AstronomyCast Episode 246 for Monday, January 2, 2012:

What if Something Were Different?

Fraser: Welcome to AstronomyCast, 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: Doing really well. So once again we're recording this episode of AstronomyCast as a live Google plus hang-out on air, which means that if you're a big fan of AstronomyCast you can actually watch us live as we record the show and go through all kinds of audio hassles and headaches, and…yeah. But it's pretty cool, and so we're still figuring out all the bugs and if you want to check it out you can join us live. The easiest way to do that is to circle me or Pamela on Google plus, and then you'll see announcements of when we're about to record. And as we sort of settle out the technology, we're going to do this more often and do it on a more regular schedule. In fact, the easiest way to find us or me anyway is…I've actually redirected FraserCain.com to my google plus page.

Pamela: Wow!

Fraser: Yeah, I know, that's brave, right?

Pamela: Yeah!

Fraser: So…cool! Alright, any more announcements? No, we're good -- let's just rock.

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Fraser: So the number of moons, the age of the Sun, and our placement in the Milky Way all had an impact on the formation of the Earth and the evolution of life on our planet, but what if things were different? What would be the implications? So the goal of this show, and this was suggested by a listener, was what would life be like, or the Earth be like if some aspect, some physical aspect of the Universe, was different? If we had a different number of moons around the Earth, if we had a different structure of the galaxy, if we were located in a different place, if we didn't have some of the giant planets, different metalicity of the star, and just what would the implications? What do astronomers think would be the outcome? So, Pamela, let's start with sort of the big picture and then we'll sort of zoom in as we go.

Pamela: OK.

Fraser: So, you know, we know that our Milky Way is located in a galaxy cluster. We're in the Virgo Supercluster in the Local Group…

Pamela: We're in the Local Group on the verges of the supercluster, we're not really in the supercluster, but we will be -- but we're not there yet.

Fraser: But when you look out into the Universe with the Hubble space telescope and things like that we see regions with tons of galaxies clustered tightly together, and other regions where the galaxies are more far-flung apart than what we have here. Some have…so I guess just galaxy density, let's say that we ended up in one of those situations? How would things be different?

Pamela: Well, we probably wouldn't have ongoing star formation. One of the things that I actually studied as part of my doctoral dissertation is how the lives of galaxies change as they go from low-density environments to high-density environments over the course of the history of the Universe. And what we find is in the biggest clusters out there, the Bell clusters that look so beautiful with all their gravitational lensing in Hubble pictures – these clusters don't have any star formation. What's happened is over time, as the galaxies have swept one past the other, the gravity of them tearing at each other has sucked all the dust out into the spaces between the galaxies, and without dust there's no star formation. So in a large cluster, much larger than the one we live in, with all these interactions over the billions of years of our Universe, you crush star formation, so we'd be living in a dead system -- no Orion nebula to look at, no Pleiades to look at, the Hydes might not even have had a chance to form. It's much more depressing.

Fraser: Right, and so it would less the chance…the stars would have been sort of young and hot, and then all have burned out, or be burning out right now and you just wouldn't have the same…but on the flipside, what if you had the galaxies too far flung apart?

Pamela: Well, in that case, it would simply be a boring sky. There's all these isolated galaxies and the places that we look trying to find nothings. There's a researcher, Martha P. Haynes, who's looked in these giant voids trying to find someplace empty, and what she finds is isolated spiral galaxies. If you let a galaxy form, leave the sucker alone, most of the time it's going to end up being this nice, beautiful spiral galaxy, lots of star formation – not too different from the place we live.

Fraser: But is there a situation…it's the galaxy collisions that help some aspect, causing more star formation and helping with the amount of metals in the stars, things like that. I mean, do you need a certain amount of galaxy collision, or is none OK?

Pamela: No. Well, once you build the galaxy, I mean, we think that large galaxies like our own form out of little tiny puffs of galaxy that build up over time to form the giant galaxies, but once you get to the giant galaxy stage, any galaxy interactions that you have are either going to be minor things -- like we keep eating dwarf galaxies, it's what the Milky Way does -- or they're going to be giant star formation, crushing events that initially trigger massive star formation. I mean, that's the irony in this: you get two galaxies that interact just right, you get this massive burst of star formation, but then after that, nothing -- no more stars, and without new star formation, there's no pretty nebula to look at, but worse than that, there's no new planetary systems forming. If you have this happen too early in a galaxy's life -- that means that high-metalicity stars haven't had a chance to form; you might not end up with nice, interesting planetary systems. This massive burst of star formation's going to create everything, but there'll be nothing coming after that.

Fraser: So then let's roll back the age of the Universe a bit. So what if events conspired, and the Sun formed much earlier or our galaxy's evolution, was much earlier in…after the Big Bang, like say almost right away? Like, I'm not sure how old the star could be, or how young a star could be after the formation of the Universe. What if we were as close as possible to, you know, the formation of the Universe early on?

Pamela: Well, if our Sun had been one of that 0^{th} generation of stars which formed pretty much 400,000 years after the Big Bang, it would have been giant. It would have been a runaway star because it wouldn't have had any metals to help it cool off. That's one of those strange things in star formation.

Fraser: Right, so that's one of those "we wouldn't be here" situations.

Pamela: Right, and well, and there wouldn't have been any of the stuff to make planets. Initially, it was hydrogen, helium, trace amounts of lithium, and beryllium -- none of the silicon we need to make rock, none of the iron we need in our blood, none of the metals at all existed initially, so that first generation of stars, if we'd been one of the first generation of stars, no planets would have formed, and the Sun would have been this giant short-lived thing. So that's just different.

Fraser: Then, you know, on the flipside, if we were trillions of years into the future, you know, where the expansion of the Universe is quite large…I mean, I know it would have implications for astronomy in that we wouldn't see other galaxies. We might not even know that there was an expansion of the Universe at all, but would it have any impact? You know, will stars still be forming a trillion years down the road?

Pamela: No.

Fraser: No?

Pamela: No.

Fraser: Really? Wow.

Pamela: Yeah, that's the thing to think about is our Universe is slowly using up all of the material or spreading it out to the point that it's spread out so much that it can't condense down into new stars. There's a few exceptions; there's repositories of gas that's fairly high-density in the centers of galaxy clusters. That's not going to change, but really hot gas doesn't collapse into stars either, so we're going to reach this point where all of the gas that's cold enough to form stars is spread out so much it can't collapse. All the gas that is dense enough to form stars is too hot to collapse down to form stars, so there's this future of no more star formation.

Fraser: So we really are at the right place. So I guess we could have a more loosely organized galaxy cluster, but we really are at the right time for this one.

Pamela: Exactly.

Fraser: OK. So let's focus in on the Milky Way then. Right now we're located more closely to the outer edge of the Milky Way, nice and far away from the turbulent and crazy galactic core, but what if we were located much closer to the core?

Pamela: Well, we would have still formed, we could have still formed with planets, but the probability that we wouldn't have had the outer parts of our solar system constantly harassed by stars passing nearby… yeah, that probability says that we would have been harassed by other stars, and one of the things that astronomers think is that some of the past epochs of heavy bombardment where, all of a sudden, all the random rocks, ice, stuff from the outer Solar System came plunging in, creating craters in the inner Solar System, there's thoughts that some of that might have been triggered by a nearby star passing. Now, if we're living in an extremely dense environment, the probability that there's going to be these chance encounters with a star disrupting the Oort Cloud, disrupting perhaps even the Kuiper Belt starts to go up. There's even the possibility that we'll pass so close that…we don't worry about collisions. The probability of a collision's very low, but passing close enough that Jupiter gets stolen, that's…[laughing] that could happen, and three-body encounters start flinging things in all directions.

Fraser: Right, so we've got this situation where a lot of the stars passing beside each other are just wrecking the structure of the Solar System, and so, you know, do astronomers think that if we…you know, once we can better map the star systems that are closer in to the core, they're going to have sort of stolen planets? The planets being flung around, and…?

Pamela: Well, you can't actually tell in a lot of cases if a star has stolen its planets, but what we do think is that there's probably a habitable zone not just around stars, but around galaxies as well, and it's that region within the galaxy where the probability of two star systems encountering one another is sufficiently low that you don't have to worry about life getting disrupted by an overly close hot neighbor coming through.

Fraser: Right, so you've got enough time of not getting your solar system wrecked that life can form and things can be stable. So then what about on the flipside, right? What if you're further out in the galaxy? What if we ended up forming, you know, right at the very rim of the galaxy?

Pamela: [missing audio]

Fraser: But it wouldn't really have any implication, but what about amounts of metals, or radiation?

Pamela: So the thing you do have to worry about is if you're still in the disk of the galaxy, most of the disk of the galaxy still has metals in it, but as you start to get out into the halo of the galaxy – this is the spheroid of globular clusters and random stars that just sort of… it's still part of our galaxy, but isn't part of the pretty disk we think of. Those stars are generally so metal-poor that they can't form planets, so once you get to these older areas…and that's the thing too is these are stars that formed much further back in the history. In fact, for a long time, globular clusters were thought to have been some of the very first objects that formed in the Universe. These systems – they don't have the metals you need to have planetary systems, and so far we haven't found any planets in globular clusters.

Fraser: Now, you mentioned globular clusters. That would be crazy, I mean, we formed in a nebula kind of like the Orion nebula or the Pleiades or the Hides…but what if we formed in a globular cluster? Cause then the stars would be still around us, right?

Pamela: Right and there's some fabulous art, I believe, by the artist Loretta Cook, who sat down and then figured out all of the science behind what it would look like, and literally… if you have a thin atmosphere, so you don't have to worry about scattering of light that creates an opaque, blue atmosphere like what we have, if you're sitting on an atmosphere-free moon, for instance, as you look about, it's stars everywhere, and it's not just stars little points, it's you can resolve the disks, you can go, "Oh wow! There's a massive solar flare on that thing that's half a light year away. There's…" You can start to see details.

Fraser: Like Venus brightness? Like moon brightness?

Pamela: Somewhere between the two...

Fraser: Yeah, OK, alright, so brighter than Venus…wow! And depending on the age of the cluster, you'd have variation on the brightness of stars. If the cluster was older, you'd have just a smaller…

Pamela: Well it would be red in general, so imaging Betelgeuse everywhere you look.

Fraser: Right, but you know, we typically don't see those. We see the red giants, but we typically don't see the red dwarves as easily just because they're dimmer, and so we don't see them very far away, but if they were packed in a globular cluster, they'd be all over the place. OK, so then let's talk about the Solar System itself. So what if, for example, I mean, we have this sort of nice, series of planets, and then we have some gas giants, and then we have this, you know, the icy area around that, so what if, you know, some of those things were different? For example, what if we didn't have some of the gas giants?

Pamela: Well, the gas giants are actually kind of useful because they're vacuum cleaners gravitationally. We used to think that things hitting Jupiter was probably a once-in-500-year kind of event, but we're [laughing] now learning, yeah, we're now learning if you look at Jupiter long enough any given year, you're going to see it get hit by something.

Fraser: Like, we've had two major impacts in the last 20 years.

Pamela: I think…aren't we up to three now?

Fraser: Yeah, but anyway two big ones for sure: Shoemaker-Levy 9, and there was another one just a few years ago that smashed into Jupiter. So yeah, this is happening a lot.

Pamela: So you have Jupiter eating things, you look at all the outer planets have what were probably once upon a time Kuiper Belt objects or comet cores now as their moons… Gas giants are vacuum cleaners; they protect us from some of the large rocks that might otherwise come into the inner Solar System, and by protecting us by eating things, that means there's a lower probability that we're going to get hit by things, so it's thought that perhaps you need these giants out there vacuuming up as many rocks as they can to lower the probabilities low enough that life has a chance to evolve.

Fraser: But in our solar system, Jupiter is sort of the size that it is… and you know, Saturn and Uranus and Neptune, but at this point now with the thousands of planetary systems that have been discovered, thanks to Kepler, you know, we're seeing every variation. So there would be worlds with far more gravity, a lot more mass -- I know they don't get a lot bigger than Jupiter, but they would have a lot more mass than Jupiter. So you know, if we had some of those, would that have an implication?

Pamela: Well, so here you have to worry where's the trade off? When our planet first formed, it got completely blasted dry by an early hot Sun, and so that dry Earth got the oceans we now enjoy from comets hitting the early planet, and re-giving us back our volatiles. Now, if you had too heavy an object, or too many heavy objects protecting us, then maybe we wouldn't have gotten enough water, but that's really one for the planetary modelers to play with, but there is this trade off where you don't want to get hit too much, but you do need to get hit some to get your volatiles back.

Fraser: For the right period of time for…to give life a chance to form, and then what about the rocky planets, then? We have the four rocky planets that we have. Would it have an impact if we had more or less?

Pamela: Boring skies? I mean, that's the impact of things that wouldn't cause "negativeness" is they just make the Universe more boring.

Fraser: Right, but if we end up with say a Mars-sized object in the same orbit as the Earth, as we've seen, you know, that has it's implications.

Pamela: Yeah, right.

Fraser: That's the Moon, right?

Pamela: Yeah. [laughing] Once the Universe, once the Solar System is stable, what the rocky planets look like don't matter. Having extras that hit you – that matters.

Fraser: Right, right. So it's really all about…again, it's sort of back to that clearing out the Solar System.

Pamela: Yeah.

Fraser: OK, well, now let's take a look at our Sun. So we talked a bit about sort of if our sun formed at different periods of the Universe, if it formed early on in the Universe or later, but what about the age of the Sun? The Sun right now is 4.6 billion years. What if for some, you know, I mean…but we've had life on Earth for almost the entire period, so what if the Sun was younger right now?

Pamela: Well, the younger Sun was hotter and our planet actually had a point when its temperatures were hotter due to that hotter Sun, but at the same time, the composition of our atmosphere was different early on, so it's hard to figure out how to put all of these different variables together. We had hotter sun, we had different atmosphere, and we had a planet that was quite honestly not acceptable to us because it was so methane-rich. It wasn't until the Sun got a little bit older and a little bit cooler that we had an oxygen-based atmosphere to enjoy.

Fraser: So, I mean, that took billions of years to get going, right?

Pamela: A couple of them…not a lot. It's really amazing how quickly our planet settled down to start getting amoebae, or amoebas.

Fraser: Right, but again, let's run the clock forward. What if we were 5, 6, 7 billion years – the Sun was older?

Pamela: So when the Sun gets older, we're kind of in trouble here on the planet Earth. Our Sun is going to switch how it produces energy in its core, and when it does this it's going to bloat itself out and undergo extreme amounts of mass loss, and the combination of getting larger, getting brighter – it's going to get cooler as well, but you still move that surface right against the surface of the planet and it doesn't matter if it's a little bit cooler. We're going to get blasted, and essentially imagine broiling the surface of the planet and blasting it with a wind that is high-energy enough to remove the Earth's atmosphere, and you're looking at our future.

Fraser: Right, and we've talked about this in earlier podcasts that the Sun is actually heating up right now. You know, not "global warming" heating up, but heating up over the next 500 million to a billion years. It's going to make temperatures on Earth a lot hotter than they are today, and this is just the process of the Sun converting hydrogen to helium and sort of changing its energy up, so actually that number is pretty tight. I mean, we're within a few million years from [missing audio] life forms to be able to live?

Pamela: Yeah, the big thing that we have to worry about is as the Earth's temperature goes up, it's going to cause the oceans to evaporate, which is going to put more water vapor in the atmosphere, which is going to cause the planet to heat up, which is eventually going to cause a runaway greenhouse effect, which will evaporate our oceans completely. No surface water -- it's a lot harder to live.

Fraser: Right, and then I think one of the ones that's most interesting to people is the Moon, right? I mean we have one moon, and we've mentioned this a lot that the Moon is kind of important. Why is the Moon important?

Pamela: [laughing] Well, gravitationally it stabilizes our planet. If you've ever watched a top when you set it spinning, this little top happily precesses around and around and around, and the amount that a planet does the same thing varies from world to world, and here on Earth, our precession is at least somewhat stabilized by having the Moon there, so for us, the Moon is a way of keeping that spinning top somewhat upright. Now, the other thing that the Moon does is, just like Jupiter, it helps sweep things up. Things hit it; we look at it and we see the poor thing has been completely obliterated with craters. Every part of its surface has been hit by something at some point in the past. This is what creates the regolith that we see. Now, the Moon also has the effects of churning up the tides, so when you see the ocean moving, that's because we have a moon. And it's thought without those tides, life might not have been able to evolve the way it did. Now, there's still argument over whether life started in water, it started in volcanic springs, it started in dirt…we're not sure where life started. It could have started in all of the above – that's fine too, but no matter how it happened, we know that biological functions are at least in some part tied to the lunar cycle, so there's a good chance that life would not be the way it is without our moon there.

Fraser: So then what if we had more moons?

Pamela: That would depend on their spacing, their sizes…more moons, if you have the Moon we have now, and then you've got a little one close in…

Fraser: Oh, OK. Sure.

Pamela: So imagine a little one close in, we call that one the International Space Station…

Fraser: Right, but if we didn't keep boosting it up, it would crash.

Pamela: That's true.

Fraser: So a little further than that…

Pamela: So you do have to worry about…and this is actually a problem Mars has in its future; it's going to get bombarded with one of its moons in the future, so we'd want to have moons far enough out that they're tidal effects cause them to keep going further out, rather than to come closer in, which would just be a bad thing, but as long as they're small enough to not wreak gravitational havoc on our planet, then they simply serve as a protector that helps eat things headed our way.

Fraser: But you would get weird tides, right?

Pamela: It depends on the size. I mean, you can imagine if we had a much smaller moon in addition to the one we have now, it would be sufficiently small that the tides that it rose up (assuming it's further away) would be so minor that they'd be washed out in the noise of the tides that are there. It's sort of like if you're at a rock concert, your phone ringing -- you might notice, but barely.

Fraser: Right. I know that we get things lining up. We get the Moon and the Sun lining up -- you get much bigger tides.

Pamela: Right, and you would see things like that, but it doesn't mean that it would affect life.

Fraser: Oh! What if we had two stars?! What if we were in a binary system? I forgot to ask that. I wanted to ask that.

Pamela: We've actually seen solar systems like this. There's lots of them out there.

Fraser: Yeah, this was thought to be impossible, right? And now, well, not so impossible.

Pamela: We have this one extremely endearing, old professor who keeps wandering through, and he's like, "what about planets with more than one sun?' And we're like, "they exist!" and he's like, "no!" He's very cute and very, very old. So anyway, 61 Cygni B, it's one of them. We see things like this: there's the star Tau Boötis A, that has planets, and its companion Tau Boötis B (don't say that one too fast with elementary school audiences) -- all of these systems generally have widely-separated stars, and the beauty of these widely-separated stars is you end up with all the planets gathered around one of the stars, and the other one sort of hangs out, shining beautifully in the distance.

Fraser: So, it all depends on the distance?

Pamela: Yeah.

Fraser: If they're too close, things won't work out. If it's really far away, things work out a lot better.

Pamela: If they're close, then the planets start to experience what's called a three-body problem, and those fling things, again, so any time you're getting gravitationally interacting with three different objects, flinging occurs. So you need two things close together that you can treat as one thing, and then something else further away.

Fraser: I think that's the whole theme of this whole episode, when you think about it, is it's really about 3-body interactions.

Pamela: That's entirely true.

Fraser: You know, that is, if it's too much gas, too many galaxies, too many moons, too many planets, too many stars, then you get these 3-body interactions that wreak havoc. One last thing that I wanted to bring up is the mass of the Earth, right? I mean, the mass of the Earth that we have is…

Pamela: …kind of awesome.

Fraser: Kind of awesome, well sure! Yeah, but I mean, would things be different if the earth had double the mass? …half the mass?

Pamela: So if you adjust the amount of mass we have, assuming that the density doesn't change, as we adjust the mass that we have, you run into things like well, if we get small, we don't have enough mass to hold on to atmosphere.

Fraser: Like Mars...

Pamela: …like Mars. Now, if we get big, we kind of end up with too much atmosphere, so if you can imagine having a much thicker atmosphere, life's still possible, but you're going to develop entirely differently, and as you increase the pressure more and more, you can imagine needing exoskeletons to protect yourself. It starts to be much more like the situation life has at the bottom of the ocean, where life always finds a way given that it has the proper stuff, but it takes on a very different shape.

Fraser: Right, so I think in that situation I'd almost prefer to have more gravity.

Pamela: Yes, more gravity is good; less gravity is less atmosphere, which is bad.

Fraser: Which is bad…cool! Alright, and while this episode is running out, I was looking through some questions from people, so that's kind of cool. Cool! Well, thanks a lot, Pamela! And thanks to everybody who watched this live episode of AstronomyCast. Your thoughts and ideas were very helpful -- I stole them all.

Pamela: Thank you for joining us, and stay tuned – more of these are to come.

Fraser: And more good stuff…yeah. Absolutely. Alright, well, thanks a lot Pamela and we'll talk to you next week.

Pamela: My pleasure. Thanks, Fraser.