Astronomy Cast Episode 220 for Monday, February 14, 2011: Mass Extinction Events

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Fraser: Welcome to Astronomy Cast, our weekly facts-based journey through the Cosmos, where we help you understand not only what we know, but *how* we know what we know. My name is Fraser Cain, I'm the publisher of *Universe Today*, and with me is Dr. Pamela Gay, a professor at Southern Illinois University – Edwardsville. Hi, Pamela, how are you doing?

Pamela: I'm doing well. How are you doing, Fraser?

Fraser: I'm doing really well, let's roll. Happy Valentines Day!

Pamela: [laughing] For those of us…for those of you confused (we're already confused) for those of you confused by the laughter…

Fraser: …we recorded this about six weeks late.

Pamela: Right, so we record things in order. We backdate things so that in the future, the weeks that we release 4 and the weeks that we release 0 even out to one a week.

Fraser: This is going to be one of those "4-in-a-week," so lucky you! Alright, so the Earth seems like a safe place most of the time. With evidence of terrible catastrophes in the ancient past, times when almost all life on Earth was wiped out in a geologic instant, what could cause so much devastation? And will something like this happen again? So, there are a few of these names, right? There are these various extinction events and they all -- many of them -- have names.

Pamela: K-T extinction is the one everyone talks about.

Fraser: The K-T extinction, yeah, yeah, the Permian Extinction, the…

Pamela: Late Devonian -- that's just fun to say!

Fraser: Yeah, so there are all these big extinction events, and in each one of these, everybody died.

Pamela: Or at least most stuff…

Fraser: Most stuff died all at the same time, right? So, when scientists define a mass extinction event, what are they talking about?

Pamela: For the major ones, there's usually something where 50% of the varieties died off, so for the -- just to grab one -- the Triassic-Jurassic extinction event; this was about 205 million years ago. This one about 40% of all genre, if you remember that big "tree of life" you had to learn probably in high school, 48% just died on land.

Fraser: Right, and this is the way they measure them, right? They look at the fossil record before the moment -- the event -- and count up the variety of species in the rock layer, and then they take a look after the event and count up the variety of species, and you're looking at, there's 50% variety, but it's not necessarily how many creatures died, it's the…how different are the creatures that are remaining.

Pamela: And it also goes into things like: Was it only on land? Was it only in the ocean? Did everything everywhere die? And what's interesting is, like, bugs have a tendency to live.

Fraser: Cockroaches, yeah...

Pamela: They will out-survive all of us, and so you start looking at the different places that things died, and you also start looking at the varieties that died: Did you only lose the dinosaurs? Did you only lose the frogs? Which currently we're undergoing a massive extinction event. We're in the midst of what may be the number six (or it may be even higher than that) extinction rate that the planet Earth has ever had, so we see frogs going away, amphibians in general going away; we see bees going away, birds going away, so as we start losing biodiversity across the planet, that is the definition of an extinction. There's still life everywhere, but the *types* of life are decreasing in radical numbers.

Fraser: But it's hard, you know? The extinction event that we're in right now -- it's hard to notice it. It's not like I notice like, "Oh, there's one less type of frog showing up in my backyard these days," but I don't think that the previous extinction events happened that subtly, right?

Pamela: Well, so when the dinosaurs died -- giant asteroid fell out of the sky -- that was rather noticeable [laughing], but some of the other extinction events, we're not sure. They could have been like the one we're experiencing right now, could have been the type of great dying that it took time, and it was due to an environmental change, and so while you did have massive amounts of death and destruction of life forms, it wasn't a sudden "in the moment" destruction, and we're in one of those "not in the moment" destructions right now.

Fraser: So then, can you give me some examples of some of the big ones? What were the big extinction events?

Pamela: Well, the most recent big extinction event was…

Fraser: Yeah, we'll go backwards.

Pamela: OK, so the most recent one was the Cretaceous-Tertiary Event, which is spelled with a C and a T, but is referred to as the K-T Boundary, which is one of those things that just baffles me, so there must be a language where Cretaceous is spelled with a "k" and that would just make me happy.

Fraser: Russian or something…

Pamela: They don't so much have the "c" and the "k," but I'm right there with you.

Fraser: Right, and that's 65 million years ago, right? That's the famous one that killed the dinosaurs.

Pamela: And here we're looking at, we're trying to figure out the geological boundary between "have dinosaurs"/"don't have dinosaurs" – it's an important boundary. Below here lie the T-Rex…when we start looking at this boundary, it was actually discovered that there's a very distinct difference in the geology of that boundary layer. This is research that was done by Lewis Alvarez and his son Walter Alvarez, as well as the chemists Frank Asaro and Helen Lanko (editor's note: chemist's name is Helen Michel), and what they found is there's iridium, which is extremely rare on

Earth, but is rich in certain types of asteroids. There's basically a planet-wide layer of iridium at the dinosaur/no dinosaur boundary.

Fraser: And it's also like a dark black line, isn't it? I've seen them sort of showing you the K-T Boundary… it's this black line that runs in the strata.

Pamela: And so you can actually see something happened, and it's believed that this was caused by some sort of giant impact here on the planet Earth and this, of course, is where you start trying to figure out "OK, where's the big hole in the ground?" And living on a planet that's largely water, it can be a bit annoying at times, but this one actually is partially on land. And it looks like the Chichalu coast of the Yucatan in Mexico is part of an impact crater. And it was partially oil geologists -- people out there surveying to figure out where to find petroleum resources are in part responsible for finding this crater because as they were going out making measurements of "OK, I know how far I am from the center of the planet Earth, what is the gravitational pull where I am right now?" And by combining the information of where you are and distance with the amount of gravitational pull you experience, you actually get a sense of the density beneath you, and they found these gravitational anomalies that added up to: there's an area of the ground that's been compacted, and this is that crater.

Fraser: And so then, you know, looking back in time, what do they think happened? You know, it's a big space rock, but as a good example for the kind of event, what are we looking at happened?

Pamela: So basically, you have rock from the sky comes in for a rather violent landing, and based on this 180-or-so km crater, you can guess that when it impacted, there was a lot of rock that was basically turned into dust and thrown into the upper levels of the atmosphere. There's a fabulous scientific American caption that says when it hit it threw dirt, rock and dinosaurs out of the Earth's atmosphere -- and that potentially happened! So you can just imagine being the poor dinosaur munching leaves or munching another dinosaur, and you look up and there's giant rock coming from the sky, burning up, huge light, fire, ground shakes…and the shock wave goes traveling through the ground and it's that shock wave that's so dangerous and throws things up, and that shock wave leads to you being thrown into low Earth orbit and dead.

Fraser: Yeah, but what about the rain of molten rock that falls down around the whole Earth and lights everything on fire?

Pamela: Right, so it's unclear exactly how much of that story would actually have happened, but there is a problem with molten rock being generated and tossed up, and then it's a matter of: How long is it in the air? Does it have a chance to cool off? Does it actually have ignition temperature when it hits the ground? None the less, there's all this stuff thrown into the atmosphere; this leads to acid rain which kills vegetation, kills plankton, kills all the stuff that gets eaten by the things further down on the food chain. Those things start dying, so things at the top of the food chain start dying. You have changes in the planetary temperature, which makes cold-blooded animals have kind of a rough day. You have all of these things coming together at once, and some things ran for the right environment. Like we now see some animals living further north than they used to trying to find some place where it's still cool enough to survive. Here you would have had animals and things running toward the equator trying to find someplace warm enough to survive.

Fraser: Right, so you would have had the event itself, and, you know, exactly how devastating that was is unclear, but in the worst case scenario, it's like the whole earth was on fire with temperatures hot enough to boil water everywhere you went.

Pamela: Right.

Fraser: Right? And the only place you could survive is if you were quite a depth underground, and even when you emerged the entire planet was cooked to a crisp, nothing to eat…Not a good day, right? Not a good day to go hunting for food…

Pamela: Yeah, it probably wasn't that extreme. There is evidence that things did live for a while, and it was that "Wow!"…

Fraser: Right, and so afterwards, right? You get this horrible event in the moment, where it's possible there's nowhere safe on Earth at all, and then you have the after-effects, where it's also a very horrible place to live for a very long time. You're looking at, what, hundreds of years before things might get back to normal?

Pamela: And this is where it's unclear, but you're definitely looking at 10s of 1000s of years for the diversity of life to recover, and so we're unsure exactly how long it took for the suffering to end, basically, so there was still a couple tens of thousands of years where it looks like some dinosaurs managed to just barely hang on, but it's unclear how much of that is …you can actually have fossils move around in the geologic record, which is kind of annoying, so for plus or minus a few 10s of 1000s of years there's a question mark, but it looks like you could have had a few tens of 1000s of years of things barely making it before they just died off and were replaced by new, up-and-coming life forms. So all non-avian dinosaurs died off near this period. Some of the avian ones, well, they still exist today -- we call them birds.

Fraser: Right, so we've got all of the birds surviving and some of the mammals and some of the plants, and then…and insects, and then you get this re-speciation, right? So shortly after you've got very few species, and then things recover.

Pamela: And what was amazing about the K-T Boundary is it pretty much killed everything off that was big and wasn't cold-blooded, and the reason this is: you can take a cold-blooded animal and get it cold and it basically hibernates and stops eating, so things like crocodiles could survive, but all of the big dinosaurs that were a wee bit warm-blooded in one way or another – dead. Any large mammals that might have existed – dead, but luckily, most of the things were small at that point, and the small mammals, the avian dinosaurs (which in order to fly you have to have fewer demands on your system where you get too massive and flying becomes hard), all of these things were able to survive this period. The other thing that's kind of weird, though, is pretty much all of the northern marsupials died off. You don't really think of marsupials in dinosaur times, but there were a bunch of marsupials in North America and some in Asia, and they were all gone after this boundary period, so that's just one of those weird, "Huh!" things that came out of this extinction.

Fraser: We could have kangaroos here in North America if things had gone differently.

Pamela: That would be so cool!

Fraser: Right, so the K-T is the big, famous one, but there are some other ones that make the K-T event look kind of small in comparison.

Pamela: No, that would be entirely true.

Fraser: Yeah, so like your worst day ever is nothing compared to the Earth's worst days ever.

Pamela: [laughing] Yes.

Fraser: The dinosaurs' worst day ever…so let's talk about some other mass extinction events and how they're different.

Pamela: So, we're going back in time. The next big "bad boy" of the extinctions was the Triassic-Jurassic extinction event, and this was one where you lost vast amounts of the stuff in the ocean, and so that's one of the things that makes you notice: what caused the ocean of all things to have problems during this period? A lot of the large amphibians were able to survive, but the aquatic environments just had these huge die-offs – 20% of marine families, 55% of marine genre became extinct -- and so in trying to figure this one out, there aren't any asteroid impacts that seem tied to it, and well, it looks like there were gradual sea-level fluctuations. It doesn't explain the suddenness of what happened in the marine environment, and so it's thought maybe this was due to some sort of volcanic eruptions, and there's what's called the Central Atlantic Magmatic Province, which is basically this large expanse of magma that was created, and any time you have lava coming out, if you watched any of the eruptions recently in Japan or Indonesia or Iceland or Hawaii, you end up with carbon dioxide, sulfur dioxide and all this stuff just thrown into the air. And if you have basically continent-wide magma release, that's going to throw vast quantities of stuff into the atmosphere and cause some sort of a temperature effect globally, and with the combination of changing ocean levels predicted, and this predicted change in the environment – all of these factors together probably led to just reaching a point where life just wasn't sustainable anymore, and you had massive die-offs.

Fraser: But it's interesting that it was largely targeted in the water, as opposed to on land as well, I mean, I wonder if huge eruptions under water or something just started off.

Pamela: Well, there's that, and the other thing is if you have changing ocean levels, if you look at where the most diversity of life is, you're looking at the low-depth areas, the coral reefs, the edges of the crustal plates, basically, and it's in this slope down to the deep sea trenches that you have so much life and if you drop the water levels, this long expanse of shallow water goes away and all those places for biodiversity go away.

Fraser: OK, so let's keep moving back.

Pamela: So, the next big one we have is the Permian-Triassic, and this is where you start thinking about "where did oil come from?" Well, that's Permian times, Triassic times, and so when we look back at this: this is the Big Death. This is 96% of all marine species, 70% of terrestrial vertebrates – everything died…dead, dead.

Fraser: This is the Great Dying, right? If you hear anyone talking about the Great Dying, this is the event.

Pamela: No more life.

Fraser: No more life.

Pamela: None.

Fraser: None. Wow! Well, obviously some because here we are.

Pamela: [laughing] Right, so there were those remaining 30% of terrestrial vertebrates, remaining 4% of marine species… The weird thing about this is: this is the death that killed insects. There's really no other "dying off" that killed insects. And the other thing about this is there's actually a gap in coal being created during this period, so if you're looking for coal to come from during the Permian-Triassic extinction event, there's no coal there.

Fraser: And there are whole – I'm not a biologist, so I forget the classification – but there are some basic types of animals, really basic body plans, and they disappeared during that extinction. I mean, you have whole branches of the "tree of life" that went away.

Pamela: 96% of corals, for instance, went away.

Fraser: Yeah, I know, I know, but you have like whole types of animals (I'm sorry, biologists, but you know what I'm getting at, right?) that went away.

Pamela: Trilobites – gone! The coolest fossil ever – all gone!

Fraser: And so there are whole kinds of life that just never made it past that moment, that event.

Pamela: Sea scorpions! Who doesn't want to have underwater, deadly sea scorpions? But we don't because of this extinction event. And what starts getting frustrating is we look at these things that are further and further back in time is our planet has this nasty habit or resurfacing its surface, and so as we try and understand what happened in the more distant past, we start to lose the ability to look for evidence of impacts. The crater would have probably gotten worn away, plate-tectonic carried away…so many different things could have destroyed it by now, so while there are impact craters that are linked as possible causes to this, there's no one thing we can look at and go, "That! That is the cause of this extinction event!" so we look instead at there seems to be a peak in some of the quartz crystals found at the Boundary layer, there's fullerenes that have trapped all sorts of gasses at the Boundary layer, but that could have just been one local event in Antarctica where all of these things are being found, and in Australia where all these things are being found. That could have just been a regional thing. People also point to all sorts of massive volcanic events that took place. There was massive volcanism going on in China, in the Guadalupe area, in Siberia, and with all of these massive volcanic events, maybe that played a role. Maybe the impact caused the volcanism…we're just not sure. And then there's always the case of "Well, why is it that we see sudden changes in the carbon isotopic ratios at this point? Could it be that there was some sort of an out-gassing that caused this change?" So as we look at what could have happened at all of these different things, we're just not sure, and this particular "everything died" event probably was tied to a whole bunch of bad stuff all happening at once, all feeding off of one another, and what we're learning is: global catastrophes – one of them can trigger many other things to happen. It used to be thought that if you hit a planet with an asteroid, you caused localized volcanism, well now we're finding maybe/maybe not. Maybe on the other side of the planet, on the antipode, maybe you had volcanism.

Fraser: OK, so the Earth would be hit by an asteroid so hard that you would get ripples of force moving through the planet, and then bunching up on the opposite side of the planet, and then it would explode as volcanism.

Pamela: Or maybe it's just enough to take existing volcanoes that were sitting there kind of quiet, kind of minding their own business, and all of them go off at once.

Fraser: And so that seems to be the model right now, like it took a very special circumstance to cause so much destruction. You had to hit the Earth and then when it was trying to get up, hit it again and again and something is [missing audio]…and it's funny because there's the "volcano people" and there's the "asteroid people," and a lot of people are just like completely on the fence, or "I think it was some of one and some of the other."

Pamela: I'm right there with you.

Fraser: A little of both makes it seem more likely. What a catastrophe! We've done a few articles in *Universe Today* like that. There is some subtle evidence, as you said, like common characteristics of craters or minerals found around the earth that maybe could have caused that, but still, there's just no smoking gun, we just don't know. But if you go further back, there are more of these, right?

Pamela: So we have two more and we're leaving out all the little punctuated things.

Fraser: Well, that only killed 10%, 20…who cares?

Right, [laughing] so this is where we start getting the Late-Devonian extinction period, well just the Devonian extinction in general. This was an event where, basically, 50% of the genera went extinct all at once. There were probably different periods of extinction during this, and so you saw one die-off, and then not too long after it another die-off. Now, this is one of those that when we start talking about what died, well, the planet didn't have anything on land more sophisticated than bugs, so it's kind of hard to measure die-offs when you don't have giant skeletons to go searching for, so trying to make sense of this particular extinction has taken time where they've done neat things like look at fossilized leaves to look at how much insect munching had occurred to try to get a sense of the biodiversity based on what bugs ate. And it's cool, and this is how we learned lots of things died, and there were two sharp peaks in this particular event of things dying off.

Fraser: You said there was…were those the two events? Is that what you're saying, there were two events previous? Or was there another one?

Pamela: It looks like during the late Devonian period of extinction there were two separate extinction events. These are referred to as the Kielwasser and the Hangenberg events, and exactly what triggered them we're still trying to figure out. The Kielwasser one is detected based on marine invertebrates getting killed off, and the Hangenberg one – it's this final spike of dead stuff that's basically found in the rock layer, where as you're looking at the sandstone and the shale layers, you see this material that's anoxic – it's just different life that suffered and died, and it's that marking in the records that distinguishes these two different events that occurred fairly close to one another and killed lots of stuff.

Fraser: Now, the obvious question of course, is will there be more mass extinction events in the future?

Pamela: Yes. Yes, and I…we can go even back further than this. There's still the Ordovian-Silurian extinction event, and that only affected oceans because there was really only life in the oceans. And whenever there's been life there's been death, and sometimes the death clusters up. We're undergoing massive extinction right now. It's unclear how much of it is due to global warming, how much of it is due to human beings… I highly recommend reading Guns, Germs and Steel…and there are asteroids in our future. There are potentially supernovae in our future. The Ordovian-Silurian one actually -- it's considered that this might have been a gamma ray burst, this might have been a supernova that affected the ability of our ozone to protect the planet Earth from UV. That could happen to us again.

Fraser: And then, of course, we're going to have the final one when the sun heats up to the point that it bakes the Earth.

Pamela: I think that one goes beyond "extinction event" to "planet destruction."

Fraser: Yeah, the final…the "big one."

Pamela: [laughing] But in the interim, what we find is life has ways of recovering, and while we've been undergoing this every few tens of millions of years, extinction's pretty much like clockwork in a lot of ways, although there's no extra star, there's no passing through the galactic plane, it's just, statistically, we tend to die off every few tens of millions of years. This will keep happening. The universe will keep finding ways to kill us. We have a poster you can buy here at astrogear.org.

Fraser: Yeah, "the Universe is trying to kill us all..." Well, that's great Pamela, great! Scary, but great! Alright, we'll talk to you next week.

Pamela: Sounds great! I'll talk to you later.