Episode 13: That Which Lies Beneath The Ice
Physicists: Ken Clark, Laura Gladstone

Transcribed by Denny Henke

Ben: Over the course of my studies in theoretical physics I’ve traveled across the continent and around the world sampling new ideas and tasting different answers to the questions of how and why. And still I find there remains a deep hunger which lives within me, a burning desire to share these great ideas with the people around me. And so, I have assembled a team of some of the greatest, most lucid, most creative minds, I have encountered in my travels and I call them my Titanium Physicists. You’re listening to the Titanium Physicists Podcast and I'm Ben Tippett. And now allez physique!

[1:49]

Ben: Neutrinos. Now, we've already spoken about neutrinos once before. Episode 4, the Solar Neutrino Problem with Amy Pollien. We introduced the neutrino and talked about how a bottle of water at the bottom of a mine was used to tell us that the sun is not going out. So, in brief, there is this thing called the neutrino.
So, imagine you've got a microscope. A really, really good microscope. A fictional microscope, it's so good and you focus in on an atom. First you see the outer shell of electrons. So, I zoom in on the nucleus in the middle. Now, the nucleus is composed of protons and neutrons bound together by the strong force. Now, I want you to take your little tweezers and pull out a neutron. Now, outside the nucleus, neutrons tend to pop like a popcorn kernel. Well when they blow up they turn into three things. A proton which is positively charged, an electron which is negatively charged, and a neutrino. Neutrinos have no electric charge and they have very, very small masses. Now, the problem with neutrinos is that they interact through the weak force. Recall that there are four elementary forces in physics. At first, there's gravity which holds your feet to the ground. Then there's the electromagnetic force which is responsible for keeping your feet from falling through the ground. Then there's the strong force which is much stronger than electromagnetism and binds all the positively charged protons in the nucleus together. Finally there is the weak nuclear force. It's the reason that really heavy nuclei decay, like plutonium. Okay, so, back to neutrinos. Neutrinos only interact with other matter through the weak nuclear force. Well, gravity as well but their mass is tiny so don't mind them. Okay, so, when it comes to bumping other particles they'll only interact through this really, really weak mechanism. So they are terribly difficult to detect, terribly, terribly. In episode four we told you about the Homestake Experiment. It used a big vat of dry cleaning fluid at the bottom of a gold mine and occasionally a solar neutrino passing through the vat would turn a chlorine atom into argon. And when they collected up all the argon every few weeks they could tell by counting them up how many neutrinos had interacted with this vat of chlorine. Now, there 10^{10} neutrinos passing through each square centimeter every second on earth from the sun. And there were a 100,000 gallons of dry cleaning fluid in this vat. In spite of this the homestake experiment only detected one, one! neutrino every six days. These numbers are crazy! So, to quote Douglas Adams, the chances of a neutrino actually hitting something as it travels through all the howling emptiness is roughly comparable to dropping a ball bearing at random from a cruising 747 and hitting, say, an egg salad sandwich. So, today, we'll talk about the newest and best experiment for measuring these terrible, tiny things. Here's a hint, it's in Antarctica, it's on a glacier and it's one cubic kilometer in size. Today we're talking about ICE CUBE.

So, my guest today is the incomparable Andrew Johnstone, host of the Podcast Squared Podcast. Hey Andrew.

Andrew: Hey, I actually, apparently I'm in the wrong podcast. I thought we were talking about Ice Cube the rapper?

Ben: Oh.

Andrew: This is not, ah, I guess, Titanium Physicists should have clued me in but I thought maybe there was some special physical property to the actor/rapper but that's fine we can keep going with this.

Ben: Anyway, guys, Andrew's show is a show about podcasts and podcast culture. It's called Podcast Squared. He interviews podcasters and gives good reviews about all types and qualities of podcasts on all different subjects. It's one of my favorites to listen to. So, Andrew, today I have assembled two of my finest Titanium Physicists for you. Arise Dr. Ken Clark.

Ken: Whoooosh!

Ben: Oh, it's a bird, it's a plane. No, wait, it's Dr. Ken. Dr. Ken did his undergraduate at the University of Toronto and his Masters and PhD at Queens University. He's now at Penn State working on ICE CUBE. Now, arise Laura Gladstone!

Laura: Wwhhhhoooojjjjjshhhhhhh whhhhhhooojjjjshhhhhh.

Ben: Sweet. Laura did her Bachelors in physics from Columbia and she's currently a PhD candidate at the University of Wisconsin Madison. She's also working on ICE CUBE and her thesis is on neutrino oscillations.

Alright guys, let's start talking about neutrinos.

Andrew: So, what's significant about a neutrino? So, it's this tiny particle inside of a neutron, sub, sub, sub, sub atomic. What's special about it.

[6:39]

Laura: It is, it's sub, sub, sub atomic. It's about a million times smaller than an electron and the exciting thing about them for me is that we don't know, there's a lot that we don't know about them. It's the forefront of physics right now. It's the wild west of physics.

Ken: And there's a lot of really cool things with neutrinos. Ah, since they don't interact very much they can be a really good carrier of a signal, for example. Like, we can see neutrinos from really far away because basically nothing stops them. They go through everything. So, we can see neutrinos from mega parsecs away and still be able to detect them here on earth.

Ben: There was this supernova in 1987 and it was really cool because before we saw any light from it all the neutrino detectors on earth spiked. And, what was happening is, so the star blew up and all the neutrinos produced at its core where it was exploding flew out and passed right through all the dust and right through all the gas of this exploding star and we received the signal. The light, on the other hand, had to bounce around through all this dust and all this gas before it could reach us. So, the moral of the story is the neutrinos from this supernova arrived at earth before the light actually did.

Andrew: Is that when people started hypothesizing that neutrinos might travel faster than the speed of light?

Ken: That's a good question since it has been in the news so much but it turns out they probably don't.

Andrew: Why are you ruining the magic of science?

Laughter.

Andrew: Let's just believe. If we all believe hard enough, that neutrinos can travel faster than light, it'll be true.

Ken: That is true, yeah.

Laura: That's an interesting question that's cropped up a lot recently and we found a lot of evidence that it doesn't work.

Andrew: So, but then how did we detect the neutrinos before we saw the light evidence of the supernova.

Ken: So, the key is that all of the stuff, all of the light and neutrinos is produced in the center. So, to get out it has to go through most of the star. So, the neutrinos, since they don't interact, they just go straight through all of that matter. Nothing happens. But the light, it bounces around and it turns out that matter is really dense so it bounces a lot and it takes a long time to actually get out of that matter and then start heading towards earth.

Andrew: So, they got a head start.

Ken: They got a big head start, yeah.

Ben: Imagine that you got a big crowd of people and so there's a cake on the other side of the crowd that you and your dog want to eat. So, what happens is as you try to go through the crowd you have to kind of push your way through it, bounce off people and shove them out of the way. Meanwhile your dog just kind of weaves through their feet and makes it all the way through and doesn't interact with any of the people at all and so he reaches the cake much faster than you do.

Andrew: I hate that dog.

Ben: Yeah, it's a bad dog.

Andrew: I wanted that cake. So, how far away in light years was this super nova, approximately?

Ken: 168,000 light years.

Andrew: That's not that far away. That's pretty close.

Laura: It's within the galaxy.

Ben: It's in the Large Magallenic Cloud. So, it's in one of the little baby galaxies that are hanging out with our big giant galaxy.

Andrew: And so, when did we first discover that these existed. Was that during the Manhattan Project?

Ken: Postulated before that, 1930 apparently. We've known about them for quite awhile and they were postulated to solve a different problem with beta decay in a non-linear spectrum which doesn't really matter. But we knew about them, we just, at the time didn't realize that they were going to be this great tool that we could use to study all this other stuff.

Andrew: Ah, so what's, gimme one example, if you will, to illuminate me, about like what, if we studied neutrinos, we could get X out of it. Like as a, say I'm a business man trying to invest in the next big thing, sell me on neutrino research.

Laura: My usual example is just something about basic research and the foundations of society.

Andrew: Oh, that's no good. How am I going to make money off of the foundations of society, that's...

Laura: I mean, that's where we were with electrons a hundred years ago. We just barely knew that they existed and now electrons are running the world economy. So, we don't know what neutrinos are going to be good for. But we're just figuring out the basics of what they can do at this point.

Ken: What I usually use is like the NASA example. Like, we never know what kind of technology is going to spin off from these things. I mean NASA gave us Tang and Velcro, right? We don't know what we're going to learn in doing a neutrino experiment that we can spin off to make money from.

Laura: Not to mention That CERN gave us the Internet.

Ben: Your guys' answers suck, I'm going to use mine.

Laughter.

[11:05]

Ben: Here's my answer. Alright, so, let's say we have an intergalactic civilization Andrew. I own one of the Magallenic Clouds and you say hey I want to buy one of the stars in this Magallenic Cloud. It's like buying a car in the future, you'll buy stars, right? And I say sweet, which star would you like to buy? I have a perfect star here, it's about the size of the sun and it's no where near going red giant. It's a perfectly healthy star, here's the rate at which fusion is happening inside of it and I give it to you on a sheet and you say okay how can you show me that what's going on inside the star is what you say is going on inside the star? After all, I may be selling you a crummy, really old crappy star, like a crappy old car. And you want proof that this car actually only has 10,000 Km on it. It takes a photon something like 10,000 years to make it from the core to the edge. So the color of the star won't tell you about the health of the fusion going on inside of it but neutrinos pass right out. They move through the outside of the star in almost the speed of light. So, you're getting almost immediate data of what's going on inside the middle of this star. And so we'll take out this neutrino detector and I'll say look at these reaction rates, look at the spectrum of the neutrinos, this is a healthy star, guy. And then you'll pay me all the money and then you'll own a star and everything will be great.

Andrew: Of course, now, if we're in the future in which we're owning stars, I don't know how much money is going to matter but I get your point.

Laughter.

Ben: Okay. The moral of the story is neutrinos are useful because they pass right though almost everything. So if you have a way to detect them you can see through anything.

Andrew: This has a huge market in the back of comic books as I understand it.

Ben: That's right, well you can see under the Hulk's clothing, you can finally see what's under those ripped jeans using a neutrino detector. But, I digress. Let's talk about the neutrino detectors we have on the earth already and the mechanism that they use to detect neutrinos. Because as I mentioned in the introduction, they're super subtle things, they hardly interact with anything. Let's talk about Cherenkov detectors.

Laura: Okay. So, the way that we can see neutrinos is through something called Cherenkov light. Ah, Cherenkov light is a kind of shockwave in light. So if particles are going faster than light can travel in that medium, so like, like an ice or water then they make a shockwave. And, I'm not too familiar with how things act when they're going that fast so I like to think of shockwaves in slower things like ducks. We have some lakes in Madison, here, and when a duck lands on a lake, when a duck swims across a lake, it makes a wake, the shockwave going back behind it and you can tell what direction it's swimming and you can kind of tell how fast it's going. If all you can see is the wake then you can still tell where the duck is. So, if you have a particle that's disturbing the ice molecules then it makes a shockwave in the same sort of way that the disturbance is, when it's going fast enough, the disturbances all line up and you get a shockwave in light. So, if you can pick up that light somehow then you can figure out where the particles are going. So, that's used in a lot of neutrino detectors. When a neutrino interacts it will make a charged particle but if that particle is going fast enough it makes a shockwave and you can pick up that light and do physics with it.

Ben: So, you usually have a big tank of clear media, clear fluid because you want the light to be able to pass through it.

Laura: Right. So, historically it's clear fluid but it's not for ICE CUBE.

Ben: And then a neutrino comes in and each atom in the system is like a big soccer ball with a little tennis ball sitting next to it. And, occasionally a neutrino comes in and it kicks one of them and sends a charged particle like an electron flying.

Ken: That's right. Now, so that happens for detectors, for example, like SNOW which is a detector full of heavy water in a mine in Canada. So, the neutrino comes in, it hits, it hits something, kicks off the charged particle and the charged particle leaves the wake of light and SNOW detects it. But that's primarily low energy interactions. So, for ICE CUBE it would be like if, instead of kicking the soccer ball you completely blow it apart with a cannon ball. You completely change part of the nucleus to another particle. So, you don't get an electron out you get something much heavier like a muon or perhaps a tau. But, something much heavier, much more energetic. And so, when it goes through the ice it can light up your whole detector like a Christmas tree.

Ben: So, there are a variety of Cherenkov detectors that use water on earth right now. Right, there's the Sudbury Neutrino Observatory, that's SNOW and it's in Canada. And then there's the Super Kamiokande or Super K and that's in Kamioka Japan.

[16:11]

Andrew: Oh, that's why it has the ridiculous name. Got it.

Laughter.

Laura: So, yeah, they're always named for the place.

Ben: So, Laura, you mentioned how ICE CUBE is different than these other ones. So, let's talk about ICE CUBE a little bit.

Andrew: Well, let's say this first, based on the website, this is what I've learned. It's at the South Pole...

Laura: Yes.

Andrew: Which is cold. And um, it's massive. Anything else special about...

Ben: Okay, Laura. So, you go and you fly in and then where's the detector? Can you walk into it and like, poke around it or...

Laura: You actually fly over it and when you land on the runway everything off to your right is like the station, the summer camp, with all of the things that we have for regular living arrangements. And everything off to the left for about a kilometer is like ICE CUBE. The detector, it's inside the ice.

Ben: So, this detector is embedded in the glacier that you're camp sits on. Okay, so what would it look like if we had X-Ray vision?

Laura: So, this kind of goes along with telling you how it was built. We bored holes down into the glacier, 2.5 kilometers down, and we put a, strings of light detectors down each hole. So, when it all refreezes then what we've got is a matrix within the glacier of photo detectors so that anytime there's light within that cubic kilometer we can see it with our detectors. So, on the surface you've got these arrays every 120 meters or so, there's a little collection of flags where we drilled down into the ice.

Ben: So, um, this detector is a cubic kilometer and it's one kilometer down under a glacier, right?

Laura: It starts a full kilometer and a half underneath the ice.

Ben: Sweet.

Laura: Yeah, it's crazy. So the kilometer is just the active volume. But there's a bunch of glacier on top of the active volume.

Ben: Did they use hot irons to get the detectors down or did they drill.

Laura: Yeah, so the way that we had to drill through the ice, there's a lot of engineering development that went into that. And they used high pressure hot water and just burned through with jet fuel to melt that ice into hot water.

Andrew: When I was saying, you know, sell this to me, what's the benefit and nobody mentioned that you already developed new engineering techniques for drilling.

Laura: Oh, good grief, yeah, there's an amazing hot water drill. High pressure, hot water, huge energies. They figured out how to make a hole drill that will go sit in hot water for 2.5 kilometers bearing huge masses of detectors and not fall apart.

Ben: Right, okay, so, in all the Cherenkov detectors that we were talking about before, the Super Kamiokande and the SNOW, there were three fundamental elements that you needed. One, you needed a great big volume of super clear media, right? So they had super clear water or super clear heavy water that was transparent, essentially. So, you needed a whole bunch of it and you needed to put it under a whole bunch of material to shield out all of the incidental radiation. So, they put SNOW at the bottom of a mine in Sudbury. They put the Super Kamiokande detector in Japan under a mountain. It was a mine that got drilled in horizontally if I remember and then...

Ken: That's right.

Ben: Then the Super K lived in the middle if this mountain. So, it was a mountain to shield it. In ICE CUBE the mile of ice above this cubic array of detectors acts as the shielding, right?

Laura: That's right.

Ben: So what are the properties, what are the other properties of this ice that make it so desirable? Why couldn't they just put it on the ice in my backyard. Because I'm in Canada.

Laura: Well, like you said, there's a lot of it and it's very clear. So, the ice that's in the South Pole has been compressing from very pure snow to start off with. But then because it's under such high pressures, once you get towards the bottom of the glacier all the impurities have been pressed out towards the top over the course of millennia. So, this is some of the clearest ice in the world. This is clearer than ice that we can make in the lab. Plus, there's a huge amount of it and it's all there. It's right by base operations. We have a runway we can access it pretty easily and we don't need to blast into a mountain to get to it. We can drill down from the surface.

Andrew: Can I just remark right now since we've described the scale of this thing. The cost, the total financial burden of this construction, to fly material and manpower to the bottom of the planet which is pretty much inhospitable, and drill a gigantic freakin hole or several holes into the ground and make the largest man made construction ever. Total bill $271 million which is about what we spend in Afghanistan between 3pm and 6pm. Just want to put that one in scale. This is a cheap, cheap project which has huge undertakings and unknown amounts of implications. Doesn't cost that much money.

[21:26]
Ken: That's a good analogy.

Andrew: Mitt Romney could have afforded it.

Laughter.

Andrew: So, now we know what it is. So, what does it, so, like the neutrinos are going to pass through this layer of ice that nothing else is going to pass through. What are these cables and things doing now, once they are only being exposed to neutrinos.

Laura: So, we have all these things, like you said, we get neutrinos that go through the detector. If they interact then we get a charged particle out of the interaction and when that's traveling through the ice it makes the Cherenkov shockwave which is light. And then the light gets picked up by the individual modules of the detector. So, those have very precise timing information on them. We can tell exactly when the light hit them and also, like, how much charge there was, how much light. So, we got it all at the surface, so then we get a picture of where the particle was traveling through the ice.

Ben: Hmm, right, so what you end up with when you compile the data, a trajectory of this...

Laura: Exactly.

Ben: Right, so, the neutrino comes in and it kicks the, a nucleus so hard that it it exploded and one of these muons has the same, essentially, momentum as the original neutrino passes through the rest leaving a trail and then by looking at the trail we can tell the direction the neutrino was coming in at and also it's angle.

Laura: Yeah, so then there's a lot of cool things we can do with that direction once we have that. We can see if there were a bunch of neutrinos coming from the same direction and see if there are interesting stars in that area. We can try and figure out, are neutrinos coming randomly, we can start doing astrophysical observations that we were talking about at the start. Like we can start trying to figure out what's going on in the middle of stars. You know, if we see a star exploding and we get a bunch of neutrinos from that direction we can look at how many there are, what energies they have, how are they spread out in time when they arrived. There's a lot of cool science you can get from that.

Ken: So, I was just going to add quickly, the other thing you can tell other than direction is by looking and seeing how many of these detectors got hit you can figure out the energy of the particle that actually come in in the first place.

Laura: That's right.

Ken: So a particle that had...

Andrew: That's how we differentiate between why we're in a matter universe versus an anti-matter universe?

Laura: With a couple steps removed, yeah.

Laughter.

Andrew: So, basically what I'm getting out of this is we don't know a whole lot but this is like step one towards, like, this is gathering a lot of basic data. Angle, direction, the level of energy, this is all essential data to beginning to really understand neutrinos. Right? Or astrophysical observations as well?

Laura: Yeah, so what makes it special is the astrophysical part. That a lot of neutrino experiments have done lower energy stuff so that we can get some of the basics of how neutrinos work. The really new stuff for ICE CUBE is tying it to astrophysics. And that's where we're right on the cusp of now.

Ken: Yeah, the only thing I would say is that I have been astonished since I started working for ICE CUBE, just how much physics you can do with this detector. It's absolutely incredible.

Andrew: And if an average American ever asks you about it and you try to explain to them, you get the angle of the neutrinos and everything, you will be defunded in five minutes. They will not understand. Like, what are you do, wait, you just can't look at the neutrinos and see they're, what's wrong with you, just get a mirror.

Ken: You've just got to bring up that, look, the Velcro that tied your shoes on today was sponsored by science. So, there you go.

Laura: Science.

Ben: When I was telling you about how there were these neutrinos detected because the supernova had gone off in 1987, right? What neutrino detectors back then would tell you is, it would tell you that some neutrino had passed through and done something. The timing data wasn't all that impressive and part of the reason for that was it used a different mechanism I think. It didn't use a large enough volume of material to detect stuff. And then there was the Super K and the SNOW detectors and what they would do is they would show you the trajectories of the neutrinos coming in just like ICE CUBE does but those ones were kind of specially tuned to solar neutrinos. So, there are neutrinos that are produced in the center of our sun that rain through the earth and, ah, the Sudbury Neutrino Observatory and the Super Kamiokande detector both detected those specifically. So they were like an infrared camera that only kind of detects light at a certain energy level. And the deal with this is that there are other types of neutrinos passing through that were just too energetic to get any information from. So, it's kind of like, you need a different type of camera to take photographs of them if you will. So, what the ICE CUBE detector is good for is it has the ability, it's like um, you know, an ultraviolet camera or a gamma ray or X-Ray camera, it measures these higher energy levels and so we can suddenly get information about these other neutrinos sources that we couldn't see with these Super K and Snow. That's part of why it's so impressive.

[26:50]

Andrew: It's sort of like stepping up from a telescope to Hubble. Like, it's just way more precise. Sort of the same technology but way more precise. Way more data, way bigger.

Ben: Well, there's that. It is much bigger. But, additionally, it also measures a different energy. So, it's kind of like the difference between a radio telescope and a gamma ray telescope, they measure, they're sensitive to photons of different frequencies. The older neutrino detectors were sensitive looking at neutrinos of lower energies and the ICE CUBE one can see much higher energy level neutrinos.

Andrew: Epic.

Ben: Yeah. So, it's like being able to see the universe in a different spectrum.

Ken: The other thing I might say is that SNOW, particularly, and the other neutrino experiments, essentially had a lower threshold and a higher threshold and they could see between them. ICE CUBE has a lower threshold, it effectively doesn't have a higher threshold because neutrinos coming in at those energies are just so rare that we would never see them, so...

Laura: It does have a higher threshold in that people want to build bigger versions with different technologies that you can see even higher energy events.

Ken: Yes, very, very rare.

Laura: Very high. But I wanted to add that going from Super K or SNOW up to ICE CUBE is like seeing the universe with different eyes. But, we also like to compare it to optical telescopes. That if we're looking at stars, just like you said, you can look at stars with different kinds of cameras with gamma ray telescopes or with X-ray telescopes or optical telescopes and we expect that we'll get a completely different view of the stars with neutrinos. And that's not even an analogy, that's just, that's how we describe it.

Ben: The applications of this for astronomy are fun and I guess what you're saying is, right, in the 20s there was only visual spectrum astronomy and we saw the universe as it is, you know. The Milky Way looks like a star sandwich with stars on top and stars on the bottom and black in the middle. And then we got radio astronomy and infrared astronomy, gamma ray astronomy and these different frequencies of photons are able to pass through different medium and so, as a result, we're able to see big banks of dust floating out in space. We're able to see stars that are surrounded with dust that would absorb anything but the real low energy light that passes through them. And so, because neutrinos pass through everything and because this neutrino detector detects the energy and also the direction it's coming in from...

Laura: Then you can do astronomy with a whole new sight.

Ben: That's right, yeah. You said it earlier, we can look to see if lots of neutrinos come in along the same path and then point our telescopes back up that path and see what's emitting all those neutrinos, maybe there's a supernova that we haven't seen yet, optically.

Laura: Another big one would be a gamma ray burst. We're trying to figure out at a very basic level what those are and we know that they emit a lot of gamma rays very quickly. At some level that's pretty much all that we know about them. We've been able to describe how the gamma rays are shaped or what their timing is like, how often they happen but we would love if we could see a coincidence, if we could see neutrinos coming from the direction of a gamma ray burst at the same time that other telescopes see the gamma rays, that would be pretty exciting. That would be a huge signal.

Ben: Alright guys, that was a good show. Thank you Laura, thank you Ken. You've pleased me, your efforts have born fruit and that fruit is sweet. Here is some fruit! Laura, you get a kiwi fruit.

Laura: Yaaayyyyy! Thank you. Nom, nom, nom.

Ben: Yeah, that's the smallest of all the fruit except for the cherry and that's what Ken gets. Here's a cherry Ken.

Ken: Mmmmmmm. Delicious!

Laura: That was small like a neutrino.

Ben: That's right. I would like to thank my guest, Andrew Johnstone. I hope you had fun today.

Andrew: Oh, it was great and I am just that much more interested in going to the South Pole now.

Ben: Okay. I encourage everyone to listen to Andrew's podcast, it's called Podcast Squared.

Now, let's talk about our podcast. If you want to talk to us you can email us you can email us at barn@titaniumphysics.com or you can follow us on Twitter at @titaniumphysics. You can visit our website at www.titaniumphysics.com or you can look for us on Facebook. If you have a question you would like my Titanium Physicists to address email your questions to tiphyter@titatiumphysics.com . And if you are a physicist and would like to become one of my Titanium Physicists email physics@titaniumphysics.com we're always recruiting.

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[33:57]

Ben: So, here's another answer to your question. You were asking why neutrinos are interesting. Neutrinos are kind of like sound in a forest. So, let's say a tree falls in the forest and you're not around but you're a little bit aways away. You can still tell even if you can't see the tree falling that it fell because the sound will make it through the forest but the sound doesn't really get absorbed by anything. It just kind of sticks around. It's kind of like, I don't know, cigarette butts. Nobody ever picks them up and so...

Laughter.

Ben: So, the universe is full of this detritus, these neutrinos because whenever there's nuclear fission or nuclear fusion some kind of neutrino gets emitted. And they just kind of hang out in the universe, floating through us.

[34:56]

Andrew: I feel like at that point I mean, with a star you could power an FDL drive or something. Right, isn't that the deal. Can't we...

Ken: Absolutely.

Andrew: Can't we theoretically make a faster than light drive but we would need to basically hook up a star to power it.

Ben: That is episode... Here, I've got to look up that episode...

Andrew: I think it's episode 4 or something

Ben: Titanium Physicists...

Ken: Don't get Ben started on faster than light travel.

Ben: Noo! We did a show on it Ken!

Ken: I know. You GR people and your faster than light things.

Ben: Listen, it's not my fault, you know, that people like my research and they hate yours.

Laughter

Andrew: The only reason that Ben got into physics and I don't know Ben, so I'm just going out on a limb and assuming is because he watched science fiction as a child and he...

Ben: True.

Andrew: You always want a light saber and you want a tricorder and you want faster than light travel and ah, other, like class 4 civilization nonsense.

Ben: Yeah, I want to stab a wookie with a...

Laura: ... Stab a wookie

Ben: Okay, okay. I'll probably... Anyway, I'll cut this.

Laughter.

Ken: I can't imagine why.

Ben: I got it, episode 9, warp drives. No, okay, so if you have a star, stars you can make a lot of money off of stars, right? So, look at Brittany Spears, made that recording studio so much money.

Ken: Uggghhh.

[36:38]

Andrew: Hold on, uh, I was just looking at this and it closed of course and it has it's own Twitter which means it's sentient and we should really be aware that that's dangerous.

Ken: Take over the world.

Laura: That's run by it's minions, it doesn't do its own Twitter.

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Laughter.

Andrew: How often are scientists hooking up, how much pot are they smuggling in, what's the deal with gambling.

[43:12]

Laura: When I was there in the summer, you know, there were people going in and out everyday, there were like, there were several flights in and out everyday, ah, I don't know, it's a handful.

Andrew: I bet there was less waiting than at Heathrow.

Laura: There's people from the government coming in and out, they want to check out the station, make sure it's working okay, there's like, Ahhh, a 100 and... 250 people on the station when I was there, it was pretty big. There was a lot of turnover.

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Andrew: Yeah.

Laura: Yeah.

Andrew: So that's everyone has a beard. All the dudes are bearded because they never get a chance to shave.

Laura: Well, I mean I've heard that it's better for insulation, I mean, dudes grow beards around Wisconsin during winter too. I'm sure Canadians could tell me more about that.

[48:10]

Ken: I'm still rocking a little bit of my winter beard.

Laughter.

Ken: It's my playoff beard now, I guess.

Ben: The playoffs last till July now. Okay, let's get back to talking about physics. Um...

Andrew: What, no, let's talk about summer camp... But no, science I guess?

Ben: We're at science summer camp.

Andrew: What's this podcast called again?

Ben: Podcast Squared.

Andrew: It's math. Come on. Squared. I threw something in there.

[48:47]

------------- Content begins to loop, jump to [1:01:17] ---------

Andrew: Well, let's say this first. Based on the website this is what I've learned. It's at the South Pole...

Laura: Yes.

Andrew: Which is cold. And um, it's massive, anything else special about... Hold on, I was just looking at this and it then it closed of course. And it has it's own Twitter which means it's sentient and we should really be aware that that's dangerous.

Ken: Going to take over the world, yup.

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[1:01:17]

Andrew: Can we, real quick, can we build a time machine? Send me back to 18 years old and major in not the nonsense I majored in so that I can be like you guys and actually do exciting work?

Laura: Well, if you'd like to learn more about ICE CUBE we can certainly help with that but...

Andrew: Can you take me to the South Pole.

Ben: You know Andrew I've met people who started learning physics in their, what, early 30s. You meet them sometimes. You can go back to school.

Andrew: Ah, that, no...

Ben: Within six years you could be at the South Pole.

Andrew: Six years?! Don't I, I'd have to get an undergrad degree and then a grad degree. Well, I guess I wouldn't have to would I?

Laura: You know, if the Pole is the major draw you could try and get a job that's not related to science at the Pole, so, there's a lot of very motivated people there doing other kinds of jobs.

Andrew: I love firefighter, that's my favorite job in Antarctica.

Laughter.

Ben: Do they just throw snow balls at them or...

Andrew: No they just sit a lot.

Laura: I like firefighter also. Like, you get a job that you do everyday and then on top of that you get training to be a firefighter. That's what I've heard.

Ben: You just open the windows, what?

Laura: Well, how do you put out a fire in a giant server room? I've heard that the training also involves ah, putting out an exploding car which sounds exciting.

Ken: That does sound exciting.

Ben: Push it into a flock of penguins.

Andrew: Well, yeah, that's the thing, is if you've got the time, push it away from things and then it's just in the middle of the ice, it's not going anywhere.

Ben: It will sink down in the ice, like the, actually, did they use hot irons to get the detectors down or did they drill.

[1:02:57]

---Repetition---
Laura: Yeah, so the way that we had to drill through the ice, there's a lot of engineering development that went into that. And they used high pressure hot water and just burned through with jet fuel to melt that ice into hot water.

Andrew: When I was saying, you know, sell this to me, what's the benefit and nobody mentioned that you already developed new engineering techniques for drilling.

Laura: Oh, good grief, yeah, there's an amazing hot water drill. High pressure, hot water, huge energies. They figured out how to make a hole drill that will go sit in hot water for 2.5 kilometers bearing huge masses of detectors and not fall apart.

---end repetition---
[1:03:34]

Ben: I had a joke, I forgot what it was. Oh, right, that's why you only get to shower for two minutes a week, all the hot water's going to the drill.

Ken: That's right.

Laura: It's all going for science.

Ben: Have you got any other questions Andrew?

Andrew: No, I think I pretty much understand as much as I'm going to without getting an advanced degree. It's not that complicated, actually,

Ben: No.

Andrew: From what you. I mean, it would be complicated if I, if this didn't exist yet and I was on the team trying to build itut, well, now that it exists in a way and detects neutrinos and it's purpose and its mission all make pretty, pretty clear sense. I feel like I've been educated.

Ken: Good.

Ben: Alright, yeah, we've got a, this is a pretty fun, loose episode. Um, is there any, do you think we need to talk about anything else you guys?

[1:04:33]

Andrew: Other than if Laura knows where I live and is going to turn me into the next Thing, ah...

Laughter.

Ben: Oh, before we go, Cherenkov radiation, you need to know this, it's the light that Godzilla gives off when he's under water.

Ken: That's such crap! Godzilla's not real!

Ben: Godzilla...

Andrew: Have you not done an episode on Godzilla yet?

Ben: I'm the only expert on Godzilla physics.

Ken: Listen, when I lived with, when I lived with Ben for a year and a half he had an alarm clock that was in the shape of Godzilla and it would make the Godzilla screaming noise when he was supposed to get up at noon everyday.

Laughter.

Andrew: That's a terrible idea. That's the worst alarm ever.

Ben: Now I have a wife that screams at me when it's time to get up at noon.

Laughter.

Andrew: So, hold on, but wait a minute Ben. Have you considered... First of all, did they actually call the radiation that he emits, did they name it after the real radiation or did someone just throw a Russian word into something and whatever, it's radiation.

Ben: No, no, the thing is, as far as I know, I've only watched the English version, as far as I know, nobody has every talked about why Godzilla lights up when he walks under water. But they make a point of making it, so, it's this blue shimmering light and it's Cherenkov radiation.

Ken: Well, that is blue. I mean, you're in the right wavelength.

Laura: Yeah, usually you see, when you see Cherenkov light it's in some cartoon of a nuclear reactor or something.

Ben: Yeah.

Laura: In a cooling pool.

Ben: It's usually green in cartoons.

Laura: Oh, is it? It shouldn't be green. It should be blue.

Ben: Right.

Andrew: Because people don't actually know what radioactive material looks like. They think that, they think that uranium oxide is green, well, actually it's black.

Ben: Let's count our blessings that that's the case.

Laughter.

Ben: That's not the color that my tap water glows.

Laughter.

Andrew: Brilliant.

Ben: Um. Yeah. So. You needed to know about Godzilla.

Andrew: Okay.

Ben: Everybody needs... Anytime I hear about Cherenkov radiation I have to inform them about Godzilla.

Andrew: You really should do a giant Japanese monster episode.

Ben: Well, aside from Godzilla, I don't know if many other ones are very physicsy.

Andrew: Mothra? Sure. You can find a way to make Mothra interesting.

Ben: Well, Mothra, Mothra's a mystical creature that defends children.

Andrew: Fine. Mega Godzilla.

Ben: Oh yeah, that's sciencey.

Andrew: I mean, if the Japanese can build guns, life size gundoms, maybe they can build Mega Godzilla.

Ben: They should. He'd probably be more stable than a Gundom too.

Andrew: Hmmm. Possibly.

Ben: He's got that tail.

Andrew: He's got a low center of gravity.

Ben: He's like a tripod.

Andrew: Yeah. By the way, your, Laura and Ken are not into this apparently. You've lost both of them. You stopped talking about the South Pole and they are both like I don't care...

Ben: That's fine.