Astronomy Cast Episode 286 for Monday, December 24, 2012:
How to De-Bunk an End of the World Myth

Fraser: Hi, Everyone. It's Fraser here. So this is the third episode that we recorded during the "Not the End of the World" cruise in front of our live audience. So, again, I apologize again for the audio quality. We recorded this on a portable audio device, so you can definitely hear the audience in the background, which is great -- adds to the live show. So this corresponds to episode 286: "How to De-bunk an End of the World Myth," and this is for December 24, 2012. Enjoy the show!

[begin live recording]

Fraser: Everyone's always predicting the end of the world. Someone's going to tell you that this is the year it's all going to end, the end of the planet Earth, and they're always wrong, but someone will eventually be right. Planet Earth is doomed. We have to figure out how. This is my favorite topic ever. We're going to talk about all of the ways the Universe is just trying to kill planet Earth. So first, just to put this into context, how long has the Earth been around?

Pamela: Somewhere around 5 billion years. Exact numbers are still being argued, so I'm just going to go with 5 billion is a good starting point. 5.5 is out there, 6 is out there somewhere...

Yeah, right. So all of the ways, all of the dark forces working against our planet have failed so far.

Pamela: All the real nemesises.

Fraser: For almost 5 billion years, all failed, and here we are still, and yet the end of the world is [missing audio]. In fact, as we're recording this, we're about to...

Pamela: So the end of the world is always nigh because the Universe truly is trying to destroy life as we know it on the planet Earth, whether it be a random black hole that comes tumbling into our area of space and out of nowhere starts sucking in materials, or a comet comes colliding toward our planet out of the Sun and we don't see it until, well, we're about to die. There are so many ways that every day we somehow survive miraculously, except really it's just probability.

Fraser: OK, so let's take a look at some of the kinds of classes of ways that our planet could end, and I think we should be really clear to distinguish between the ways that we can kill ourselves, or the ways that human beings can be killed...

Pamela: Those are almost as numerous.

Fraser: No, I understand that, but those are easy. It's easy to kill all of humanity, ways to kill all life, which would be a lot tougher, and then ways to actually destroy the planet right down to its very essence.

Pamela: Which at the end of the day is by far the coolest thing to discuss.

Fraser: And difficult. Yes. OK, let's talk about humanity. I think most people talk about that they are, we're going to...we need to save Earth, we need to protect the Earth. That's not what we need to do. We actually need to stop killing all of ourselves.

Pamela: And protecting...

Fraser: ...and the environment

Pamela: We're going through a mass extinction right now.

Fraser: Yeah. Absolutely.

Pamela: Within our lifetime, we will probably lose the black rhino. So this is where people are working hard to try and gather seeds, gather genetic samples against that future just like when people are now trying to resurrect the woolly mammoth that was killed off by human hunters. Well, someday we may need to resurrect a whole lot more.

Fraser: What are some of the ways that we are potentially going to destroy the planet? Sorry – destroy humanity.

Pamela: Destroying humanity starts with viruses and bacteria at a certain level. There is always that inquisitive scientist who forgets the power that he has to destroy everything. If you ever want to terrify yourself, read White Plague by Frank Herbert.

Fraser: Well, I always think about this – that in the olden days, if you wanted to create a nuclear weapon, you need to have the sum capability of a super power, and then you could create a nuclear weapon, and then over time, these viruses and genetic stuff... it's getting easier and easier. Eventually, you can imagine. it's going to be, in the end, some hacker kid...

Pamela: Well, worse than that, you have bored individual working at a drug company with full access to the labs, full access to state-of-the-art equipment going in after hours, toodling away at what they think is going to be the next way to genetically engineer a cure to some horrible thing, and there's that one gene off. We had scientists who created silly putty, which is "win," while not trying to do it.

Fraser: Not trying to destroy humanity. Right. Yeah. Of course.

Pamela: So if people trying to create new adhesives can create post-it notes, which are awesome, but not that sticky, you have to worry about what someone manipulating genes and viruses could do by accident.

Fraser: Someone's going to accidentally make a virus, kill us all, OK, let's move on. [laughing] You know, we can harm the environment enough that it can't support life, right? We [missing audio] on that right now.

Pamela: That's kind of the awful, evil, ugly...

Fraser: Is everyone depressed yet? This is going to get a lot worse too. I love these shows.

Pamela: So then there's the fact that we live in a developing world. We live, you and I, in developed nations, but the rest of the world is working to get to the same one-car-per-driver's-license-in-the-household that we experience in so many parts of the United States. And as we increase the number of cars, as we increase the number of television sets, as we increase the infrastructure that humans have to travel and entertain themselves, this requires massive loads on our manufacturing, our shipping. Amazon Prime, something I am guilty of using, is destroying the world one overnight shipment at a time.

Fraser: See, and as a Canadian, I do not have access to Amazon Prime, so I am really doing my part for humanity.

Pamela: My husband and I compensate for you.

Fraser: Yeah. OK. Alright. Push those boxes around your house with a snowplow.

Pamela: Yeah. Sadly, yeah.

Fraser: So, OK, we're going to sort of make the environment unlivable for humanity, and there's always these weird things that we could be doing as well when you think about some of the [missing audio] some kind strange matter...

Pamela: That's not going to destroy the Earth. That might lead to...

Fraser: It would destroy the whole Universe, right? And we live in the Universe.

Pamela: We do, but that one falls on the statistically as likely as monkeys to create Shakespeare.

Fraser: ...with devastating effects.

Pamela: True.

Fraser: But yeah it's not going to happen. No. Seeing risk analysis, that's all I'm saying.

Pamela: So CERN can create a micro-black hole, and that would be awesome because if it happens to evaporate, Steven Hawking finally gets his Nobel prize because theorists don't get Nobel prizes until what they theorize actually happens, so we kind of need to evaporate a black hole for him. The man deserves it. But if it doesn't evaporate, we now understand more about the Universe, and we end up with a microscopic black hole very, very, very slowly nomming the center of our planet, which is fine because it's only going to eat an atom every few decades. That's OK.

Fraser: So why are we talking about this black hole?

Pamela: Because it's awesome if we get Steven Hawking the Nobel prize.

Fraser: OK, so we've talked a bit about the kinds of ways that humanity could kill itself, so what are some of the ways that we're not going to do it, just humanity.

Pamela: Just humanity.

Fraser: Well, think about like an asteroid. It's going to come in...

Pamela: It's going to affect everything.

Fraser: It's going to affect everything. We're part of everything.

Pamela: So a stupid way that it would affect only humanity, that would devastate our way of life is we actually are running out of helium.

Fraser: What?!

Pamela: This is one of those things people don't think about.

Fraser: Save your balloons!

Pamela: Think about the florist because the price of helium balloons is currently going through the roof, and the reason for this is because helium is really a disposable gas. Once helium gets into the Earth's atmosphere, it is such a light gas that any random collision with an oxygen molecule could put it on a trajectory out of Earth's environment. It could hit, well, escape velocities through that type of collision. Helium, once in the atmosphere, is destined to leave our atmosphere. So as we mine helium as part of other ways that we're getting gases and, well, petroleums out of our soils, eventually we're going to run out of helium. This is something people don't worry about, but if we run out of helium, that destroys industry, it destroys science because we use helium to cool so many different things.

Fraser: There was a great theme, I'm trying to remember, I'm sure someone's going to remember the name of this book, but there's a great quote about how we as human beings have really gotten all the easily accessible resources on the planet Earth. We've gotten all the chunks of iron, and platinum and gold that were just sitting around on the surface of the Earth, so if we do go through some kind of mass die-off, or real devastating impact to our way industrial way of life, it would be really, really difficult for any following civilization to do that because we're at the point now where we've got massive oil fields [missing audio].

Pamela: We went from you stab a stick into the ground in Beaumont, TX and out shoots oil to "Oh, crud. We have to dig a kilometer into the ground."

Fraser: You have to tear apart northern Alberta.

Pamela: There will be no second Bronze Age. This is it. If we destroy our civilization, you have to wait...well, think of how long it's been since the dinosaurs died. That's how long it took for them to become oil.

Fraser: So there are all of these kinds of events that are going to impact humanity, but now to actually kill...OK, enough "humanity is in trouble." Let's move on to life -- all life on Earth. What would it take to wipe out all life on Earth?

Pamela: All life on Earth gets tricky because even an asteroid or a comet coming in, unless it's like a Mars-sized or a Mercury-sized object, in which case it's no longer an asteroid or a comet, it's a rogue planet that does not actually exist!

Fraser: Right. Nibiru, Planet X...

Pamela: So the reality is a lot of the things that we freak out about (asteroids and comets) are a real concern because they can wipe out large parts of the planet. You can imagine if an asteroid hit, say, off the Pacific coast, everyone up to the Rockies – dead. That's a bad day.

Fraser: That's back to us again, right?

Pamela: Well, everything. We would lose all the redwoods. Losing redwoods would be a bad day.

Fraser: What about the fish? The fish are OK.

Pamela: Not necessarily...the ones that were right there, some of them are now in orbit.

Fraser: [laughing] Right! OK, so the orbital fish – not so happy, but the rest of the fish, until of course we get this great column of shrieking hail of rock and steam that fill the whole Earth and lights all of the forest on fire and burns, but even then it's not going to kill all the life.

Pamela: The worst case in terms of asteroids is -- and this is when it gets scary when you go to Planetary Science conferences, is if you have a comet or asteroid headed toward planet Earth, and we realize this far enough in advance, you can do things like try to steer it, blow it up, things like that. Now the energy necessary to actually blow up an asteroid, we don't have that kind of energy, not a concern, but you can certainly remove chunks off the surface in the process of trying to steer it in a new direction. So you can imagine, and there's Soviet, former Soviet, Russian students trying to actually do this in the future to practice. You can imagine you take an asteroid, you attach explosives to it, to fire the explosives to shift the orbit of the asteroid, well, this is inevitably going to remove chunks of asteroid, that are now new, smaller asteroids, but if they're not small enough and they're headed toward us instead of somewhere else, you could end up with a ring of impacts all the way around the planet, and if this ring happens to occur in the Northern Hemisphere, well, that's where most of the land masses of our planet happen to be.

Fraser: That's going to wipe out all life on Earth?

Pamela: No, it's just going to make most life on Earth sad.

Fraser: Most life! That's the thing, so again, they call it...remember like Armageddon [missing audio]? But even that wouldn't do the trick. And, of course, now there's all this research, in fact, maybe the vast majority of the biological life on Earth is not on the top, the outside, on the crust, but actually is within the crust of the Earth.

Pamela: By mass, but not by complexity. There's complex life...

Fraser: But it could be complex later. It could evolve out of the ground and take over.

Pamela: And it could take long enough that we'll be oil, so it's all good.

Fraser: Yeah, yeah, and in fact, people could have recycled the elements. Iron would be lying around on the ground again, and the ground bacteria will come back...

Pamela: ...billion years in the future that the Sun will kind of have destroyed our planet, but the way that we really do need to worry about 50 billion years...

Fraser: We'll get there. That's one of the things I want to talk about, but...because there's other stuff that can scour stuff off the Earth. Like think about a gamma ray burst.

Pamela: You do have to worry about...now as far as we know, at this point in our orbit around the center of the galaxy, now this can change as we continue to orbit (this is the problem with orbiting is we're a moving target) is at this point we're safe. As far as we know there are no nearby giant stars getting ready to go hypernova that have their rotational axes and thus their future gamma ray jets pointed at us. Eta Carinae could potentially be a gamma ray burst. As near as we can tell from looking at its structure, it's not pointed at us. We'll be able to see it. We're close enough that we could have been destroyed, and this is actually a really neat way to destroy life because it basically...so the gamma rays are only going to hit one side of the planet and then the other half of the planet is going to get protected by that first half of the planet, spherical object, three dimensions and all that. So the gamma rays hit one side of the atmosphere, they instantly destroy large amounts of the ozone layer and cause all kinds of neat chemical reactions that cause larger molecules to form in the upper atmosphere. This has the double effect of overall dimming the amount of light that hits the planet, cooling things off, but also allowing ultraviolet through, which is kind of dangerous and kills things. So in the process of destroying our atmosphere, it destroys the ability of plants, the basis of our food chain would be plants, so you end up with dead plants. So it sterilizes half the planet and this becomes a chain reaction working around the planet, and so things that are underground when this occurs, probably OK. If they stay underground, probably OK, but will eventually starve to death. It's that starving to death part that's problematic.

Fraser: But then you know [missing audio] returns and life finds a way. OK, so then [missing audio] supernova explosion going off, I guess if it was close enough...?

Pamela: And this is the creepy one is we could actually...people forget about white dwarfs. They're small, they're not that bright; it's easy for them to go unnoticed. Now, if you happen to have a white dwarf in a binary system that is fairly close, hidden in gas and dust so it's fairly obscured, and that white dwarf starts selfishly gravitationally nomming its neighbor, and it exceeds the point at which its electron degeneracy pressure, the pressure of which the electrons are pushing against one another to support that white dwarf star, it could become so massive that the gravitational crush on that star overcomes the electrons pushing the star apart, the electrons are going to go, "OK protons, we're joining forces and becoming neutrons," there's a burst of energy, it collapses down into a neutron star, there's a supernova in the process, and that could happen nearby, and we just haven't seen that pair of quietly-considering-self-destruction-suicide-murder-pact stars.

Fraser: So we get this Type II supernova within...

Pamela: Type 1A

Fraser: Type 1-A. We get a type 1A supernova within...how far? If it's Alpha Centauri, are we doomed?

Pamela: Alpha Centauri? Yes, totally doomed.

Fraser: Totally doomed...you mean it could destroy the Earth?

Pamela: Yeah, we're looking at order of kilo-light years on this one.

Fraser: Within 1000s of lightyears, if you get a type 1A supernova it would probably destroy life on Earth.

Pamela: Same way the gamma ray burst did.

Fraser: We're safe...but for how long? OK, so explosions in space, black holes, so then, OK, so I think what we're driving at is almost everything that we're afraid of really just something that we should just personally, humans and life, current life forms should be afraid of. [missing audio] life forms -- they don't care, they'll evolve out of it and they'll be a long-forgotten. They might dig up some crater under a seamount, "Oh yeah, that's where the humans were destroyed, right?"

Pamela: And this is where organizations like the Lifeboat Foundation, which both David Brinna and I are both on the board of, this is where organizations like that are working to collect vast samples of genetic materials and seeds to essentially figure out how do we create a genetic ark that would allow all of the different critters that we wish we knew more about to exist in the future. How do we create that future where black rhinos can exist again? Funding's not there yet, this is probably good, but I don't know, black rhinos are kind of awesome.

Fraser: OK, so I think we can throw a bunch of others out, like alien invasion. Again, that's just us. Invacom, they'll kill us all, enslave us, take our water...

Pamela: You know, we do have to worry about Death Stars.

Fraser: Death Stars? Oh, right, right, of course!

Pamela: Alderon is not coming back together again.

Fraser: But the amount of energy required...

Pamela: Aliens?!

Fraser: I know, but the amount of energy to actually destroy...

Pamela: Aliens! They got here, didn't they?

Fraser: Wait a second! Isn't this backwards? Aren't I the one who's supposed to...yes, that's true, the aliens got here, they've somehow brought their death star, and then they shot their super laser and destroyed the Earth. Actually, there's a fantastic website that somebody actually did the math on what it would take...I forget what. It was ludicrous. No way in the world...

Pamela: Phil Plate's run the calculations as well. It is ludicrous. We do not have the capacity. It's doubtful the capacity will ever exist. 10 to the 23rd joules…. Martin is saying down front.

Fraser: So that's not going to happen, so let's move on then, I think, to the things that will probably, most likely, and eventually inevitably destroy the Earth. The first one you were sort of jumping at already is our Sun is heating up.

Pamela: Our Sun is heating up, and it is a gradual process, but even before our Sun decides to bloat up to become a red giant star, it's going to heat up enough that the slight change in temperature of the surface of our planet is going to cause the oceans to evaporate just enough that it creates a runaway greenhouse effect. And the problem is as you get more and more water vapor in the Earth's atmosphere, it becomes harder and harder for IR radiation, heat to escape the surface of our planet. The hotter it gets, the more water evaporates, the more of an insulating effect it has, eventually we end up with no more water that isn't in our atmosphere, and when you're trying to drink it, that's not where you want it.

Fraser: Right and we talked about how it would take, whatever, six billions years, seven billion years for the Sun to actually turn into...

Pamela: A billion years.

Fraser: Yeah 5 or 6 billion years for the Sun to turn into this red giant and actually [missing audio], but the Sun is heating up, and it's not long. I mean, you say...

Pamela: 50-60 million.

Fraser: Maybe 500 million years on the outside, and, again, there's a really great book, was it <u>Life and Death of Planet Earth</u>? I don't remember what it was, that essentially 500 million years ago Earth was really too cold, and the Sun the heating really hadn't kicked in, so you couldn't get these complex life forms, and then within this billion-year zone, you get enough heat that the complex life forms can come out and fill our atmosphere with oxygen, and then the Sun's going to get too hot and it's all going to go in reverse, and the complex life forms aren't going to last, and eventually it's just going to be this parched desert, and all the water and all the carbon dioxide has been pushed up into the atmosphere...

Pamela: ...which will cause new chemistries, which will cause us to look more and more like Venus.

Fraser: Yeah. All that water, though, is going. All those hydrogen atoms, just like our helium atoms before -- they're going, right? They're leaving?

Pamela: Unless they get tied up in molecules.

Fraser: But they're in the water [missing audio]...

Pamela: Well, this is where carbon monoxide, carbon dioxide...there's so many molecules, hydrocarbon chains are going to end up forming, sulfuric acid potentially. What's really scary is when you start looking at the models of how Venus got to be Venus -- that's potentially our future. And Venus -- 900 degrees Fahrenheit -- not so good to live in!

Fraser: So we're going to get this heating, and that will kill all the surface life, and maybe that inside life inside has got a few more billion years, right? So what's next?

Pamela: So the next inevitable death of the planet Earth – inevitable, there's other ways we could die, but inevitably our Sun is going to end up bloating up into a red giant star, along the way it has mass loss, so while the red giant star will be bigger than the Earth's current orbit, as the Sun loses mass, our orbit creeps further and further and further out over time, so as the Sun has less mass, our orbit increases, so it's pulling on us less, it's just the way orbital mechanics works. It's kind of convenient because if our current models for mass loss are correct, the Sun doesn't eat us, it simply fries us.

Fraser: Right. It kills most life on Earth, but still the stuff that's inside, heated by the internal cooling heat of the Earth is still going to be around.

Pamela: Internal cooling heat of the Earth?

Fraser: Sorry. The stuff, by the internal heat of the cooling Earth, is still going to be around.

Pamela: I think what he's trying to say is while the surface of the planet is going to be a crispy critter broiled by the Sun, as you dig down, while radioactive decays within our planet will continue to keep the inside of the planet fairly warm, it's still cooler than the surface.

Fraser: Yeah, and eventually, you know, when the Sun goes away, and the whole environment cools back down again, you're going to have a slow cooling off [missing audio], but still an environment that organisms can grab energy from.

Pamela: Well, and the thing is, once our Sun is done with its whole being a bloated star phase, it's going to let go of its atmosphere and become a beautiful nebula, like the Owl Nebula – it's one of my favorite things to look at -- and our Sun is going to leave behind a cooling white dwarf that will continue to feebly cast a very harsh light for a while. So our whole future, well, it's long stretching before us.

Fraser: But it's weird to think about that that we, as complex life forms, we don't have a long time on this planet in the vast scale when you think of how tough life is when you scrape it off radioactive cooling towers, nuclear reactors, you find it in all these places. "Life will find a way," to quote Jurassic Park, and again, you can imagine... Then you can imagine the life that has been kicked up into space [missing audio] floating around the solar system, landing on Mars.

Pamela: My favorite magazine caption of all time is from Scientific American. It's an article on asteroid impacts and in fact the impact that killed off all the dinosaurs when it formed the Chicxulub crater in the Yucatan, and one interesting Mayan fact is the sinkholes that have water in them where the northernmost settlements of the Mayan culture are, those are tracing the route of the Chicxulub crater, but anyway, when that crater was formed, a happy little brontosaurus, or a happy big brontosaurus as the case may be, eating leaves, minding its own business on the Yucatan peninsula, or wherever on the planet that part of the planet was, when that asteroid came it melted a large area and sent a shock wave through that flung debris plants, and that brontosaurus at escape velocities into space, and so this magazine caption wrote, "When the asteroid hit, it flung soil, plants and dinosaurs into orbit." It was awesome!

Fraser: That's cool. So, yeah, we definitely wiped out humanity a long time ago. Life is still tricky, and still surprising that, even the Sun goes through this phase, now maybe if the math is wrong then maybe the Earth might get consumed by the Sun.

Pamela: And it's not just the math, we're pretty sure we're doing the math right. What we're not sure about is if we understand mass loss rates correctly yet; we're still understanding that. We don't have any stars other than our Sun close enough to measure mass loss rates precisely, and since we're trying to predict what our Sun will do in the future, can't measure that precisely.

Fraser: So we've got this burned-out center of the Earth, orbiting the Sun. Sun is a small white dwarf. Is there any chance that now with all this loss of the Sun that the Earth is somehow going to spiral inward?

Pamela: No. Gravity does not work that way.

Fraser: So it's going to be spiraling probably outward?

Pamela: Well, once the Sun is happily a white dwarf, it's no longer undergoing mass loss.

Fraser: But hasn't it lost a lot of mass?

Pamela: It has, so we're further out.

Fraser: We will compensate perfectly, yeah.

Pamela: We'll compensate, and we're just going to keep orbiting that little sucker.

Fraser: Now what about the interactions between the remaining planets? Is there a chance that you could just [missing audio] the planet for trillions of years that they're just going to collide?

Pamela: Not that we know of. And the neat thing is when you look at the Nice model for how our solar system got to where it is now, in the past, the planets were in radically different situations, but over time, through the age of the heavy bombardment, Jupiter, Saturn, Uranus and Neptune migrated outward with Jupiter and Saturn passing through different resonances that had the effect of flinging the other two ice giants to further orbits. Now, everything seems to be settled where it is, so unless we get some new resonance forming because somehow we capture another planet, low probability, not going to happen unless monkeys make Shakespeare, I think we're good.

Fraser: OK. Another star system collides, passes within...

Pamela: Space is empty.

Fraser: I know, but you've got a long time. Take a trillion years, so could we have these interactions? It's still not going to wreck the Earth. It's just going to fling it out into space.

Pamela: No, it's just going to put it somewhere else.

Fraser: Right. OK. Black hole.

Pamela: This actually is a non-zero probability, and greater than monkeys creating Shakespeare issue.

Fraser: Is a black hole?

Pamela: Yeah.

Fraser: OK. OK. I'm intrigued.

Pamela: So we have a couple of different things to worry about: first of all, is the rogue stellar mass black hole. This is a former star that started out probably greater than 10 solar masses. We say probably because, again, mass loss rates, if it loses enough mass, it ends up becoming something other than a black hole. Started out probably greater than 10 solar masses, when it died it ended up collapsing down into a black hole, and during the process of having a supernova explosion, and now that dark sucker is just happily orbiting the center of the Milky Way, and its orbit is perhaps elliptical, causing it to cross our solar system's orbit the way comets cross our planet's orbit. There's nothing about this that makes the black hole a hunter-seeker out to eat us. It's simply orbital dynamics. If it has an elliptical orbit that crosses our solar system's orbit, it could sneak up on us, pass through the Oort cloud, and as Oort cloud objects gets eaten, we might see flashes of high energy – might. It's fairly empty out there, but we'll start seeing things get their orbits changed, and if we're unfortunate, we could get nommed by that...

Fraser: Hold on. Hold on. Think of the chances of this stellar mass black hole actually colliding with Earth. It's most likely to do is just run through the solar system, scatter the planets, and again, we get back to that Earth floating through space, cold and alone, but not destroyed.

Pamela: So it depends on crossing times. This is the neat thing is black holes have great reach. They like to reach out and gravitationally touch other objects, so if that 10 solar mass-ish or greater, so let's say it's a large stellar mass black hole, it started out as a huge star, it's passing through our solar system, it has great reach. Now, if another solar system passes through our solar system, that might be a one solar mass star, everything's thrown into chaos, but that one solar mass star doesn't have the gravitational reach that the black hole has, and if the orbits are such that we end up co-orbiting so that it very slowly migrates, it's that slowly passing black hole with a long duration to gravitationally yank on us, that's what we have to fear. If it's moving fast, we're good, but slow motion...

Fraser: If it's moving slow and it's got a long reach, it could pull the Earth in into doomed trajectory.

Pamela: Yes. Yes.

Fraser: OK. Now, we're cookin'! Now we got something here! Seriously this is it!

Pamela: ...[missing audio] the age of the Universe.

Fraser: We've gone through all of these encounters, these situations and we still haven't found something that could really take out the planet. We got one. I love it! OK! Let's say though that we luck out, and we don't get a black hole. Is that possible?

Pamela: That's the thing is people always talk about some day in the future the black dwarfs will vacuum up the entire Universe, and the Universe will be nothing but one giant...   No. No. Gravity doesn't work that way. So yes, over the future trillions of years before protons decay (we're going to get to that), black holes will slowly as they gravitationally interact with other objects making their merry way, orbiting through space, they will gradually eat things up, including the photons from the cosmic microwave background (we'll get to that as well), but they're not going to eat everything. There's going to be white dwarfs that escape; there's going to be planets orbiting white dwarfs that escape. It all depends on how dense a region of space you're in. If you're in a low-density neighborhood, you're probably good because the crossing times, the probability of interaction...all of those work out to the protons go first, so you're inevitably going to be destroyed via some interesting process, it's just not the black hole.

Fraser: Whoa, whoa...what? Hold on. What interesting process will destroy...? Feel free to offer some suggestions because I'm out. [missing audio] proton decay [missing audio] get smashed into a star...

Pamela: Low probability. Black holes...

Fraser: Gobbled up by a black hole...

Pamela: Yeah.

Fraser: What else is there? Hit by a jet from a quasar? What's going to destroy it?

Pamela: So really, we have to worry about being decayed or nommed. Those are really the two fears.

Fraser: Right, so that's it -- black holes. Obviously, we've talked about stellar mass black holes, we've got the supermassive black hole, so this is the question, right? We've got these planets orbiting their stars, which are orbiting the Milky Way, and this whole collection is orbiting this supermassive black hole at the center of the Milky Way. Will everything eventually make its way into that supermassive black hole?

Pamela: No, but what's interesting is in about 5 to 6 billion years, depending on whose models you read, we're going to combine with the Andromeda galaxy to, depending on whose paper you read, either form Milkomedra, Milkdromeda, which is easier to say

Fraser: Yeah, I like Milkdromeda.

Pamela: Yeah, and there's actually...I got to narrate my second planetarium show, but my first one, that I was really excited about because it's all science, this is one of the things they talked about, called cosmic castaways (follow me on Astronomy Cast, which hopefully you already will, and when it hits the internets we will let you know. I'll go to Youngstown State University, you can watch it). Anyway in about 5 to 6 billion years we're going to combine with the Andromeda galaxy to form an even larger galaxy that will no longer be spiral in structure. Eventually, our central supermassive black hole and their supermassive black hole are probably going to merge into an even more supermassive black hole. Now, over the course of history, or the future of our Universe, as the case may be, we're eventually going to also combine with Triangulum, with magellenic clouds, with all of the other galaxies that are part of our Local Group. We're working our way towards our nearest supercluster, and as the Universe expands, that's eventually going to become the entirety of our Universe. So we will become part of one giant galaxy that used to be the Local Group, and we're going to be part of one supercluster, and everything else will have drifted across the observable Universe's horizon.

Fraser: Will this giant elliptical galaxy destroy the Earth?

Pamela: Probably not.

Fraser: OK. Same problem, right? Nommed, or...OK so fine. So obviously the math is aweome [missing audio] in space and the Universe.

Pamela: So stellar collisions are possible, black hole nomming is possible, getting somehow -- we don't think from the current models -- sucked into a supermassive black hole. Again, models say no, but it's possible.

Fraser: Some kind of three-body interaction that fires us on an orbit that [missing audio]...

Pamela: Yeah.

Fraser: OK. Great! But then maybe by all likelihood, or maybe, we don't know yet, we'll miss all that, then none of these potential collisions will happen with the Earth, and it will last until when?

Pamela: This is where we start looking at long time. Take a one, add 38 zeros: 10 to the 38th seconds into the future. This is where we start looking at potential proton decay. Now, the problem is we keep trying to detect proton decay because, well, we know from supernovae that galaxies like ours should have one supernova explosion roughly every 100 years. This means if you look at 100 galaxies for one year, one of them will have a supernova explosion. If you look at 100 x 365 in one night, you'll probably see one supernova. That works. So in theory if we're looking for proton decay, take a large vat of water, make it large enough so that it has 10 to the 38th protons in it, in theory we should watch one of these suckers decay and they refuse to, so our estimates of how long it takes protons to decay keep evolving.

Fraser: If they even decay.

Pamela: And this is the problem: there really is no good particle physics underlying theory. This is one of those great frustrations of scientists. We desperately want that set of equations that describes everything, so that we can in our computers, from first principles, F=MA, build the Universe, and particle physics refuses to behave, so until we have a model that works and explains why we get the masses, why we get the spin, why we get all of the different characteristics that we find in particles, we can't figure out how long it will be until (and if) protons decay.

Fraser: And so what you're telling me is that the Earth is unkillable.

Pamela: Only if protons refuse to decay.

Fraser: Yeah. If it turns out that protons do not decay, and the Earth's protons will last forever...

Pamela: But, so if the Earth is going to last forever, then eventually it will get nommed by something because the crossing times allow...

Fraser: It's just a matter of time

Pamela: Yeah.

Fraser: But still, I don't think the Mayans predicted that.

Pamela: But one of the really awesome things about how all of this works is right now the reason supermassive black holes aren't happily sitting out there evaporating is because the cosmic microwave background, that echo of light from when atoms first formed and electrons and protons and atomic nuclei stopped all interacting together – that moment the cosmic microwave background was formed, light was let loose and we're still seeing that echo of light, and that echo of light is sufficient to counteract a supermassive black hole -- in fact, any stellar mass large black hole from being able to evaporate. But over time as the Universe continues to expand, that radiation is getting to longer and longer wavelengths, lower and lower energies, and eventually that light's going to get spread out and eaten up. At that point, the supermassive black holes are going to be able to start evaporating, turning our Universe into this basically smooth continuum of energy. Then the protons start decaying into energy.

Fraser: If they decay.

Pamela: If they decay.

Fraser: Right. Otherwise it's Earth and this smooth energy field -- this expanding, accelerating Universe.

Pamela: But, you know, in that Universe eventually black holes do get to eat everything. So if the black holes do get to eat everything, then we get eaten by the black hole, and the black hole evaporates, and we have a smooth continuum of energy.

Whoa. OK. I get it. Infinite time, and everything is eventually eaten by a black hole, and all those black holes will eventually evaporate. Either way... Well, thank you very much, Pamela.

Pamela: My pleasure.

Fraser: Alright!

[applause]