Astronomy Cast Episode 57:
Jupiter's Moons

Fraser Cain: Alright, this week is going to be a continuation from last week. So last week talked about Jupiter, and we could sense right in the beginning that was going to be too much show to handle, so we thought we'd split it in two and handle Jupiter last week, and its moons this week. So… we covered the Jupiter side of it, this week we'll do the moons, and let's just get right into it. Pamela, how did we learn that Jupiter had moons?

Dr. Pamela Gay: Well, Galileo looked up. Uh, that's the snarky answer. The more fleshed out answer is, telescopes finally came into existence in the 1600s, and Galileo was one of the ones who pointed out Hey we can use these to detect the enemy ships coming in from a distance, and then he also went off and realized wait we can also use this device to look up at the sky.

Fraser: That amazes me, that didn't occur to anybody, I wonder if that's just sort of the way the story's been told to this point. 'Cause I can just imagine someone with one of these telescopes going, huh I can look over there, and I can look at the moon.

Pamela: Well the problem is that we can only say for certain the things that people bothered to write down.

Fraser: Yeah, yeah, it's a history thing.

Pamela: There are arguments that other people discovered Galileo's moons at about the same time. For instance, the German astronomer Simon Marius, claimed to have seen the moons around the same time as Galileo, but he didn't write it down, he didn't publish his observations.

Fraser: And I guess if you're one of the more well-respected people of the day, it's almost like it's public relations thing. He won the battle.

Pamela: He won the battle, and so he proved to the world that he knew what he was saying, he documented it, he kept a proper observing journal, he did everything right, and he saw the four Galilean moons; Io, Europa, Ganymede, Callisto. And he documented their motions, and this was about the same time that the world was getting ready to get set on it's head with Kepler's discoveries of the laws of planetary motion, this was after people had been looking at the Copernican model of the solar system with the sun in the center, and here Galileo is observing, wait not everything goes around the sun. Not everything goes around the Earth. We have things going around the sun, we have things going around the Earth, the moon, and now we also have things going around Jupiter.

Fraser: So this was like the first time that anyone had seen anything orbiting something else.

Pamela: It was completely revolutionary. The world was still ruled in large part by the Greek philosophers. There was this idea that the sphere was the perfect form, and anything in the heavens had to be a sphere. The music of the spheres, this idea just kept cropping up over and over and over again. Even Copernicus's idea of the sun being at the center of the solar system was based on his ideal that Apollo was a more fitting god to have in the center, with the sun worship, and Apollo having been the driver of the chariot of the sun.

And here Galileo is going, wait, Jupiter not perfectly single colored sphere, it has moons, it has features. They didn't see the red spot at that time, but he looked at the moon and saw mountains on the moon. He looked at Venus saw the phases of Venus. He was able to prove with his observations, with that telescope beyond anyone's doubt, anyone who was willing to look at the data, couldn't not believe that the Earth went around the sun, instead of the sun going around the Earth.

Fraser: And so from Galileo's first observations of the moons of Jupiter, I'm sure bigger and bigger telescopes just got better and better, and saw better and better views of it.

Pamela: Exactly, although one of the really weird things about it was, okay so he's off discovering Io, Europa, Ganymede, and Callisto, way back in 1610, but the next moon of Jupiter wasn't discovered until 1892. And that's when Amalthea was found. And then a couple more were found in the early 1900s, there were four moons discovered between 1904-1914, another couple more in 38, one in 51, one in 74, another in, actually several in 79. And then between 1979 and 1990, there was nothing found. So like all the textbooks you and I grew up with said Jupiter has 16 moons, and we were happy with that. And then in 1999, we started finding them one after another, in quick succession, until today there's over 60 moons of Jupiter known, and we're still finding them. It's a busy system.

Fraser: They're just small. Yeah. And so, when did we actually reach out and start to get a good look at the moons?

Pamela: So there were the pioneer missions on the early 1970's, and then Voyagers 1 and Voyagers 2 in 1979. Then there was a gap until 1990s when we had Ulysses and Cassini both take great images. And then we had Galileo hanging out there for most of the 1990s. And the majority of what we know about the details of the moon comes from the Galileo mission.

Fraser: Well there's one more too you forgot. New Horizons just went by.

Pamela: New Horizons, brand new mission. Uh, it just went by and snapped a picture as well and caught one of the outer moons in the process. So, the way we're finding these moons is actually mostly ground based. But we're getting the good

pictures, the good understandings of them from sending missions out. And while Galileo is dead, there's lots of scientists who are just jumping to propose to NASA the opportunity to send another mission out to explore in particular Europa, but the moons one more time 'cause they're just so fascinating.

Fraser: Now, I've got a question. I would think that it's a bit of a paradox with Jupiter's moons, because its gravity is so large, I can see how it would suck a lot of objects into orbit around it, but I could also see it just eating them.

Pamela: Yeah, that's actually a problem, and in fact most of Jupiter's inner most moons are rather temporary. For instance, Amalthea. It's on an orbit such that it's going around the planet faster than the planet is rotating on its own axis. And this causes tidal effects that are eventually going to cause Amalthea to drop into the atmosphere of Jupiter, and get consumed. Any of the moons that are so close in that they're orbiting faster than Jupiter's rotating are eventually going to get sucked in and die. But for now, it's happily getting shredded into forming a nice gossamer rings. So it's keeping us amused in the interim.

Fraser: Now can you give me a sense of time-scale, are we seeing, I don't know it's almost like if you look at a line, you're only seeing the people who happen to be in the line at that time, right? Or like a river, here you're looking at the water, that has to be there, are we seeing just the moons that happen to be there right now? But, what kind of time frame will it take for it to gobble up some of these moons or, or let them spin out away from it?

Pamela: I have to admit that I haven't actually seen, um, the full calculation on how long it's going to take for it to fall in. But we're talking millions and millions of years here.

Fraser: Right.

Pamela: But, on the outer moons we are actually seeing a effect of when we live. The outer moons of Jupiter, they're constantly getting captured by Jupiter's gravity. Some of them are in fact because of they way they were captured, orbiting Jupiter in the wrong direction. They're on highly inclined orbits, they're interacting with one another. And some of them are going to end up getting flung back out of the system. That's very rare but can happen. Some of them are going to get flung further into the system. And, there's still getting eaten by Jupiter. Shoemaker-Levy 9 is an example of an object that could have become a moon had it's orbit been different, but because of the orbit it had it just got eaten by Jupiter entirely.

Fraser: Well so lets talk about some of the big moons. Do you want to start on the inside-out, or the outside-in?

Pamela: Well let's start from the inside-out, and there's also one really neat thing about how they're orbiting. And that's that they're not only totally locked to Jupiter, but they're also in sync with one another in this really neat way. The, the way it works is Io's the closest one in, and then Europa, then Ganymede, then Callisto. And, the inner three are synced up such that for every one time Ganymede goes out, which is the third planet from Jupiter, Europa makes two orbits. Europa is a little bit closer in, it goes around faster. And the moon Io goes around four times. So we have Io goes around four times, Europa goes around twice, Ganymede goes around once, in lock-step with one another. And this actually has the effect of tweaking Io's orbit such that it's slightly a centric. It's slightly oval shaped instead of being a perfect circle. And because Io changes how close it is into Jupiter, it actually gets stretched in shape the equivalent of about a thirty story building. So during the brief period that it takes it's little moon to whip itself around Jupiter, its surface gets flexed thirty stories.

Fraser: And I think we talked about it in the tidal forces that we go up and down maybe a...

Pamela: A couple meters.

Fraser: A meter.

Pamela: Yeah.

Fraser: Yeah, yeah...

Pamela: Yeah.

Fraser: And its going up, a hundred meters?

Pamela: A hundred meters. So when you think of so much smaller of an object, getting flexed a hundred meters in size, this is causing the moon to have a largely molten interior, and as this bulge gets pulled out, it causes this molten stuff to constantly be looking for places to escape through the surface.

Fraser: And now these are not volcanoes, these are... VOLCANOES!

Pamela: Mega volcanoes, yeah, this is Hollywood does volcanoes. This is, the volcano that ate all of California, except, we're talking about a moon. These volcanoes are spewing material up into the atmosphere of Io that Jupiter is pulling away at a rate of in some cases, a thousand kilograms of material just as the magnetic field sweep across the planet during the orbit. This material that's getting pulled away from Io as it interacts with the magnetic field lines of Jupiter forms these amazing plasma streams. This triggers lightning in Jupiter's atmospheres. There is so much violence that uh, yeah, this is just some science fiction horror movie waiting to happen.

Fraser: So let's talk about the moon itself, like if you were standing on the surface of the moon, what would it look like?

Pamela: It would look like, every cartoon version of hell you ever imagined. Everything is sulfa and silicate. It is shades of orange, shades of brown, there is lava fields everywhere, the ground is belching sulfur clouds. Its take the nastiest, smelliest part of Yellowstone National Park and make an entire moon out of it. And then, make the moon covered in constantly refreshing lava.

Fraser: Lets talk about these volcanoes. How big and powerful are they?

Pamela: On average they're about forty kilometers across, so that's, that's big. But what they do with their size is even more spectacular. They're blowing ash and other pyro-clastic materials into space, five hundred kilometers. So you could be five hundred kilometers above the surface of Io, that's higher than the space shuttle goes, and you're still getting blasted with this material.

Fraser: Getting hit by lava.

Pamela: Yeah.

Fraser: That's hilarious.

Pamela: They actually talk about how it's snowing sulfur ash, they uh Galilean space probe at one point was going over the poles of Io, and since the poles aren't getting tweaked by the tidal forces of Jupiter quite so much, the Equator, the everything's getting a hundred meters of deformation, they weren't expecting as much volcanism up towards the poles, and its flying along and it just gets blasted with ash snow, and of course this made all the scientists giddy-stupid-happy.

Fraser: I've seen pictures of Io where you can see, like, it looks like there is a fountain going off, on the, on the side of Io.

Pamela: Yeah.

Fraser: So I linked to some of that stuff on the show notes, but its just amazing. It really is one of the most amazing objects in the whole solar system.

Pamela: Yeah its both terribly beautiful and terribly frightening all at once, just the power of nature on this little moon.

Fraser: Now we talked about Jupiter's magnetic field and how it's causing, it accelerates particles and causes radiation. If you were on Io, what would that be like.

Pamela: Jupiter's magnetic fields get carried around with it as it rotates, and Io passes in and out of the magnetic field lines. When its going through one of these magnetic field lines, that's when you're getting about a thousand kilograms of material, one ton of material, pulled out every second. And that material is getting Ionized by the magnetic fields. And it forms what's called a plasma Taurus.

When that Taurus of material hits Jupiter's atmosphere its carrying along electricity. This electricity, it can be four hundred volts across Io, an electric current of three million amps. You're dead. It's just that simple. Just massive power output by the magnetic field going through this conductive material, pulling it along, generating current with the motions. It's, it's a very powerful electric generator, of a very deadly variety.

Fraser: And radiation too though right? You get shocked, but you also get irradiated.

Pamela: You can get the radiation with particles getting accelerated. There's all sorts of radiation. An alpha particle is just a high speed helium atom, and so you can get the radiation as well.

Fraser: And as we mentioned last show, every time NASA sent Galileo passed Io, they weren't sure they were going to talk to it again on the other side.

Pamela: Yeah.

Fraser: Okay well that's, that's uh, quite a moon. So lets move out one, one step.

Pamela: So was we move out through the solar system, we start getting to more normal but still not completely normal looking moons of Jupiter. The next one out is going to Europa, which is the place that we most often think of as here's where life might be in the solar system. It's a perfect sphere, at least as far as any object in the solar system can be a perfect sphere and still be solid. It has the least amount of features in terms of up and down features. It doesn't really have mountains, it doesn't really have valleys, it has almost no craters. And this is because its top crust is basically a five kilometer deep ice. Its an ice mantle. And we think, think, that beneath that is another fifty kilometers of liquid ocean.

Fraser: And so this is one of those situations where, like on Mars, geologists can look at the various craters and say "Okay, this place is old, while that place is young because that place has tons of really large craters, while this place has very few craters." And so if there aren't a lot of craters then geologists know that its being resurfaced. By lava, or I guess in this case, the ice. But we're saying there's nothing. There's no craters, there's no mountains, there's no valleys, there's just smooth.

Pamela: Cracks. There's cracks, there's swirls. It looks like what happens when you have a lake freeze and expand, and it gets cracks as it expands, and when you get glacial flow you can get compression lines in the ice. And scientists are trying to figure out what all the different swirling patterns, what the freckles, what the different strange features, that are mostly features because they're a different color, in the ice just might be.

Fraser: And so if you've got a shell of say five kilometers. There must be spots where its just crack open, where its almost straight to the water. Maybe just a couple of hundred meters.

Pamela: And there are these features called freckles, that we think might actually be where you had a warm cell of water underneath that was heated up by interactions with Jupiter and its magnetic fields and gravitation, and the cells of warm water rose to the surface and were basically hot water volcanoes that came up through the surface and made a small mound on the ice. So yeah, we see hints of the warmer water from below coming up and refreezing on the surface of Europa.

Fraser: And so on Io we've got volcanoes with molten rock pouring out. Europa's further away from Jupiter so we don't have the, the molten rock, at this, you know the same kind of volcanoes, but instead the interior of the planet is kept warm enough to heat the water underneath, but its also exposed to space so you're getting this icy shell on top.

Pamela: Exactly, and its just fantastic to look at it and, there are different places where we think that spirals on the surface in the ice might have been generated by slight changes in what part of the ice was pointed towards Jupiter, and there's actually thinking that while the surface of the ice is generally tidally locked to Jupiter, just like our moon is tightly locked to the Earth, such that if you were standing on Jupiter you'd only see the same face of Europa at any point in time, for every one time Europa goes around Jupiter, the moon rotates once on its axis.

We think this is true of the crust on top, but there are people who put forward theories that maybe the core of the moon is rotating a little bit faster so we have differential rotation between the core and surface and this could be even generating magnetic fields it could be helping to heat up everything and keep this ocean vibrant and interesting underneath the surface ice.

Fraser: And its time for the old cliché, if we find, here on Earth if we find water we find life.

Pamela: Exactly.

Fraser: So the thinking is, that there could be life on Europa.

Pamela: And one of the great questions is how do we go and explore for that life, and not accidently take life with the space probe. How do we go and search Ganymede and make sure that we don't accidently carry Earth born critters off to the outer part of the solar system.

Fraser: Alright. Lets move one more out.

Pamela: Now we're getting out to Ganymede. This is a moon that is bigger than the planet Mercury. This is an object that were it allowed to happily orbit all by its lonesome instead of orbiting around Jupiter, it would be a full-fledged planet, no questions asked. We have a planet.

Fraser: And it's bigger, it's the biggest moon in the solar system, right?

Pamela: It's the biggest moon in the solar system. Its diameter is 5,260 kilometers. It's planet sized.

Fraser: And I actually remember that people used to think that Titan was the largest moon in the solar system, but after the Voyagers went passed was what they're seeing with Titan was actually it has this big thick hazy atmosphere.

Pamela: Yeah.

Fraser: And once you took the atmosphere away, Ganymede wins out.

Pamela: And Ganymede doesn't really have an atmosphere, its this mostly rocky, it has some water, it has some ice, moon, that is just really neat to look at it. Because it has this variation of light and dark, its highly cratered. Its just a really neat place, and it has a very complex geology. It has mountains, it has valleys, its had some sort of volcanism in the past.

There's signs of lava flow, but not so much lava flow that it's erased the craters. So when you look at it, it really looks like some sort of piece of sporting equipment that's just had a really, hard, hard life. Its also an object that generates its own magnetic field. It has a liquid iron core we think, and that liquid iron core is enough to give it its own magnetic field, making it just as interesting as Mercury in a lot of different ways.

Fraser: So its got going for it that its big, but we don't think that it has like ice and an icy crust, or an icy shell, we don't see a lot of lava, and we still see the record of the asteroid bombardment, so we can get a pretty good sense that its not being resurfaced as, as quickly as the other, as the other moons.

Pamela: Mostly true, but we actually don't know for certain that it doesn't have a subsurface layer of liquid water. One of the weird things about it is, it does have

some ice on it, and there's thinking that maybe there is an underground sea there, that perhaps this is what is helping to drive the magnetic field is if there's salt water, salt water conducts electricity.

What if there's a conductive layer of salt water that's sandwiched between other layers of material in this planet moon, and that's part of what's behind the magnetic field. It could be that this object is another place we go looking for life, although it's no where near as probable as looking for life on Europa.

Fraser: Alright well let's move one more.

Pamela: Okay. So now we're out to Callisto. Callisto is another one of these rocky giant moon objects. It's almost the size of Mercury, but not quite. It's totally covered in pox marks. It's covered in these light colored chips from where its gotten hit with different, uh meteors, hit with different debris, and it started with a darkish surface, and each one of these nicks exposes the ice beneath. And it just makes it a really neat looking moon.

In some places where its been hit there's these ring patterns traveling out from it, so if you hit it hard enough at the right period of time, and we're still working on understanding how these ring-like patterns emerged, not only do you get the crater, but around the crater you get a series of concentric rings, like waves traveling away from a rock that splashed into the ocean.

Fraser: Once again that's one of the things you've got to see the pictures to really appreciate that because its quite an amazing, spectacle.

Pamela: What one of the most famous ones is called Valhalla. The catering on this moon is just truly spectacular, there's also a bunch of different features where we can tell that something that was disrupted, a comet or an asteroid that was broken into multiple different pieces, just nailed itself into Callisto, and left a train of little circular craters behind, as it hit in successive order.

Fraser: Now just to talk about all the moons in general, its funny, I mean with the space craft that have already been there, they've turned up so much interesting information, and yet we still have so many questions about what's going on with these moons, including I guess the most important question, is there life on Europa. So what plans are there to go back and reexamine them.

Pamela: Well, there was what was called the JIMO project, but last I checked NASA had canceled it, and you never know when NASA's going to resurrect a program.

Fraser: That was the Jupiter Icy Moons Orbiter.

Pamela: And it was one that they'd done amazing work designing a nuclear power generator for it so that it could carry a little bit heavier sensors, it was just a

really nice mission. It was going to drop a probe onto Europa, and just explore the system in detail.

Fraser: Yeah that's right, with JIMO I know that it was going to be an ion engine, like Dawn and Deep Space one, but it would be a nuclear powered ion engine. Most, most are solar powered. This would actually use a nuclear reactor. And it would have the, a thrust and fuel to drop into orbit around each one of Jupiter's icy moons, so it could go into orbit around one, make a whole bunch of analysis and discoveries, and then come out of orbit and go into the next... and yeah they cancelled it.

Pamela: Yeah it was an expensive project, we were redesigning the way space probes get from point A to point B, and it's a design that could be reused for other projects, which makes it frustrating to see it cancelled, is here's this great technology we were completely designing that could be reused in so many different ways and it got cancelled. But hopefully someday something similar will get resurrected, and we will be able to go out and re-explore Jupiter, look at each of these amazing geological active worlds in detail, and look for life.

Fraser: And I've also heard ideas about various things that could land on Europa and as you say, have like some kind of nuclear powered, or heat reactor that would warm up the probe and it would just melt down through Europa's shell until it reached the ocean underneath and then deploy a submarine, and the submarine would look around and look for life. It sounds very complicated. But once again it would be great, it could answer the most important question. But I, but I also heard that there was some of those upwellings that you might actually get life just sitting, or the water from down below just ending up right on the surface of the moon and maybe you could just sample it right there.

Pamela: And we're doing as much practice as we can on the planet Earth sending in robotic missions to explore the underwater lakes and watery cave systems down in South America, going and exploring underneath the Antarctic ice, uh wherever we can practice we're trying to practice, so that when the time comes and NASA says yes we're ready to send this mission, all we have to do is hand over the technology.

Fraser: Well I can't wait. That's...

Pamela: It's going to be a great new day.

Fraser: Yeah these, this is one of the places that space craft have to go back to as soon as possible because there's still so many mysteries outstanding.

Pamela: And volcanoes are just cool.

Fraser: Yeah. Uh, okay well that was great Pamela, so we covered Jupiter, and so next we're going to head out to Saturn, and I think we'll probably do the same thing, because Saturn's moons are even weirder, and it has more interesting moons like Jupiter has the four main ones, but Saturn has a dozen that are bizarre, so it's going to take sometime, so we'll split that up into two shows as well.

But we're actually going to take a quick break from a tour of the solar system I think next week to cover a topic that's just been, that we just get so many emails about it, we just got to deal with it, which is the concept of inflation, which is... sort of a modification of the big bang. So we'll talk about that next week, and then go back to our solar system tour.

This transcript is not an exact match to the audio file. It has been edited for clarity.