit of gravitatonal acceleration there, right. Even as far as they are and it should be obeying Newton's universal law of gravitation, it should be a dying off like, you know, $1/r^2$. But it wasn't. The acceleration was slightly different and nobody knew why so a lot of people were guessing that it might be corrections to Newton's gravity and we, you know, this was, this was about ten years ago, people were also interested in finding alternative explanations for why, for dark matter. And so, one of the, one of the possibilities was that Newton's laws, at large distances from the sun didn't quite work the way we expected it to. But, no one was quite sure. And then, more recently, 2012 I think, a group did a really, really comprehensive simulation of the probe, because one of the, or probes rather, because one of the possible reasons for this weird acceleration that it was detecting was that, you know, all the panels in it, were cooling off.

Ryan: We do, we talked about this on the show.

Ben: Yeah, I, so, it, they were right. It was just, ah, it was just that the thing was cooling off, it was releasing thermal radiation into space, but it wasn't releasing thermal radiation in all the directions at the same pressure. And so that difference in radiation pressure caused it to accelerate slightly and I don't know. So, I haven't crunched the numbers on this EM Drive, but...

Ryan: It was episode 146 that we did the Pioneer paradox.

Ben: Yeah. But, essentially, you have a system where there's a cavity, the cavity isn't, isn't symmetric, it's not like a cube, right? And so the energy distribution of the, the energy density inside of it is going to depend something on the shape.

Jacob: It's going to be asymmetrical.

Ben: Yeah, it's going to be asymmetrical. You're pumping into it and it's not melting so, you know, either the sides are getting really hot and radiating heat out or, I don't know, melting? It depends on how much energy you put into it but, I don't know. I wouldn't be surprised if it was just some weird radiation pressure thing. The, ah, I glanced through the paper and it seemed to say that one of the things that they weren't controlling for was interactions with the sides of the chamber they were doing tests in, so, maybe there's some weird thing going on there. I was hoping you could tell me because you're the rocket scientist.

Jacob: Ah, once it gets, once it gets past, you know, exploding something and throwing it out the back, I'm a little lost.

Ryan: At least your big enough to admit that.

Jacob: Yeah, and I see where you, on the Pioneer anomaly Wikipedia page they talk about thermal recoil force.

Ben: Yeah.

Jacob: I've never heard of that before, I don't know what that is but...

Ben: They probably had to invent a term. It’s just, you know, thermal radiation that isn’t uniform in all directions and so there’s more pressure going out one side than the other.

1:30:09

Jacob: Yeah.

Ben: Then you get a net force cause you’re loosing momentum. You’re essentially using photons as your fuel, as it were.

Jacob: Right. But would that require a photoelectric effect where, like,the heating of the panel is actually releasing photons as a result of getting heated up?

Ben: Yeah, I mean, it does. All matter does when you heat it up.

Jacob: Okay. So, even if it’s like, very low levels of heating, there’s always going to be some amounts of photons that are being released.

Ben: Yeah.

Jacob: Okay, so, potentially the microwaves in the EM Drive could be heating the container and because the container is shaped asymmetrically, it could be releasing more in the direction that was result in thrust than, ah, huh.

Ben: That’s my guess. It’s an order of magnitude thing and I haven’t done the calculation.

Jacob: Well, the paper also doesn’t reference thermal recoil force as a proposed explanation, so, it might be worth, honestly, it might be worth sending it in.

Ben: Someone here is a rocket scientist and someone here is just a humble country physicist. I don’t know if, I don’t know if we should be making that call.

Ryan: So, there was more to digest there than even I expected but, you know, if you wanted another segment of the show, basically, you got it. So, that’s good. Ah, my Paleo POW, very short, very sweet, well, it’s not actually that sweet, no, it’s fine. It’s from Paul K and he wrote in about episode 254 where I had said that chlorophyll was green because green is the peak wavelength produced by the sun. I was wrong on that, slightly. So, let's see, he says, "You said that chlorophyll is green to take advantage of the sun's light peaking at around the green wavelength. If chlorophyll appears green to us that's because it reflects green light. Sorry to be pedantic but you guys' comments are usually so on the ball but this really stuck out. Keep up the great work, this is one of the best podcasts out there." I don't have any excuse for that, it was not the intended topic of that discussion, Charlie just, like, asked what the peak wavelength of the sun was and that was the only thing I could remember about peak wavelength so I said it. And I know Jacob and Ben can attest to this. Your brain does weird things when there's a microphone recording you.

Ben: Yeah. Yeah, yeah.

Ryan: You just say stuff that you would know was wrong any other time but you say it and you just have to deal with the consequences. So, I'm sorry Paul, thanks for the corrections.

Ben: Chlorophyll absorbs ultraviolet, doesn't it?

Ryan: I don't know, I'm not going to touch it because Paul's going to yell at me.

Ben: Well, isn't it like, high school biology, it's literally been 10 years since I learned this, but, I thought chlorophyll absorbed ultraviolet light and then, and then, you know, did its thing. ATP something...

Ryan: Well, we'll have to get Matt from *In Defense of Plants* back on the show to talk about plant stuff...

Ben: Alright.

Ryan: Because I was not up to the task. I tried, I failed. Paul called me out on it. I'm reading the correction, I don't know what else you want from me. All I got. Ah, so, thanks Paul. Thanks to anyone else who writes in with corrections. We get them from time to time. People are always worried that they are being pedants as if that wasn't the point of the show. So, ah, with that, Jacob, Ben, you guys got anything to plug?

Jacob: Nope, not particularly.

Ben: Oh, oh, I guess...

Ryan: According to Wikipedia, Ben...

Ben: Yes.

Ryan: Ben, according to Wikipedia, chlorophyll absorbs energy from light strongly at the visible frequencies.

Ben: Oh, really? Well, let's go...

Ryan: It makes sense.

Ben: ...let's go back in time and kick my high school biology teacher.

Ryan: Done.

Ben: Okay.

Ryan: So, Jacob doesn't have anything to plug. Ben, do you anything to plug?

Ben: I have a podcast. You guys want to listen to my podcast? It's called the *Titanium Physicists* podcast...

Ryan: I do listen to your podcast.

Ben: ... and I have people who are smarter than me on explaining things better than I could. It's great.

Ryan: Awesome.

Ben: To people that you'd want to know.

Ryan: You can find a link to Ben's show and to Jacob's old show on Sciencesortof.com or you can also find the show notes for this episode and you can interact with us on all the various social media networking sites that you use except Instagram because we're not hip. And, ah, the best way that you can support us is by listening to the show, telling friends about it, leaving us ratings and reviews on iTunes. You can also donate to us through PayPal or shop with us on Amazon. Ah, Amazon gives us money for the things you buy from them but doesn't charge you any more for it so it seems like a win-win for everyone but Amazon and we're willing to take that so go do.

1:35:00

And, ah, thanks everyone for listening and thank you both for joining me. I think this was a good episode and ah, we will see you all next time for a whole lot more Science...

Ben and Jacob: Sort of.

Announcer: Visit sciencesortof.com for show notes, links to all the stories we talked about, and ways to interact with the hosts, guests and other listeners, Science sort of is brought to you by the Brachiolope Media Network of podcasts with audio engineering by Tim Dobbs of the Encyclopedia Brunch Podcast. That's all for this week. See you next time on Science sort of.

Music

Ben: Well, I can't, you've got to turn it away from me. So, I managed to get that explanation out by rotating my drink away from me because it was too much fun. I just can't stop looking at it and like, getting off track

Transcriptions provided by Denny Henke of Beardyguycreative.com