Episode 26: Black Gold
Physicists: Laura Hainline, Mike Zemcov

Transcribed by Denny Henke

Ben: Fascination, it is an unquenchable hunger that compels our hearts. As long as there are elegant explanations too complicated phenomena science will never lose its romance. Over the years I've traveled the world indulging in my fascination with physics and now I find that a new hunger has woken within me a fiery need to share these great ideas with the people around me 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: Hi everybody, before we start I have just a quick note. Two things, first Kai Nagata's Skype connection on this was really shoddy it kept cutting out and so as a result I'll discuss it with him is a little bit less than satisfactory. Well it's actually okay but only through the virtues of editing. Second, I want to thank a guy named John Heath. He is an audio guy decided to have a crack at clean up for our show. He has frankly done an amazing job at cleaning up the audio track of our show. Thanks John! I think you've done a bang up job and so, everybody, please enjoy the show.

Ben: Alright everybody, black holes! Energy! Turns out you can get energy from black holes. You can get a lot of energy using a black hole. Go believes me? Nobody. That's what today's show is on - getting energy from black holes. Alright so who is awesome? It's Kai Nagata! He is a journalist, activist, Half-ninja. Since he quit his job in 2011 as a television journalist he is been working to change the nature of public discourse in Canada. This spring he and his crew made on Ezra Levant's enemy list when they made a Muppet puppet out of him and then did a cool rap video on the Internet lately he's been working for the Tyee and working with Deep Rogue Ram making conservative hinterland who's who video and other viral videos that all Canadians should be watching. Now welcome back to the show Kai.

Kai: Hey thanks a lot for having me. I'm just out here in Vancouver eating dim sum so excuse the chewing.

Ben: Alright Kai. So, for you today I have assembled two of my great titanium physicists. Arise Dr. Michael Zemcov! Dr. Mike did his undergraduate degree at UBC with me, he did his PhD at Cardiff University in Wales and he is currently a senior postdoctoral fellow at Caltech working on experimental cosmology. No arise Dr. Laura Hainline. Dr. Laura did her PhD in astronomy at Caltech. She is an expert at studying accretion disks around black holes. She currently works for company which may not be named! Alright everybody let's start talking about black holes.

Laura: Well, so black holes sound all mythical or whatever but we actually think we see them in the universe in the form of these active galactic nuclei and basically when I say active galactic nucleus I am just talking about the very compact center of any galaxy. And at this compact center they tend to be tremendously luminous at all wavelengths so it will be very bright in x-rays, optical wavelengths down to the radio. So pretty much what we I found over time is that there's no way that we can come up with to generate that much energy, that much luminosity from something so small. The only thing that we can come up with is that the energy must be produced by material spiraling around a black hole and as the material spirals around a black hole it heats up, it radiates, therefore becomes very luminous.

Ben: Why don't we back in this truck up and talk about, just generally, what an active galactic nuclei is, right? They're really, really, bright. We know there really bright because they're bright and they're really, really, really far away, right?

Kai: Yeah, and because Laura used the word luminosity which I have reverse engineered to mean bright.

Laura: Yes. You're absolutely right. Black holes are at the center of these really bright galaxies, How's that?

Ben: Oh, okay.

Kai: There, that was like five words and now I understand.

Kai: So, Laura I have a question how do we know that black holes are small and how much energy is coming out of them.

Laura: The energy question is a little tougher to explain, but how do we know that it small, that's something I can tell you about from our own galaxy. So when we look towards the center of the galaxy there's a star cluster right at the center of the galaxy. And we see that these stars in this cluster are orbiting, they're circling around this very small area.

Kai: A point.

Laura: Basically, yeah, as far as we can tell it's like a point. It's tiny but we can analyze how they move around that little point and get out the amount of mass that is causing them to be orbiting. It's the gravitational mass that's attracting them so what we find out is that we end up with a tremendous amount of mass in that tiny little point that those stars are circling around. And in astronomy we tend to refer to everything it terms of solar masses so this is going to be like a million solar masses.

Kai: What's a solar mass

Laura: The Mass of the Sun.

Kai: Our sun?

Laura: Our sun. But, our sun is something like, somebody's going to have to back me up here, I want to say like 1 million times the mass of the earth.

[6:50]

Kai: That's pretty crazy.

Laura: So, multiply that by a million.

Kai: Yeah, so that's like 10^{40}, no 10^{39}?

Laura: Yeah, 10^{39}, so you're going to take that amount of mass and squish it into an area that's less than the distance between us and the next star.

Michael: Yeah, that's like me trying to get into the jeans that I wore in high school.

Ben: Yeah, it's actually neat because usually in the universe when you take photographs of the same region the stars don't really move but in this one little star cluster they're actively moving as time goes on you can take photographs and they almost act is a video. So you see these stars all swinging around this one point and the point isn't moving which is strange enough itself because stars are very very heavy like the sun is much heavier than the Earth, like the Earth goes around the sun and the sun doesn't move at all because it's so much heavier than the earth. So you have these huge stars and they are circling this point, and it's not moving at all, and based on how fast they're swinging around it you can calculate its mass. And it's millions of times even though you can't actually see what's at the point, so you know that it's not a star because if it was a star you could see it. And then theoretically the only thing it could possibly be is a black hole.

Kai: Okay.

Laura: It's the only thing that could have that much mass in that small of a size.

Kai: So, the whole way that we can figure out that these things are there is basically by inferring that there is something small and dense that's causing other things around it to act in a particular way but we can't actually see, we can't see into that, there is no way we can visually pick it up other than by looking at the pattern of the stars around it.

Laura: That's exactly correct, we can only infer that it's there. Technically the black hole is not going to be emitting anything itself. So we have to infer its presence based on what is near it.

Kai: Gotchya.

Laura: Right.

Kai: So how do you go from there to solving the Galactic energy crisis?

Ben: Yeah, let's do hey quick review here. You have these galactic nuclei, So the center point of galaxies. If you look out at the universe astronomically you see that some galaxies that are really, really, really far away are really, really, really, really bright. And they are much brighter than anything around them, so bright that you can actually see them and spite of them being so far away. So there is an enormous amount of energy being output by a very small region. And so the reason that's causing this, it is called an active galactic nuclei. The idea here is that somehow the black hole at the center of a galaxy is interacting with the other stuff in the galaxy to output just an enormous ton of energy that we can see. So, okay how are you going to get all of this energy from the black hole? And the trick is that you can. There are multiple mechanisms for getting a lot of energy out of a black hole so I thought we would talk about that because it's fun! So, first off I want you to not think that getting energy out of a black hole is all that crazy because we use gravitational potential to extract energy all the time. So if you think about a hydroelectric dam, right. Effectively all we are doing is if it rains up high on the mountains or something and then we gather all that water up where it landed, essentially, at a high up place. And then we make it pass through a turbine as it goes down to a lower altitude, so all we're doing is extracting gravitational energy out of this droplet of water that started up high on the dam and then moved down, out through the bottom of the dam.

Laura: Also when we pass a satellite close to the planet to give it a little bit of an energy boost.

Kai: Oh, I didn't even know about that!

Laura: We do, when we send up satellites out to go study Saturn or Jupiter or whatever to help them get all the way out there, we will pass them by, say, Mars or even the Earth.

Kai: Like a slingshot.

Laura: Like a slingshot exactly. In that way we are taking some of the Earth's gravitational energy or whatever planet that we just used as a slingshot, and transferred it to the spacecraft.

Ben: And if it weren't for that energy we couldn't get our stuff out that far. You know how Voyager is out on the periphery of the solar system now, right. It's like out farther than anything, there isn't enough energy, in our technology, to be able to get something out that far. But using, essentially, this gravitational slingshot trick we can steal gravitational energy from really, really big planets like Saturn and use that energy to speed up our spacecraft. So it's a little bit weird to be putting it in these terms but it's not such a weird thing to be stealing usable energy out of gravitational potential energy.

[11:33]

Michael: Kai, do you know what we mean when we say gravitational potential?

Kai: I mean, I think so. All objects, any mass is attracted to other mass, right?

Laura: Yup, that's right.

Kai: We can you calculate that at what was the number?

Ben: 9.81 meters per second^2.

Kai: Yeah, right, so you can actually put a number on how quickly most things are going to be sucked towards the planet. And then, if you, you know drag a railcar of a certain weight up a hill and then let it roll back down you can calculate, based on how big that object is how much energy it's going to take to pull it in a certain distance away from the earth and how much you get back, assuming it's perfectly efficient and doesn't squeak or make any heat, then you can estimate how much you might get back when you've a roll down the surface of the earth. In my sort of on track here?

Laura: Yeah

Ben: Perfect. Leave too a journalist to get the story right.

Michael: That's right.

Kai: I just got possessed by like, my grade 11 physics teacher and that was his voice I just came out of me, so.

Ben: Beautiful. So you understand gravitational potential energy so let's move on to start talking about black holes. Have you got any idea what a black hole is?

Kai: I'm going to say no and save myself the embarrassment.

Ben: You've done enough lifting already. Okay, let's talk about where they come from just so they're not so bonkers. The ones in the center of galaxies really, really heavy ones, come from a slightly different place but they all come from one type of gravitational collapse or another. Actually, okay so let's suppose you are in a house that's really old and crappy and the floors are rotten okay?

Kai: I don't have to pretend.

Laughter

Ben: Okay, perfect.

Laura: It's not so hard to pretend.

Ben: So in some places it's easy to stand in place and not fall down through the floor. And in other places the floor isn't strong enough to hold your weight and it collapses down when you step on them and then you fall into the basement with the killer.

Laughter

Ben: So, the deal is the reason that all of us don't fall down into the center of the earth is, in essence, the rock, the stuff the earth is made out of, is strong enough to hold our weight, and to hold its own weight and the reason it's strong enough, is in essence, it's made of atoms and the atoms are pushing against each other using the electromagnetic force. But on the inside of really, really big stars - really, really, really big stars, the deal is that the electromagnetic force isn't actually strong enough to push the atoms apart. What keeps them from collapsing is, the fusion that's going on inside them is producing a ton of photons and the photons bounce around inside causing a pressure and that pressure is enough to keep them from collapsing in on themselves. But when they burn out there fuel, on the inside of really big stars, the cores end up collapsing down and then the electrostatic force isn't enough to keep the matter from collapsing down into a smaller ball. And then what happens is there a few other quantum mechanical forces that can keep a star from collapsing in on itself. But, you know if the star is big enough at the start then not even those quantum mechanical forces are strong enough to keep it from collapsing down on itself. And, the middle of the star just ends up collapsing down into a point and all that's left behind is the gravitational field from all of the matter that collapsed down into the point. So, if you were far away from one of these collapsed stars the gravity would be unchanged. It starts off weighing like 1000 times the mass of the Sun then it will still act like an object that is a thousand times the mass of the Sun, there just won't be anything there. It'll just be gravity, so that's what we call black hole. The defining characteristic of a black hole that everybody talks about, I'm sure you've heard people say that black holes are so heavy that not even light can escape from them, right. So, the deal is that just like anything on earth, right, if you're up on the moon and you try to jump, you're on the Moon, you can go really, really high because the acceleration from gravity from the moon is really low. And, if you're on earth you can only jump like I don't know how high can you jump? Two feet, six feet?

Kai: 1/6th of the height I could probably jump on the moon is my guess.

[15:44]

Ben: Ha, that's a good answer. Okay so so on earth you can jump us high because the acceleration from gravity is really strong. So the deal is that the force of gravity gets stronger the closer you get to the center of, the center of mass of an object, right. So if you're up on a satellite the force of gravity on Earth will be less than if you're standing on the ground and if you're in the bottom of Death Valley, closer to the center of the Earth, the gravity will be slightly stronger than if you're standing on Mount Everest. So the deal is that the closer you get to the center the stronger the force of gravity is. So when you're near black hole, I mean if you're out far away from the black hole it my just seem like, the acceleration of gravity might not be very much. It would be the same as if you were orbiting a fairly heavy star but because there's nothing there you can get as close to the center as you want. There's going to be a radius at which the acceleration from gravity is effectively its infinite okay it's so strong that not even light can escape from it, so we call that radius the event horizon. So, the deal for the event horizon is let's say I throw you into a black hole and you want to get back at me so you have a laser, you try to shoot me with your laser gun. When you cross this event horizon the photons from your laser gun aren't going to be moving fast enough, even though they're traveling at the speed of light, that's as fast as anything can move, they won't be able to move fast enough to escape this specific radius. They will just kind of sit in one place forever and then you'll fall into the black hole and get crushed, but don't worry about that. So that's call the event horizon and it is illustrative for our purposes to talk about black holes in is slightly different way. Instead of talking about what it looks like to fall into a black home let's talk about what it feels like to stand still near a black hole, okay? Let's imagine that there is a black hole and somebody has built concentric spheres around it. So there is a central sphere near the event horizon and then little bit farther out there's one story up there is another sphere, and another story up there is another sphere and then you can move between these floors just like floors of a building, okay? So out pretty far away it would feel like standing on the earth if you stood on one of these floors, the acceleration of gravity would be about 1G. You go down one story and the force from gravity that you feel pulling your towards the ground would be slightly heavier. You move down another three or four floors and it gets heavier. And the closer you get to the event horizon radius the higher this force of gravity is going to get until when you stand on the floor surrounding the event horizon the force of gravity is effectively infinite. So if you try to stand still near one of these black holes you're going to get flattened like a pancake because you know the atoms in your body are not strong enough to withstand the force of having to try to stand still near a black hole.

Kai: This is mildly terrifying.

Ben: Oh yeah black holes are scary but don't worry about it. They’re only kind of scary in that they can't actually kill you because there aren't any near us right now.

Laughter

Ben: Actually, our last episode, episode 25 of Titanium Physicists, we talk about what it's like to fall into a black hole and that's much more frightening. But let's talk about energy extraction from a black hole because now that we have imagined that there are, essentially, stories that we can move between to get in and out of the black hole it is easy to imagine extracting energy from a black hole. So I can actually extract gravitational potential energy using, essentially, an old-fashioned well, right? So in an old-fashioned well you have a bucket and then there's a rope attached to the bucket and the rope is wrapped around the wheel and the wheel’s attached to a crank. So you crank the wheel and the bucket comes up and down. So the way to get energy out of the system is take a duck or something heavy, you put the duck in the bucket and then you let go and the gravity affecting the duck pulls the duck in the bucket down to the bottom of the well. And then, when the duck is at the bottom of the well, it smashes through the bottom of the bucket and then the bucket weighs less because it doesn't have a duck in it anymore, but the wheel at the top of the well is spinning, right it's like a yo-yo. So it’s still spinning and because it’s still spinning, what it'll do is it'll pull the bucket back up to the surface and then, when the bucket get’s back up this wheel ends up still spinning and you can hook that up to a generator and use it to get power from. Can you imagine what I'm talking about?

Kai: Yeah, totally. You’d need a lot of dental floss or cable or whatever if you're planning on throwing a duck towards a black hole but, yeah.

Ben: So, effectively with the black hole it's the same thing. Instead of just a well were we drop it three floors before the duck dies, we're going to drop the bucket with the duck down a whole bunch of floors until it gets near the event horizon. Then we're going to press the button that kicks the duck out of the bucket the duck falls into the black hole. But because the wheel at the top of our well is spinning, it has angular momentum, it's going to keep on spinning. Just effectively, that's the trick, it's like a yo-yo, right? The reason the yo-yo climbs back up to the top is that, as it rolls down the rope to get to the bottom it gains rotational energy so it's spinning at the bottom of the rope it uses that rotational energy to climb up the other side.

[20:59]

Michael: This is a trivial case right because you could do this with any gravitational potential.

Ben: Yeah, you can do it with any gravitational potential. Look here's the kicker, if you drop off, and the deal is, because we’re using gravitational potential energy we can extract, essentially, the rest mass of the duck from the system. Okay, $E=MC^2$, right.

Kai: Sure

Ben: Okay.

Kai: If you say so.

Ben: Yeah, well I've heard somebody impressive say this once. The deal is that the mass of an object is equivalent to some kind of energy and usually that energy is inaccessible but in places like nuclear power, where you have, essentially a nucleus of an atom that will decay, sometimes that rest mass, trapped in an atom, will turn into kinetic energy that you can use to heat things which is part of why nuclear power is so effective. So nuclear fission is, what is it, 0.1% out of an atom’s mass turns into usable energy.

Laura: Fission is a pretty small percentage. But fusion is the one I know the number for and that’s .7%. So, for fission and it's going to be less than that.

Ben: Yeah, for fusion it's insane. Fusion is much higher than fission and the deal is that even though it's just a small percentage of the mass of the object of these hydrogen atoms turning into energy it's still a sizable amount of energy compared to how much we get out of say burning gasoline. So the deal is that instead of a small percentage that you would get using fusion you get most of of the rest mass turns into usable energy. And so it's an incredible amount.

Michael: So the statistic we heard is that if you had a car that was efficient and could use a black hole is power you could drive a billion miles from a gallon of gas by this process.

Kai: Gotchya.

Michael: Which is pretty far.

Kai: If you say so.

Laughter

Laura: Wouldn’t that get you to the edge of the solar system?

Ben: Yeah, it would. The deal is, that that's one way to get free energy from a black hole. It's not exactly free though, right. I mean you lose one duck in the process of keeping a city warm and heated for several years. So you still losing something but it's just a duck right, nobody's going to miss a duck.

Kai: Hey, we didn't miss all those ducks that fell into the tailing ponds in the tar sands.

Ben: Oh, that's right

Kai: Or, at least the sacrifice was considered worthwhile.

Ben: Our current energy system where we sacrifice ducks to get energy is much less efficient than doing it just throwing ducks into black holes. I think that's the point I'm getting at. Okay so the deal is that's one of the ways to use black holes to get energy. It's terribly efficient, and in fact, it's pretty much the mechanism that drives active galactic nuclei. So we talked about how they're the brightest thing in the sky and the deal is that it's just hydrogen gas and other gases falling into the black hole and some of the hydrogen gas and other gases are falling into the Black hole, doesn't quite fall in. It's coming in on kind of an orbital path and so it it makes kind of a disk of gas that’s kind of flowing in slowly and as crap falls in and hits this disc or as the gas inside this desk slowly migrates towards the center of the black hole up to 40% of the mass of the crap falling in the black hole turns into the energy that we see as the active galactic nuclei. It's just an incredible amount of Energy. So that solves that mystery but it's not the only way that you can get energy out of black holes. It turns out that more speculative theoretical physics has come up with slightly more exotic ways. And one of them is named after Roger Penrose. Have you ever heard of Roger Penrose?

Kai: No

Ben: Everybody's Heard of Stephen Hawking right? So Roger Penrose is kind of Stephen Hawking's contemporary and he is a little bit of a jack of all trades but he's just this brilliant mathematician who likes to make really visual, obvious arguments and after Roger Penrose says something everybody's like, oh why didn't we think of that. He's just one of the smartest men in the world and he is just fantastic. So most people think that black holes, you can't get any energy out of them but Roger Penrose figured out a way to steal it from them which is absolutely fantastic. So, in order to do it though you need to type of black hole that's rotating. There's not very many things that a black hole can do just because there's no matter, it's just space-time. So black holes only really do two things, either they rotate or they have a charge, or they don't have a charge or rotate. So if a black hole is rotating it does something called frame dragging which is really bonkers. One way to imagine it is let's say you are swimming around the Titanic and the Titanic was in the midst of sinking, okay?

Kai: Mmhmm.

[25:46]

Ben: The Titanic has a great big propeller and as it is sinking, the propeller of the Titanic, it's pointing up vertically and it's spinning, okay. So it's churning the water around it and all the water is swirling in a whirlpool as the Titanic's propeller spins in an attempt to not sink, alright. So the deal is if you were sitting bobbing in your life jacket or in your boat near this big propeller, because it's churning the water around it you would get dragged in a circle around it because of the force of this water that is being turned around the propeller, okay?

Kai: Mmhmm.

Ben: So the deal is a rotating black hole does the same thing to space-time. Because it's rotating what happens, is if you get really close to the black hole kind of near the event horizon but outside of it, so you're still not going to die necessarily you're just outside of the event horizon. There is this region where it drags the space-time around it is the direction that it's turning. Not just black holes do this everything rotating does this. So the earth does this frame dragging where it drags space-time around it to. There are some satellites then have measured this affect, they have gone up to see whether this prediction of Einstein's theory is true and they've seen it. But the point is, that the closer you get to the black hole, the more this effect will take hold, the more space time will be spinning around along with the black hole. And if you get close enough to the event horizon, there is a region where you can't stand still. So one way to imagine this if you imagine back with the Titanic and there's this big propeller churning around the water eventually, this description is kind of like imagine if you had a motorboat, if you got close enough to this propeller because the water is turning around this propeller so fast, the speed of the current would-be so large that you wouldn't be able to stay in one spot. Does that idea make sense?

Kai: Yup, so far.

Ben: The boundary of this region where there is nothing you can do to stay in one spot is called an ergo surface. So the deal is, now there are two surfaces in a rotating black hole that are notable. There is the event horizon where if you go inside the event horizon you're just going to get sucked in, there's no speed you can travel to make it out. And then there's this ergo surface. And the deal with the ergo surface is there is no speed you can travel that would keep you from not swirling around with the black hole. So this Roger Penrose, he mentioned a way way to steal angular momentum from the black hole. And the idea here is, let's you take a Jack-in-the-Box, so you wind up and at some point in time it's going to pop open and shoot off the puppet in one direction. So it's going to break into two pieces and then the box will fly back out. So if you do this while it passes through the ergo region and it breaks in half, what will happen is the box, as it flies out of the black hole, we'll end up with much, much, much, much more energy then it started with. You are effectively stealing some of this rotational energy of a black hole. It's kind of like, have you ever been to one of those batting cages, where you have these balls that are being launched by, there is this spinning tire, the ball launcher essentially rolls a ball and it touches the tire and by touching the spinning tire it launches the ball towards you really fast. Do you know what I'm talking about?

Kai: yep, I've been to batting cages I know pitching machine looks like.

Laura: I have not been to a batting cage. I can imagine it.

Michael: Imagine two angled disks spinning at an extraordinary rate of speed and then drop a baseball between the two angled rubber discs and it spits it back at you. It's just a simple way to fire a baseball.

Ben: That's essentially what's happening with the black hole you throw something in and then it gets, it pays a little tax, it loses it's puppet but in doing so the box ends up with a ton more energy and it just gets spat out of the black hole and you can use that to actually reduce the overall energy of the black hole. So if you keep throwing puppets in, the black hole will slowly stop spinning, it will lose more and more of its rotation but in doing so you can get, what is it, up to it's almost 30% of the black hole’s energy you can steal.

Kai: Wow.

Ben: Which it's crazy, stealing a black hole’s energy. So that is the second way to get energy from a black hole.

Kai: These are interesting. So far this is entirely in the realm of the theoretical, right. There’s no plans, I hope, to actually try to steal any energy from any galactic nuclei or black holes.

Laura: Yeah, partly because they're pretty far away, so we’d never really get there. But there's also this whole problem of what would happen to the spacecraft near a black hole it might tear it apart.

Ben: Ieah I don't think there are any plans.

Michael: How do you transmit? We have a hard enough Time lane cable between Newfoundland and Labrador without people freaking out. I mean laying cable across the universe back to our solar system wouldn't that be a challenge in and of itself? And what efficiency could we possibly hope to garner from this intergalactic transmission line? Feels like we would probably lose a lot of the energy that we were able together in the first place. It would be hard to get back here.

Ben: Ok, so it's fantastic that you're asking that because when the guys who came up with this, like Roger Penrose and other theoretical physicist back in the 70s when they were just playing with these ideas, they came up with hey ridiculous but fantastic description for how it could be used. So have you ever heard of a Dyson sphere?

Kai: I've heard of the James Dyson vacuum, is it similar?

[31:26]

Laughter

Ben: It's Freeman Dyson and he has the same last name I'm glad you knew what James Dyson's first name was because I didn't. So the idea behind a Dyson sphere is, you take a star like the sun, and you build a sphere surrounding it. Okay so you totally encase it with a metal sphere and then what you can do is you can cover the inside with, say, solar panels you can extract the most of the energy being radiated by the star. And you can use this to fantastically power your cool civilization. So what these gravity physicists came up with was kind of an equivalent description. What you do is you would surround a black hole with a big metal sphere and then you build your cities on this sphere, this megastructure. And then what you do is to power your cities, you would just have these big wheels attached to buckets and then when you needed more power for your city, you would occasionally put your duck inside the bucket and drop the duck into the black hole and set this wheel spinning and then you could just use the spinning wheel to power your city. Or alternatively if the black hole on the inside of your sphere was turning if it was rotating what you could do is essentially fire little Jack in the boxes at the black hole and use the fact that the box comes shooting out of the black hole with incredible velocity to, you could grab those, and change that kinetic energy directly into usable light and heat. And so you know if you did encase your black hole with one of these spheres you could extract all the energy you wanted and you wouldn't have to live on horrible Earth anymore, you could live on fantastic black hole sphere 2 and extract energy that way.

Michael: So, Kai, there is another one that's a little bit closer to home than Dyson spheres, which is, we are talking about these really really big black holes. If you imagine you could make a very small Black hole, right as long as you could just pack a lot of mass into a small area you can make these little tiny guys. And there is a third process which we didn't have time to talk about. Which basically is that black holes due to complicated physics trickery can radiate energy and thereby lose a little bit of their mass and over very long timescales they evaporate by this process. And it ends up that that process, the amount of energy you get out of it, is proportional to how, inversely proportional, to how big the black hole is so big black holes don't do this that much, they take a long time to evaporate. But small ones do it much more and actually it is kind of a runaway process, the smaller you make it the more energy you get out, and the faster the black hole goes away. So people have posited that if we can make these very small black holes we could somehow capture of the radiation coming off of them.

[34:13]

Ben: So, that was fantastic. Everybody, absolutely perfect. Mike and Laura you please me. Your efforts have born fruit and that fruit is sweet. Here is some fruit. Mike you get black berries the blackest fruit.

Michael: Ooh, that's delicious.

Ben: Mmmm, and Laura you get eggplant, also a very blackish fruit.

Laura: Sounds delicious!

Ben: Eat it!! hahahahah, yeah, eat that delicious, uncooked eggplant!

Laura: Delicious and nutritious.

Ben: Alright Kai, thank you we're coming on the show.

Kia: Hey it's always a pleasure thank you for having me back. I must not have screwed up the first appearance as badly as I thought I did.

Ben: Oh it's always a pleasure will have you on in the future sometime as well.

Kai: I'll try to do it from a solid internet connection and not my grandma's basement.

Ben: We we'll do our best.

Ben: Alright, listeners, my Ti-Phi-ters, suppose you want to interact with the titanium physicists a little more, if you would like to keep track of us you, why not follow us on Twitter at #titaniumphysics or join our Facebook group. If you would like to hang out with us and socialize why not join our online forum? Or, if you would like to send email to me directly, to ask a question or propose a topic email me at barn@titaniumphysics.com. So let's suppose you want to listen to us more conveniently if you have an iPod or an iPad try subscribing to our show using the iTunes store and while you're there write us a review because you're reviews determined our raking in the iTunes Store which in turn determines how many new listeners we'll discover the show in the future. If you have a Zune or a BlackBerry you can subscribe to our show on those doodads as well or you can download the stitcher radio app which will let you subscribe and listen to all of your favorite podcasts on any mobile device that you have. You can download the stitcher app for free on your iPhone Android phone kindle fire or other devices. For more information and all of this, visit our website at www.titaniumphysics.com. The Titanium Physicist podcast is a member of BrachioMedia. If you've enjoyed the show you might also enjoy Science Sort of or the Weekly Weinersmiths so check them out. Now the intro music is by Ted Leo and the Pharmacists and the end song is by John Vanderslice. Good day my friends and remember to keep science in your hearts.

[38:35]

Kai: So you picked me because I know nothing about black holes and I am going to learn a lot, I feel. I'm a little daunted.

Ben: That's right but you're also an expert at criticizing energy extraction techniques.

Laughter

Kai: That's a brilliant tie-in.

Ben: We figured you might be interested in this. It's nice and clean and only involves destroying a few things completely.

Kai: Like half a universe, okay.

Ben: Like a baby duck in a bucket or something.

Laughter.

Ben: Okay, so, Kai, if I came up to you on the street or let's suppose I sent you an email saying free energy from black holes.

Kai: No, no, come up to me on the street I want to see how this goes.

Ben: Okay so I come up to you on the street and I go, psssst, hey, buddy I got a trick that will get you as much free energy as you want, all you need is a black hole. What do you say, just pay me $500 upfront, free energy forever. What would you tell me?

Kai: I would say sir I've left that part of my life behind me, please back away slowly or I'll call the police.

Laughter.

Ben: I expected you to be a little bit more incredulous about the nature of getting free energy from black holes but…

Kai: I would say sir I've fashioned this helmet out of tin foil to keep me safe for people just like you. please back away slowly or I'll call the police.

Laughter

Ben: Alright, well anyway so I think maybe this topic might be best if we start off with a little bit of an astronomical tutorial where we talk about actually how much energy you can actually see actual black holes making.

Kai: So, this is real you're not I'll take your word for it. See the problem with my ignorance is that I am kind of willing to believe anything so if you did come up to me on the street I might just be like okay tell me more let me write a check.

Ben: I’ll write that down.

Laughter.

Ben: This is an important tip for the future.

Michael: If you'll buy that I've got a car you can have.

Ben: So do all independent journalists have lots of money they can spend on…

Kai: No we are just, maybe I've lost my sense of skepticism about your energy schemes. I don't know it seems like we, we're all looking for answer, I think you might have actually found a good time in history to start going around flogging year black hole energy utility.

Ben: The the thing about energy, is that I don't really, in spite of the fact that it's clean and fantastic, I don't really want BP in charge of some pocket-sized black holes.

Kai: They already have a black hole, it's in the Gulf of Mexico.

Laughter

[41:23]

Kai: I thought that sizes were also constrained by, that, their emission fluctuates over time, and it fluctuates so quickly that the only way that it can fluctuating that quickly is if all of the activity is in a very small region in the center.

Laura: That is also correct.

Kai: And how big is that region, I have forgotten?

Laura: That’s a tricky question too because there are different regions in the nucleus so if we are talking about the area over which we think that variable emission is coming from that is going to be something like 10^{16} centimeters, so it's a hundredth of a parsec, and a parsec is about the distance between us and the next closest star. So if that tells you, that's about the radius of that area.

Kai: What’s the next closest star, is it Alpha Centauri?

Laura: Yeah.

Kai: So 10^{16} centimeters is 700 astronomical units, which is like the width of the solar system let's say.

Laura: Sure yeah, we can say that. I don't have my unit converter active today.

[42:49]
Michael: The model that might be good to have an your head for this discussion is the one, which is exactly what you said, but it's that rubber sheet where you put a ball bearing in the middle of it and it kind of dips down where the mass is and that train coming down the hill is just moving up-and-down, away from the mass on the steepness of the rubber ball, or, the rubber mat.

Kai: Ah ha, okay.

Michael: We can extrapolate on that.

Ben: My biggest problem with a rubber ball General relativity metaphor, the heavy ball on the rubber mat general relativity metaphor is that you need gravity to explain this theory of gravity.

Laughter.

[44:06]

Kai: I only had one more thing to say and then maybe you guys, I am not sure if you want to clarify some of the points that you have been trying to make in between my Skype connection crapping out but I was going to say, reality check on the human species. Do we really need a free and unlimited energy source or are we really bad at dealing with the cheap energy sources that we already have? It seems like we've managed to work ourselves into a pretty good corner just with the energy sources available to us on this planet. So, I'm just wondering in a larger sense, whether all of these fantastic Dyson sphere theories that people came up with in the 70s are still desirable or even attractive in a theoretical sense given what a hard time we have as a species dealing with life on this planet.

Michael: Way to bring it back on topical stuff.

Ben: I know, right.

Kai: Well, you know. I am not a theoretical physicist. I look around at the actual, real life energy crisis and it just seems to me that we do spend a lot of time sort of hoping and wishing for, you know more efficient systems of energy, and nuclear power was a big step. And now we start talking about, you know, figuring out new ways to harness energy from other you know interactions between elements of our universe that we might not of considered 50 years ago but it just seems like that might be the worst possible thing for us, as a species is to actually discover that free abundant source of energy. Because that would basically give us power to carry on for the next century, just you know, destroying our habitat. That's maybe a little too political for a physics podcast but it sort of sits in the back my mind when I think about even theoretical discoveries of unlimited power sources.

Ben: Awesome. Kai I wouldn't have you on if I didn't want you asking these questions. Humankind's place on the planet is a little bit of an iffy subject. I don't know maybe I'll post a short essay describing the answers and answer your question in the appendix of the show and then we'll just wrap it up now. And then you can hear my answer on the podcast at some future date, because this is cutting in and it out and probably driving you bananas.

Ben: Alright everybody that was really good I am sorry about the technical frustrations.

Laura: Hey Mike.

Michael: Yo.

Laura: Were you hearing Ben go in and out on that?

Michael: Yeah but he's recording so it'll be okay for him.

Laura: That's what I am hoping.

Ben: Yeah Yeah. I am just getting it on my thing, oh geez I wonder what the deal is with Skype today?

Michael: It's a total mess.

Laura: It does seem like it's a mess.

Michael: If you email Kai thank him on behalf of us I guess that was brutal.

Ben: Aw, yeah, I'll definitely do that. It's frustrating, I understand, it's a big pain in the butt. I'm glad he could come on. Incidentally do you guys want to discuss the answers to his question before we go.

Laura: Which, what would we do with this or do we…

Ben: Yeah, do we is it a good thing to get infinite amount of power?

Laura: Well…

Michael: I think, Ben, you know, people talk about this in a speculative fiction kind of way, I think if you're looking to power your spaceship then yeah it's good. If we invented a way to do this tomorrow that's a different question.

Ben: Yeah, I mean, I think that, there is kind of two questions here. One is man's place, humankind's place in the world and the other maybe, the ah, the individual lifespan of humans, so one way to mark our progress is in terms of the efficiency of our energy sources, right? So, originally the only energy we had at hand was human energy and so that wasn't all that efficient. You could have one person hunting and gathering or a couple people on farmland, and even that wouldn't be all that productive. Then we got horses and, you know goats, and suddenly we had the, the energy efficiency of all sorts of plants and things. Suddenly we essentially had a horsepower worth of energy and fairly portable at that. And you know, we could build cities. And the more advanced the civilization we've go,t more and more efficient energy sources you know as we go through. Woods and charcoal to actual coal to gasoline, what we're using now, or nuclear or natural gas or even hydroelectric and suddenly the way, the amount of energy that we have on hand and the efficiency of energy. The amount of energy you could extract per kilogram of thing that you have to haul around has gotten really, really high. And that, in part, has made it possible for our current longevity, right. So now we can have a lot of people on the planet all living because, essentially, it takes fewer people to run farms and we can store food for a lot longer and we can develop medicine that helps our longevity. So in terms of the individual longevity, I think that having, our current population, is kind of about to run into a wall based on how much energy we have, how efficient the energy we have on hand is. Because we are slowly running out of hydrocarbons that we can burn right, so as we run out of oil, what we are going to see, as the ratio of easy to burn resources to humans on earth decreases, as we run out of oil and the population of the earth increases, we are going to run into some troubling times as a species if we can't find more efficient portable energy. So unless we move to, essentially, an efficient solar power or efficient fusion energy somehow we are pretty much all going to starve to death. On the other hand I think Kai, you know, Kai spends a lot of time talking about the oil sands which is a part of this whole equation. People need more fossil fuels so people in northern Alberta are developing these tar sands and extracting hydrocarbons out of them that we can burn, making oil out of this tary crap in the sand, out of the bitumen.

[51:37]

Laura: But in the process…

Ben: But in the process they're messing up the environment horribly and the Canadian government you know are a party to this, they are purposely ignoring all of the environmental destruction and it might be that we are ruining the land for generations if not forever for the people who live on it. And it's like, as the worlds population, even broadly speaking it might not be good to have more efficient energy because that lets the population increase and as the population increases the more of the world we kind of develop and the more biodiversity we lose, and the more versatility the planet has to keep us alive as a species decreases. So it might be that we are shooting ourselves in the foot. It might be that people will be able to eat but then, you know, eventually some horrible ecological collapse will occur that will kill us all.

Laura: Maybe, but it seems like we often have these, you know, creative breakthrough type things, you know, instead of continuing to develop more land for example or destroy ecosystems to do things, we learn to use what we already have, saved by burning garbage or such things or building taller buildings. Things like that, you can accommodate more people without destroying so much of the ecosystem and if they could find a way to do this without, you know, generating, alternating the climate more that would be even better.

Ben: Yeah, I…

Laura: It’s a little bit pessimistic I think, to just assume, people are pretty inventive, they can be, if they are faced with it, right?

Ben: Right, no, Mike, what where you going to say?

Michael: Hello?

Ben: Were you about to say something?

Michael: No, no.

Ben: Oh, ok. Yeah, no I agree with you. I think that, you know, for instance, people thought, the human, the carrying capacity of our, our ability to create food and farms was about to go belly up in like the 70s, right?

Laura: Yeah

Ben: But then there was, I think it was called the Green Revolution. There was a bunch of revolutionary, essentially, crop technology that let crop yields increase dramatically and that's the reason we're not all starving to death today even though the population has gone up we're using, you know, essentially the same amount of farmland to make even more crops.

Laura: For the energy there could be something similar.

Ben: No, right, I mean, it's kind of like the only reason the whales are still alive today was that you know…

Laura: Well, we found an alternative source to whale oil.

Ben: That's right we found better things to burn than whales…

Laura: Yeah.

Ben: Thank god, because now there are still whales and there wouldn't be if we were stuck burning them all. So it might be that at this point in time, I mean it will be better if it came a lot sooner, but at this point in time, we are kind of reaching the end of the cheap, easy oil that we can use to the point where we are trying to extract oil from bitumen or from deep in the ocean, right. I mean we mentioned the BP oil spill earlier, it would be great if there was a technology that we could use that can replace this before we end up killing ourselves. And it would be much greater if we could find a technology that would let us replace carbon based or technology that extracts energy from burning fossil fuels because I mean the greenhouse effect, as much as people want to naysay it is a real thing, right? I mean it certainly the elephant in the room when it comes to energy production. So I think that, it was pessimistic, but I think but the truth of the matter is that if we did end up with free energy we would stop destroying some parts of the earth as we currently are but our population would keep increasing to the point where we would be destroying, you know we were cut down every tree to make…

Laura: But would we? I mean, like I said, I don't know that that is necessarily the case. I mean you can find more ways to accommodate people.

[56:14]

Ben: Yeah, I think that we would need you know, an accompanying increase in yield of crops if we were going to, you know, either you want your fields making lentils, to make lentils more efficiently or you're going to have to cut down more trees and make more farmland. Right?

Laura: Ok

Ben: So, I mean there's, if the population keeps increasing because there is nothing, because, you know, environmental catastrophe aren't killing us off, then we're going to have to do that or face… let's see, I mean, uh

Laura: Uh, starvation?

Ben: Yeah, starvation. We probably should be a little bit more pessimistic when we talk about these things but I think the, the whale, the whale conservation issue puts it best, right, I mean…

Laura: Yeah, we still have them, I mean…

Ben: I mean the only reason we still have them is because people came up with a better technology. So I don't necessarily think…

Laura: I guess as long as people continue to innovate, is it I think, is that, perhaps the worry is that with this source of infinite clean energy, would they cease to innovate?

Michael: Well, if you had a source of infinite clean energy, things become accessible that weren't before. For example, space, you know. But that's very blue sky, you know. Compared to the prosaic, like, how do we make progress over the next 50 years that Kai is worried about.

Ben: You know I think your, you argument is a good one. Because all my, you know, we could go into space if we have infinite clean energy.

Michael: If you had, yeah, right. I mean that would change everything forever.

Laura: Well, hang on though, but how would we, the question is, with that infinite clean energy, would that energy be, we would have to find a way to use it to get us to space. Right. Because the way, the way we currently use energy to get to space is still by burning rocket fuel things…

Michael: Well, but if you had energy you could make more rocket fuel, as much as you wanted until you came up with something better, right?

Laura: I mean… I suppose.

Michael: Because rocket fuel is just chemicals, they can make more it just takes energy to make them, right. But rockets are ultimately a crappy way to do this so I don't think you would stay with that for long, I mean you know. Things change very quickly.

Laura: Yeah. You got to get out of the earth's…

Michael: But… I don't know.

Laura: Yeah. You got to get out of the earth's atmosphere somehow.

Michael: Right. Anyway, the… how do I say, the question of, if we could, should we…

Ben: Yes.

Michael: is difficult.

Ben: Yeah, that's right.

Michael: I don't think there's a good answer to that.

Ben: it's like our house is surrounded by zombies and the question is do we give the 14-year-old a shotgun. On the one hand he could kill zombies, on the other hand he's probably going to shoot us. If we give humanity a chance to survive past the next 50 years, wonderful. But, we are still, we're still in some sense out of equilibrium with the rest of the world. And free energy would just give us the capacity to continue being out of equilibrium with the rest of the natural world into we destroyed all of the rest of the natural world and then where would we be?

Michael: I mean I think that's the point that Kai is getting across.

Laura: Yeah. I agree.

Michael: He's, what's the word, he's a pessimist because he's seen the worst of it and there are reasons to be optimistic too, but, ah, you have to be careful. The usual thing you know, I am reminded, with, when Kai asked about, like, Teller, what he used to talk about in the 40s and 50s about nuclear bombs and fission. And, you could re-landscape all of China with nuclear weapons, right, I mean the world would be radiated and it would be probably pretty terrible, but he was a big proponent of civil uses of these things.

Ben: Right.

[1:00:59]

Michael: And, that seems misguided now but I think back then maybe it wasn't, right? So, you know, the interface between physics in this kind of philosophical should we, is very problematic.

Ben: So, in essence, physicists, the technology of physics, to some degree, actually, Greg Proops was on, and accused us all of being a part of the problem. And it's not quite wrong because in some sense physicists historically are kind of like Dr. Frankenstein. And we keep building one new Monster to fight the previous monster… and sometimes those monsters team up but sometimes they're good butlers until they team up and it's just like…

Laura: Or we build because we can…

Ben: We continue to innovate and that's good but then there always negative consequences and that's bad. Maybe we can innovate some more and that's good but then there's maybe other negative consequences and that's bad.

Michael: Well, Laura is right we do things because we can. I don't know, I don't know many people we think about the moral ramifications of their blue skies physics research.

Ben: No, nobody ever does and should we? I mean, should the guys, I mean everybody built the atomic bomb hoping, thinking optimistically and it almost drove everybody to extinction.

Laura: No, those guys, were, I'm pretty sure, those guys were quite aware of what they were doing. And, they, they also didn't, I don't know how, I don't think, they talked, any of the people involved, really talked much about it much later.

Ben: So, I read a biography of Oppenheimer and, the, from Oppenheimer's perspective, apparently, he thought that physicists would have a lot more say in the development and distribution of the technology afterwards. So he imagined that pretty soon everybody would have atomic bombs and then nobody we need atomic bombs because everybody would have the capacity for them. He didn't imagine that governments would control them like they obviously did and like it makes sense for them to do militarily, they just didn't have a sense for, they're blue sky imagination for how the world would use the technology was completely different than the obvious strategic uses immediately after the war. And then he felt really bad that he killed all those people, so…

Michael: Well I would say that historically scientists are very naïve about the implications of what it is they build.

Ben: Does that mean that we shouldn't, that we should be less naïve.

Laura: Well, maybe think about it what the effect it might have on others.

Ben: Well, so, okay, so have you ever watched the original Godzilla movie?

Laura: Godzilla. No, I haven't seen it.

Ben: It is, so they made one, they took the original movie and they re-edited it and added scenes with Raymond Burr in it, so the American one is a very different movie. But in the original one there was this Godzilla monster, he got awakened by atomic bombs and you know started running around Japan. But the plot of the movie involves kind of a conversation between two scientists. So one of them wanted to preserve the monster because he was the only dinosaur monster of his type left and it would be a horrible pity to destroy him right. So it's like yeah lots of scientists do that. And there was another monster, even though he was destroying he was he irradiating Tokyo, yeah I can understand. It was understandable that he would say that, it was a very heartfelt plea as a scientist and there was another scientist who have developed, essentially, a type of weapon that could destroy Godzilla but he was really apprehensive about telling anybody about this weapon because even though it would solve the Godzilla problem it would cause the world endless amounts of other problems. So he ends up committing suicide at the end of the movie. He uses his weapon and then it kills himself so no one else can use that thing and so it's kind of an incredibly efficient description, discussion, sorry, of the the nature of science and society in that we scientists enjoy thinking about things in terms of independently of how humanity will deal with a repercussions of the science that we are studying. It was an interesting thing to watch because when you watch it you're like well I'm not like that. Right? Like I wouldn't do that! That's crazy what's that?

Laura: That's easy to say from the outside.

Ben: That's right it's easy to say from the outside but on the other hand you know, physicists, consistently, well not consistently, historically there have been occasions where something people make out of pure research ends up having these strange repercussions that they never considered.

[1:06:24]

Laura: This happens, I mean I think it does happen of fair amount still. Now that I'm sort of working at this defense contractor, I mean, I think I've talked to people who, they have these ideas and they were surprised later when they found out that it was used for a purpose that they did not want it to be used for.

Ben: Yeah, and it’s…

Laura: It still happens. Like they in good faith, you know in the interest of research, had come up with this idea and did not want used for something destructive… but then it got used that way.

Ben: It’s ironic that we keep comparing, I mean society keeps comparing this to like Frankenstein story right, Mary Shelly's novel Frankenstein right. And it was subtitled Modern Prometheus which is interesting because it kind of lays an idea behind this… which is a, Prometheus went and did a thing and then felt the horrible consequences all in the name of progress. And Dr. Frankenstein does this thing and then feels the immediate, personally, feels the consequences. But in the case of scientists, we read that and we're like, yeah well you know, we feel we tend to ignore the lesson because for the most part we never feel the consequences of, if our research has negative consequences, we rarely ever feel those negative consequences ourselves. Usually there are negative consequences and they don’t really apply to us. So it’s like, it’s kind of the inverse, imagine Prometheus stole fire and then burned everybody else's house down.

Laura: Right, but you know nobody had thought of that at the time.

Ben: No, right, it's a moral, the morality of science it's something that I feel people questioned but nobody has a good answer that isn’t stupid.

Laughter

Laura: Well, this comes back to, you know, the cloning, cloning humans for example.

Ben: Right.

Laura: Well, if you can should you, you know? And it's hard to come up with a good reason why you should.

Ben: You can imagine circumstances where it's like okay, that makes a lot of sense. Why not do it then? You know, somebody is suffering horribly because they need a new left arm, clone them a new left arm. But then if the technology exists because you were so big hearted and compassionate how will people come to suffer as a consequence?

Laura: But at the same time, if you think like that when you, if the scientist continually has to think like that as they develop they wouldn't do much.

Ben: That’s right! That’s the kicker. You can't do any science if you are not completely just swimming in the ocean of ideas, wholeheartedly and so it's almost an existential question for science itself.

Laura: Yeah.

Ben: But I don't know what the answer is. I think the answer is everybody is suffering all the time anyway so you know why not jump out of the frying pan and into something else. A change is as good as the rest when it comes to suffering. Maybe that's the answer.

Laura: Maybe.

Ben: Maybe true morality doesn't exist at all. Maybe we should call this the end of the show!?

Michael: And on that note…

Ben: And on that note. Well okay guys thank you, that got kind of silly at the end but I think we have managed to make a passable show in spite of technical difficulties. I think that people tend to… it's easy to edit calls falling out, you just cut off, You figure out where it starts and where it ends and you cut that out so it shouldn't be any more difficult than regular editing. Thank you guys for coming on, I think that was a fine show all things considered. Yeah I will have you guys on in the future. So Laura if there any other astronomy topics that you and Sean want to talk about in the future that's fun

Laura: Whatever, ah, I don't know.

Ben: And Danny if you're ever want to come on the show again that will be fun too.

Danny: Thanks, yeah, you should do the casimir effect that's awesome.

Ben: Okay, sure.