AstronomyCast Episode 244 for Monday, December 19, 2011:

Io

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: Good. And again, we're recording well into the future. It's early December, but we're recording this for late December because you're going to be cruising somewhere.

Pamela: Yeah, something like that.

Fraser: Not doing anything?

Pamela: I'm going to be off exploring the planet.

Fraser: You're going to have a holiday? Sounds good…but once again, we're recording this as a Google plus hang-out, and so if you want to participate, all you have to do is circle either me or Pamela and then we will give an announcement when we're going to do the recording, and then you can just jump into the hang-out and we stick around for half an hour or an hour after the recording and answer questions, and it's a really good time. So I highly recommend it -- just circle one of us. And this is kind of cool because we're recording at a really weird time, and so it's an opportunity for our Australian listeners to join us on this one.

Pamela: And it just occurred to me we're recording this a year before we're going to be on a cruise together celebrating the world not ending.

Fraser: That's right, or the end of the world -- one or the other.

Pamela: Well, yeah…either way, we'll be together.

Fraser: We're pretty certain it's not going to end. Yeah, and so you can go and find out about that at astrosphere.org/endoftheworld?

Pamela: Just go to astrosphere.org. It's the lead story right now.

Fraser: And there'll be a link to that. So once again, December 2012, we will…we're going to be doing a cruise with a bunch of other people, David Brin, astronauts, astronomers… It's going to be a really good time. So you can check that out on our astrosphere website. We sell it so well. We've got a whole year to nag you about this. Actually, you know, I think it's going to fill up, and we haven't really publicized it outside of just the AstronomyCast shows, so I'll probably start talking about it more on *Universe Today*, so and then it will sell out. I highly recommend you go with us. OK, let's get on with it.

[advertisement]

Fraser: So if you want to see one of the strangest places in the Solar System, look no forward than Io, Jupiter's inner Galilean moon. The immense tidal forces from Jupiter keep the moon hotter than hot, with huge volcanoes blasting lava hundreds of kilometers into space. And, Pamela, before we get into this, I have to let you know my daughter proposed tonight's topic.

Pamela: Yes, she is the one who text messaged me to find out if we could do this.

Fraser: That's right. So she texted…"Can I text message Pamela?" I'm like, "Yeah, OK." "I think you guys should do a show on Io."

Pamela: And I was really confused because I thought she'd written "lol" and lost the second "l" because it was an iphone.

Fraser: No, no, no, she's ligit. She knows her science; she loves Io.
OK, so then, you know, we got a whole episode to just talk about this moon and, you know, there are so many really interesting things about Io. Let's get started -- and I think, you know, we gotta get started with the discovery. When did we find out about Io?

Pamela: Well, finding out about it…there's always this lag between discovery and publication. So here we have this interesting…the first dude was too slow, so according to anything you're likely to read, it was Galileo who discovered Jupiter's moons in January of 1610. The first night he looked, he probably saw Europa and Io pretty much stacked on top of each other and couldn't separate them, but then on January 8, he clearly saw the two of them as two distinct objects, and he went on to publish this just a couple of months later in March of 1610. Now the thing is, Simon Morris, another person who'd already figured out how to use telescopes to look up, claims that he saw them in December of 1609. And that would have been one month earlier.

Fraser: Well, where are the photos?

Pamela: Well, yeah, that's the thing. And he didn't bother to publish his results, so here's a clear case of: if you don't share what you see with the world, you didn't actually see it.

Fraser: And that has happened even recently with Mike Brown, [missing audio] killing Mike Brown from Cal Tech. You know, people discovering objects and then wanting to gather more science, and then other people figuring out what he'd done and trying to break the news before him, so that still happens. If you discover it, the race is on.

Pamela: Yeah. Publish, publish, publish!

Fraser: So then, I mean, do people have an opinion about whether he really did see it? I guess it really doesn't matter, right?

Pamela: History gives all the credit to Galileo. And you know Galileo suffered enough for his good work -- might as well allow him to keep all the Galilean moons for himself.

Fraser: And so what was he able to see?

Pamela: He saw a small star that appeared to move back and forth beside Jupiter -- it was very unexciting. In fact, if you go out with a good pair of binoculars, or a Galileoscope (you can still buy Galileoscopes at Galileoscope.org)…with a Galileoscope, they actually have a lens that allows you to see exactly what Galileo saw, and it's basically this little, itty-bitty, tiny field of view, where Jupiter is a smudge that you can just make out bands, sort of, on a really clear, perfect night, and then you see the Galilean moons dancing back and forth along a straight line like balls attached to a string.

Fraser: Right, and we've talked in other episodes -- that was a mind-bending discovery because the previous thought was that everything orbited around the Earth, and here was something orbiting around Jupiter.

Pamela: And Kepler actually proposed that maybe these should be referred to as Jupiter's moons, and Io being the closest in of the four Galilean moons, that was almost planet #1 orbiting Jupiter.

Fraser: So, then it was just stars and that's all that anyone could see for years and years and years, right?

Pamela: Yeah, and the thing is all we had was this boring object; it had a great story behind it. While Simon Morris wasn't credited with his discovery, he did get to name it, and it was named after one of Zeus' mistresses. This is one of the neat things about the moons of Jupiter is for the most part, they're people that Zeus seduced at one point or another in mythology. And Io, contrary to the look of the object, Io is named after a female that Zeus seduced and then when Hera, his wife, caught him, he quickly turned poor Io into a white heifer to try and hide what he had done, and there's all sorts of myths about either the heifer ended up one of Hera, Jupiter's (Zeus') wife's, basically, animals, and all sorts of crazy things, but basically you have this passive little white cow that we eventually found out was anything other than a passive white little moon.

Fraser: Right, right, but then even with better telescopes, over the centuries, we didn't get much better of a view.

Pamela: No. In modern times, or at least within the past 150 years or so, we were able to make out as we looked at it that, well, it appeared to have slight changes in color across the two hemispheres, and by watching it over time, seeing how the colors varied over time, people were able to figure out that it's not pear-shaped. Because that's the thing -- when the north and south hemispheres don't give off the same amount of light, it could either be because, well, the one hemisphere is smaller than the other, like a pear, or it can be, as the case actually is with Io, that you simply have dark splotches, and by watching it as it rotated, they were able to figure out that this is a little, tiny, splotchy something going around and around Jupiter.

Fraser: But they didn't know why.

Pamela: They didn't know why. That actually took until the 1970s, and the first time we figured that out was when the two Pioneer spacecraft made their way out and in December of '73 and '74, respectively. They flew by and it just wasn't quite what they expected. They found high radiation, they found all sorts of weird materials -- it was a silicate world, rather than an icy body. All the other moons that we were looking at, at that point, they were just big old blocks of ice, or big old ice balls, literally, but here they had a silica planet, and…or a silica moon, as the case would be. But the thing was, the Pioneers didn't actually catch any of the volcanoes going off. For that we'd still have to wait another five years.

Fraser: Right, but I know that the Pioneer spacecraft were fairly low-tech for spacecraft. They didn't have great instruments; they, you know, they didn't probably make that close of a fly-by, so we just got a glimpse of what was going on, but I know that it was future spacecraft that really pulled things together.

Pamela: Right, so the next missions where things started to get interesting is actually a pair of missions that I'm just able to remember. Back in 1979 in March, Voyager I flew past Jupiter, and my parents made me take naps so I could stay up to watch the data coming back from the mission. And what was amazing is when they started when Voyager started sending back images, the scientists saw this planet that was covered in these weird pits and discolorations and these mountains and clear volcanoes, and as they went through the data, they were able to catch this amazing, basically, volcanic plume rising up over the edge of this small otherwise unassuming moon when you're watching it from as far away as Earth, and it turned out this is the most geologically interesting thing that we have in the entire Solar System.

Fraser: And were astronomers, like, at all expecting anything like this?

Pamela: No. No. We had no clue anything like this was out there. It was just one of those things. I mean, there was a prediction from the Pioneer stuff. When Pioneer got there, there was absolutely nothing. So let me step back. From Pioneer there's absolutely nothing weird anticipated. We'd gotten hints that there was stuff going on from Pioneers, and there had been a theory paper published that predicted that maybe tidal heating could cause some sort of a volcanism, but the level at which this was seen, the amount of sulfur and sulfur-dioxide getting thrown up, the arcs of material going between Jupiter and Io, none of this was predicted ahead of time. And it was like someone had taken every Dark Ages painting idea of Hades and turned it into a moon orbiting Jupiter. All that sulfur, all of that suddenly became real.

Fraser: I mean, I always imagined seeing, like, video of the volcanoes on Hawaii, or some of the…where you've got like these fountains of lava blasting in the air, and you've got you know, globs of lava, you know, plopping out of the volcano and landing as, you know, chunks of rock around. I mean, you've got this world, but it's that times, I don't know, like 1000, like you've got these streams of lava blasting out of the moon and, you know, creating these fountains of material. So let's imagine, you know, that we were, like, standing above Io. What would we see?

Pamela: Well, so standing -- that doesn't even give you enough perspective. So, the thing to think about is the biggest volcanic eruption that most of us are familiar with from the news is the unpronounceable volcano that went off in Iceland in 2010, and that volcano threw material several miles up into the air, but it was still "single digit number" of miles into the air. Well, Io is about a third the radius of the planet Earth, not quite, it's a little bit less than that, and it's able to throw material into space roughly 1/3 of its diameter, so…[laughing]

Fraser: Hundreds of kilometers…

Pamela: It's going hundreds of kilometers into space, and we just don't have the…

Fraser: Well, it's even more than that, right? I mean, as you said, it's trailing away from Io itself and being absorbed into Jupiter.

Pamela: Right.

Fraser: It would be like volcanoes on Earth being blasted off and being, you know, making their way to the Sun.

Pamela: Or imagine having a volcano going off and the material in the volcano becomes part of the Northern Lights because that's a closer analogy to what's happening, or even better would be imagine if the Earth's moon suddenly had a volcano that joined the Northern Lights because that's essentially what's happening is when these volcanoes go off -- some of the material that gets released into the atmosphere, it gets…or not so much into the atmosphere, that gets released into space, it gets caught up in the magnetic field lines and forms these amazing streams of radioactive material that are kind of dangerous to the spacecraft that go through them. But this is plasma streams writ large, where volcanoes, gravity and electro-mechanics are all interacting in violent and amazing ways I don't ever wish to calculate.

Fraser: No, or visit.

Pamela: Or visit. Yes.

Fraser: Right. And so, you know, we talked about, like, if you could stand on the surface, what would you see?

Pamela: If you could stand on the surface, you'd simply see a volcanic eruption that streams all the way into space. So if you've seen a rocket launch, you know how you can see the stream of material going all the way up into the sky and stretching out over the horizon? Well, this is a volcanic eruption that does the same sort of thing.

Fraser: And you would be standing on recent lava flows -- no matter where you were.

Pamela: Pretty much. This is a constantly resurfaced world. There are some craters on it, but very few. So the surface is… we've seen areas basically the size of Arizona get resurfaced just in the years that we've been watching this planet with spacecraft.

Fraser: Wow!

Pamela: I keep calling it a planet – it acts like a planet! It's not; it's a moon. So, this *moon*…

Fraser: Now, when we see the pictures…we've seen the pictures from Voyager (and we've seen the updated pictures taken by New Horizons and Cassini), it's got this strange, like, it looks like a bruised orange, like, it's got these yellows, and oranges, and browns, and all these crazy colors, so what's going on there?

Pamela: Well, the yellow is sulfur, so this really is every imagining of Hades turned into a moon. So, you do see when you look at the images some ices, you do see variations of the sulfur, where you get irons and you get different silicas mixed in, but that overwhelming yellow covering the whole moon -- that's just sulfur and sulfur-dioxide.

Fraser: Is it like snow, or…?

Pamela: No, think of it as they talked about with the unpronounceable volcano that went off in Iceland. All of the silica ash that would destroy airplanes if airplanes flew through the ash -- well, that yellow-y stuff that you're seeing is similar sorts of material. It's all the silica stuff that got thrown into space, all the sulfur ash that got (I don't know if ash is the right word), all of the sulfurs that got thrown into space, and then, gravitationally, some of it gets pulled back down -- a lot of it gets pulled back down, and it's kind of amazing the size of the arches that some of these plumes make as they go up, and then fall down far away from their volcanoes.

Fraser: And, uh, someone from the hang-out wanted to know: why is there so much sulfur?

Pamela: You know, this is actually one of those things that when I was researching for this show I was trying to find. I couldn't find a quick answer anywhere. This is a world that has a disproportionately large amount of silicon, a disproportionately large amount of sulfur, and its composition is just different from everything else, so somehow when the Solar System was differentiating, this one rock ended up in a part of the Solar System that for the most part is ice and gas.

Fraser: And, so then what…and then what is causing this? I mean, now those regular listeners to the show will know, but I think it's quite an amazing story. So what is causing this moon, unlike all the rest, to be so volcanically active?

Pamela: Well, it has an unfortunate location. So, as I was saying earlier, it's one of the four Galilean moons, which means it is orbiting

Jupiter and it's the inner most of those four, and the others are Europa, Ganymede and Callisto, and the inner three: Io, Europa and Ganymede have orbits that have, over time, settled into what's called a resonance. So for every two times Io goes around Jupiter, Europa goes around once, so if Io's at the top of Jupiter and Europa's at the top of Jupiter and you're looking down from the north (so that's kind of a weird way to think of it), you're looking…you're hovering above the north pole, looking at the planet, and at the top of the planet, you see Io and then directly above it you see Europa, then the next time Io gets to the top, Europa's going to be exactly at the bottom. Now, Ganymede is doing this exact same thing, but for every four times, so every time that Io and Europa are lined up, Ganymede's going to be lined up with them, and this resonance: this 2:1, 4:1, 1:1 resonance between these three moons forces Io to sometimes be closer to Jupiter, sometimes be further from Jupiter, and to undergo constantly changing gravitational pulls, and this constantly changing gravitational pull has the effect of, over and over and over, squishing Io like a stress ball held in the hand of an angry Roman god, which according to mythology it is [laughing], so…or in this case, yeah, I'm not going to go into the mythological connotations on this one.

Fraser: But it's that squishing, and then un-squishing, and then squishing, and then un-squishing -- just heats it up, and there's, I mean there are so many examples that you can think of something very similar. You can take a rubber ball and squish it and un-squish it.

Pamela: If you have a small child that you want to tire out, hand them a small rubber ball and have them bounce it over and over and over with a paddle, and eventually, it will actually change temperature from doing this.

Fraser: Yeah, I mean, bounce it up and down for a while, and then touch it, hold it, and you'll feel the warmth coming off of the ball and that's because it's the same process.

Pamela: In this case, this constant squishy-squishy-squishy that it undergoes is able to build it up to a temperature of 1200 degrees, and it's estimated that anywhere from 20% or more of its mantle is melted and that there's a vast subsurface -- basically, oceans of lava. The surface is probably about 7 miles (12 km) thick, or more. It's at least that thick, but it's certainly not more than 25 miles (40 km) thick, so this is a world with a very, very thin surface over a rather hot interior of magma, and all of that's just under pressure waiting to break through and fly hundreds of kilometers into the atmosphere.

Fraser: Right, and so it's that tidal forces that…well, I guess it's a mixture, right? The tidal forces are creating huge pockets of this liquid that's increasing the pressure, and then at some point it has to find a way out, and you get these cracks in the surface, and you get these geysers, and then at the same time it's a smaller object than Earth and so it's got less gravity, and so things can just fly further when they blast out.

Pamela: Right, and what's kind of awesome is not only are there the volcanoes, but there's also regularly-formed mountains from all of the forces that the crust is undergoing from having all of this squishing, all of these tidal forces, all of the pressure from the magma, and some of the mountains that are forming are actually bigger than Earth's Mt. Everest. So here again you have something a little less than a third the diameter of Earth, mountains bigger than Earth, volcanoes spewing material up to what on Earth would be the orbital height of the Space Shuttle -- I mean, just imagine if one of the volcanoes in Iceland or Indonesia or Hawaii went off and hit the Space Station! That's the scale that we're looking at here!

Fraser: And again, like, I think about how you've got Europa, which is a little further out, which possibly has, you know, a crust of ice with liquid water underneath, and it's that tidal flexing has made the water liquid. But with poor Io, it's the tidal flexing has made the rock liquid. It's just a different sense of scale. Now, you know, we always think: Europa, Callisto -- maybe there could be some life? Enceladus? What do you think are the chances of finding life on Io?

Pamela: You know, I think if we're going to find something with something more than a few cells inside, Europa's the place to look. But Io…we find out at Yellowstone, here in America, all of these amazing thermophiles that live in the hot springs, that live in the extremely sulfuric acid-rich pools, that live in these bizarre chemistries, and these bizarre chemistries are at a completely different pressure and gravity than Io, but compositionally, they're just as toxic, and if stuff can live in those toxic environments on Earth, there's no reason to think that stuff couldn't evolve to exist in the similarly toxic environments on Io. You have a thermal gradient, you have presumably some sort of liquid (that part we don't know for sure), but you've got that thermal gradient and that is one of the things that drives the chemistry of life.

Fraser: Yeah. I mean, if you've got a source of energy, that goes a long way… You [missing audio] in helping out life, so it's really interesting. Now are there any plans to re-visit Io?

Pamela: Well, we *want* to, and this is one of the problems we're dealing with now.

Fraser: Yeah, you and I want to. We want Io visited, but…

Pamela: [laughing]

Fraser: Are there any plans by you know scientists? Perhaps space agencies?

Pamela: One of the problems we're dealing with right now is lack of funding, and this gets reflected in two fairly significant ways. One of them is we just don't have any more of the radioisotope-driven engines that you need to go out and explore these distant locations in the Solar System; we just don't have the radioactive materials we need to build more of them. And Congress cut the budget to turn on the facilities necessary to manufacture those radioactive isotopes. And then there were plans to explore the moons of Jupiter in greater detail, but that spacecraft doesn't necessarily look like it's going to happen anymore. As they cut more and more of the U. S. budget, as we move toward having our own form of austerity measures, we're losing our scientific dreams, and so I have to say probably not in the next 10 years is anything going to launch to explore these moons. Now, we do have a spacecraft on the way out to Jupiter; this is Juno. Yeah, so Juno's going to do a great job at what it does. It's going to be mapping the magnetic fields of Jupiter, and it's that magnetic field that carries around the radioactive materials. It's going to be doing a great job measuring the composition of Jupiter's atmosphere, and mapping out the gravity of Jupiter. It's going to do some really awesome things, but this isn't an imaging mission. It does have a camera on-board; it's a camera designed to take pretty pictures because we want pretty pictures, but it's not really a science camera. So the science is going to be the type of stuff that makes the scientists happy, but doesn't necessarily end up on the nightly news. And so Jupiter is going to reveal a few more secrets, but not necessarily a few more pretty pictures.

Fraser: Oh, wow. OK, on that sad note…well, thank you very much, Pamela, and we'll talk to you after Christmas.

Pamela: That sounds great, Fraser. I'll talk to you later.

Fraser: Alright. I hope everybody has a great Holiday, and we'll talk to you again next week.

Pamela: Sounds great. Happy Holidays, everyone.