Astronomy Cast Episode 61:
Saturn's Moons

Fraser Cain: This week we're going to delve into Saturn's moons, some of the most interesting objects in the solar system. Let's start at the beginning: how did astronomers come to know Saturn has moons?

Dr. Pamela Gay: They looked.

Fraser: Yeah. Thanks.

Pamela: (laughing) I'm sorry, sometimes the snarky answer is the one that comes out first.

Fraser: I set them up and this is what I get?

[laughter]

Pamela: Seriously though, Christian Huygens, back in 1655 (and he has the coolest last name to say – Huygens – it's just fun), discovered Titan. It's the biggest moon, easiest to find and it reflects a lot of light. He found it and he basically called it "Saturn's Moon" and it was the moon of Saturn for a long time.

Then, other people got in the game. Giovanni Cassini came across the next moons, Tethys, Dione and Iapetus. Being a good, obedient Frenchman, he named them the stars of Louis, in honour of King Louis IX. It's a French series of words, or Latin, I'm not sure which (and I'm not going to humiliate myself by trying to say what he named them).

No one liked that name. you don't name celestial things after national leaders, so they got their final name by John Herschel, a while later. He named the seven satellites that were known when he came around 1847 after the Greek Titans. He thought it made sense that the brothers of Cronus (which was Roman for the Greek god Saturn) should be included as its moon). So you have Saturn (or Cronus, depending on which set of gods you're going by) and all the fellow Titans orbiting.

Fraser: There's more.

Pamela: There's more. They just kept finding moons and finding moons and we're still finding new moons hiding in the rings of Saturn. They're up into the mid-fifties now.

Fraser: Does Saturn have the most moons of the solar system? Is that more than Jupiter?

Pamela: No, Jupiter has more that we've found, but I suspect they're harder to find on Saturn because the ring system gets in the way of the smaller ones.

Fraser: They're starting to hide. There was recent news they've turned up a bunch of moonlets in the rings, and those are starting to really blur the line between what's a moon and what's rings.

Pamela: Or a chunk of ice. Yeah.

Fraser: Yeah. At some point there will be a great debate and maybe some moons will get un-mooned like poor Pluto.

Pamela: Oh wow. Yeah, we don't want to see the letters we'll get if that happens.

Fraser: Okay, but that's how we've discovered them all together. Let's talk about the moons, starting from the inside out.

Pamela: The inner moons are the ones that are generally associated with the rings. These are the ones that herd the rings into staying where they are.

So we have the little tiny moon Pan that is about the most inner of the named big moons, and it's tiny. It orbits Saturn about every half a day and it's basically maintaining the Enke division. It was discovered in 1990 – we're still finding these things.

Fraser: This is an actual gap in between two parts of the ring.

Pamela: his is one of the larger gaps.

Fraser: When you say maintaining, does that mean clearing? Emptying? Consuming? Pushing them in and out?

Pamela: How 'bout all three?

Fraser: Yeah.

I guess there's a bunch of these ring-shepherd moons. What do they do?

Pamela: It depends on which orbit they're in. in some cases they do like you're saying: they clear out the orbit. They own their space, you might say, and suck up everything else in the orbit.

In other cases, the divisions come from resonances with the moon. This is where you end up with a moon going around, say, five times for every three times a particle goes around. Every time they line up, the moon'll yank on that particle and cause it to fly into a different orbit. 3:5 isn't going to do a lot of damage, but when you start getting things in 1:2 resonances, that's when you start emptying areas of space out, and that's kind of cool to think about.

Fraser: There are some amazing pictures of some of these ring-shepherd moons as they're moving around the rings there's a stream of ring material moving in and out from the shepherd moons as they clear their path. It's astonishing to see.

Pamela: Gravity's a powerful thing, and it doesn't take a huge moon to move dust particles of ice.

Fraser: We'll skip past most of them. What are the ring-tending moons?

Pamela: Out tending the rings, among other things, we have Pan, Daphnes, Atlas, Prometheus, Pandora. We even end up with things sharing some orbits like Epimetheus, Janis. All of these are out maintaining the gaps in the rings. Occasionally we have things embedded inside the rings, and we'll talk about that later.

Fraser: Let's talk about the first moon, Mimas.

Pamela: Mimas is one of the ones that's using its resonance to throw things around. It also just looks cool. If you've ever seen a picture of some sort of object in the solar system that just happens to look a lot like the Death Star, that was a picture of Mimas.

Mimas is fairly large. It got whacked really, really hard by something at some point in its history. When it got whacked, it ended up getting this giant impact crater that's about 130km across. For something that only has a radius of 198km, that's a pretty impressive crater.

Fraser: Yeah, to say it kind of looks like the Death Star is an understatement. It looks exactly like the Death Star. I've seen pictures of Mimas and the Death Star side by side, and the size and shape of the crater, the position, is exactly the same. It's scary.

Pamela: The difference is the crater on Mimas looks like it has an "outey" belly button.

Fraser: It's got one of those… I don't know what it's called, but where the asteroid hit it's almost like the middle splashes back up into a little mountain peak and gets frozen.

Pamela: The Death Star doesn't quite have that.

Fraser: No, it doesn't.

Pamela: But other than that… that's the main difference between it and the death star, when you look at it.

It's mostly made out of ice, like a lot of Saturn's moons.

Fraser: It's kind of surprising. Is the moon itself just entirely a block of ice?

Pamela: It's pretty close to that. It has a very small amount of rock in it. The majority of it is ice. That's part of why it's such a reflective object: ice does a really good job at reflecting things.

If it was made of pure water that was consistent density all the way through, it would have a density of roughly 1gram/cubic centimetre. Mimas' mean density is just 1.1gram/cubic centimetre, so there's a little bit of rock thrown in there, but it's mostly water ice which is just kind of cool.

It's out there not so much shepherding, but it's out there helping to drive the gaps in the rings. The Cassini division, the gap between Saturn's A and B rings is one of the biggest divisions – the one that Giovanni Cassini was able to see, the first division spotted – that lack of stuff is in a 2:1 resonance with Mimas. This means they go around Saturn (or the lack of stuff would go around Saturn) twice for every one orbit of Mimas. So anything that tries to get into that gap ends up getting yanked on by Mimas and flung into some other orbit. Nothing is basically allowed to be there because Mimas is being a Death Star as far as anything in the Enke Gap is concerned.

There's also other gaps that it's partially responsible for. The boundary between the C and B rings it's in a 3:1 resonance with. The F ring shepherd moon Pandora is in a 3:2 resonance with Mimas. Mimas just likes to shake things up with its gravity.

Fraser: All right. Let's move out. What's next?

Pamela: The next object as we go out is perhaps one of the more intriguing objects, and that's Enceladus. It has tiger stripes, it has geysers, it's out there basically creating Saturn's E ring.

Fraser: There's been a lot of news in the last couple of years on this, so let's talk about some of those major discoveries.

Pamela: The first big discovery was that this sucker has geysers. It's spraying jets of icy particulates into space. Exactly what's driving these geysers is something that's hotly debated.

There are people that say that tidal interactions with Saturn are causing the centre of Enceladus to heat up and that this heat is creating liquid water that is forcing itself out perhaps even as steam through cracks in the surface that appear as tiger stripes. That steam, as it comes out through the surface, is becoming water ice crystals. Those water ice crystals are what form the E ring.

There's other people that are able to do different forms of modelling that, again using tidal forces, end up with ice volcanoes. Their argument is this is strictly an icy process, and you don't necessarily have to have steam and liquid water to get the cryo-volcanism.

Fraser: Or you could even have like with the tidal forces, walls of ice rubbing together and particles coming out. I think, when it was first discovered it was really exciting because there was the possibility, kind of like Europa, that you could have a water ocean covered in a shell of ice. Maybe there's life down there – and if there's these volcanoes (which Europa doesn't have) you might even have liquid water right up at the surface of the moon, and maybe a clever lander or boat could go to the moon and land and see if there's any life there. As opposed to Europa where there would be a lot of drilling to get to it.

I think some further observations are starting to question if it's just going to be pools of water up near the surface.

Pamela: We're not quite sure what's causing the geysers, but we do know the geysers are causing the E ring. This, in itself, is a really good piece of knowledge to have.

One of the things we've struggled with as a community, is why Saturn's rings are still there. They seem to be persistent. They seem to be not in the process of going away. Dynamically it seems like all these interactions should be either flinging things out of the Saturnian system or instead, flinging them into Saturn. The rings are there, they're possibly persistent, and we know at least with the E ring, it's persistent because Enceladus is putting it there and renewing its content on a regular basis.

Fraser: So that's one explanation for part of the rings and how they could last as long as they do.

Pamela: It's a pretty cool one that has some really neat graphics we'll put in the show notes on our website.

Fraser: Once again, you've got to look at the pictures of these amazing geysers pouring out of the bottom of Enceladus, just to see what's going on. It's amazing.

There's more to it as well. There are these tiger stripe features. What are those?

Pamela: What we think might be happening with the tiger stripes (and we're not entirely sure – we're still working to figure this out) is tidal forces are flexing the moon and building up heat. The tiger stripes are where heat is escaping. We know that all of the geysers are associated with four of the tiger stripes. So we think this model makes sense, but the details are still extremely fuzzy.

Fraser: Well, more research required. We're going to hear lots about that. Let's move out one more, to Tethys.

Pamela: Tethys is where we start getting into the boring little, pretty much all ice chunks. It does have one kind of cool feature.

About three-fourths of Tethys' circumference has this giant trench. We think this giant trench came from this object freezing from the outside in. any of you who've ever watched a lake in the winter, when the lake initially freezes on the surface you have this beautiful, perfectly smooth ice. Once it gets just barely deep enough, it's great to ice-skate on. As you get further into winter, as the entire lake (if it's a little, tiny, shallow lake like the ones around where I grew up) freezes, you end up developing these huge cracks in the ice that are just the right size to eat an ice-skate blade. What happens here is as the lake freezes all the way down to the ground, the lower levels expand. In expanding, they crack the surface.

If a lake gets a crack big enough to eat an ice-skate, this moon was able to get a crack 40 miles wide, 65 km wide – that's three-fourths of its circumference. This is a giant fissure. It's been named Ithaca Chasma, and this is just what happens when you don't freeze things from the inside out.

Fraser: That gives us a lot of evidence that the tidal forces aren't continuing to flex that and keep it warmed up – it's actually frozen solid.

Pamela: It's nice and frozen solid. Kinda cool.

Fraser: I did an article – there was an announcement a few months back, maybe in July – that there's been some additional ring material that's been traced back to Tethys and the next one we'll talk about, Dione. Maybe it's not quite dead.

Pamela: You also don't know if that ring material is coming strictly from cryo-volcanism or if it's also from impacts. That's one of the constant questions – these things that are just water ice, if you whack them with a meteorite, they'll throw ice up into space. We're finding cryo-volcanism everywhere. We're still trying to figure out what drives it. We also know that these things, when you whack them with meteorites, throw more ice out into the rings.

Fraser: Let's move out one more, to Dione.

Pamela: Your pronunciation is as good a guess as mine.

Fraser: If someone knows a better one, let us know.

Pamela: Here we have something that's about 46% rocky stuff – 46% silicates, the type of stuff sand is made out of.

Fraser: So not a snowball.

Pamela: Mostly a snowball – 54% snowball. It's a dirty snowball.

Fraser: All right.

Pamela: It's a snowball that's been rolled around on the beach. Here we have a slightly confused moon, when we look at it.

It's a little bit dark on one side and a little bit lighter on the other side, and cratered differently on both sides. Our normal expectation is you take something, throw it into orbit, and as it is orbiting around it will occasionally collide with things. Most of these collisions occur on the leading side of the moon.

If you have something that's rotating around clockwise, it's the side of the moon that hits the 3 first, the 4 first, as it goes around the clock, that's whacking into things and getting heavy craters.

Fraser: Does that mean that objects coming from the other direction are getting scooped up by Saturn?

Pamela: Or getting scooped up by Saturn's moons. In this case you have a moon going around and it's intersecting things that are perhaps orbiting in retrograde. As it orbits, it's intersecting with things that have slightly elliptical orbits, and it's whacking into them face first – or at least, that's what we'd expect.

The thing is, when we look at this particular moon, the majority of the big impacts, the big craters, are on the back side of the moon which really confused people.

In trying to figure this out, a lot of people did a lot of modelling. It was figured out that if you hit this moon with something that causes a crater that's about 35km across, in that case you can actually spin the satellite around. It's sort of like if you're walking down the hallway and you get hit in the shoulder by someone bigger than you, they can actually reverse your direction.

If in the past, this little moon's been hit, it could've been hit mostly on the face-side and then get hit just right to turn it around so it's now orbiting with its back in front as it goes around and around and around.

Fraser: So is it tidally-locked to Saturn?

Pamela: It is tidally locked.

Fraser: So it might've gotten hit, spun around, and then got tidally locked in the opposite-seeming direction, and that was that.

Pamela: that's exactly what we're thinking happened. The majority of the impacts happened during one period of the solar system's evolution, the period of heavy bombardment. This moon has a bunch of craters that are larger than 35km, so it's possible that this thing has been spun around more than once and its final position just happened to leave it with its original leading side, the side that originally cleaned up its orbit, facing the wrong direction.

Fraser: All right. Let's move out one more, to Rhea.

Pamela: Here we're going back to more ice. This is one that's about 25% rocks and 75% ice. It's covered in these strange swaths of stuff that we're still trying to figure out, but we think is evidence of, again, cryo-volcanism, icy volcanism.

Fraser: So this could be volcanoes inside the moon spewing out bright material that's landing on the surface? Or dark material?

Pamela: It's volcanoes of ice instead of volcanoes of magma like we have here on Earth. Just like Dione, it has a darker side and a lighter side. It has streaks and as we've been getting higher resolution images of this thing from Cassini, it looks like these bright streaks might be ice cliffs.

It doesn't have a lot of visible craters on the darker part. The lack of craters makes us think that maybe this indicates that there's some resurfacing occurring. Cryo-volcanism is one way to explain that.

Fraser: All right, let's move out to the big one: Titan.

Pamela: (laughing) This is an enigmatic moon that has been confusing astronomers for centuries.

Fraser: It's big – I mean, it's really big.

Pamela: It's bigger than –

Fraser: Bigger than Mercury, yeah. It was thought to be the biggest moon in the solar system.

Pamela: Then we realised we were measuring from the centre to the edge of its atmosphere instead of from its centre to its surface.

Fraser: I'm sure people said, "atmosphere?!"

Pamela: Right, how do you get an atmosphere on a moon? Mars doesn't even hold on to its atmosphere.

But this particular moon happens to have one of the thickest atmospheres in the solar system. I came across this great random detail. It's gravity is so low, and its atmosphere is so thick that a human being who glued wings to their arms, could flap their fake wings and actually be able to fly.

Fraser: That's awesome!! I heard you could do that on the Moon too. If you put Earth's atmosphere there, like eventually if there's a moon colony, that you could do the same thing. Flap your wings and fly.

Pamela: But there you have to put the atmosphere there. That's nowhere near as fun as you could just go to Titan and do it. It's easier to get to the Moon, but still!

Fraser: That sounds like some future extreme sport.

Pamela: This atmosphere is the only other nitrogen-rich atmosphere in the solar system. It's about 98% nitrogen, and the remaining part of the atmosphere is methane gas and other hydrocarbons, other molecular bits that are made of carbon and other stuff. You have ethane gas and things like that also in the atmosphere.

Fraser: Astronomers think this is what the Earth's atmosphere looked like early on, right?

Pamela: This is what makes Titan so interesting to us. It's so cold that it's hard to envision life originating there. It's actually right around -180 degrees Celsius (-290 degrees Fahrenheit) – it's cold. We can't imagine how (and this may be a lack of imagination) life could evolve even though all the stuff you need is there in the proper densities. We do think that it's a place to go to try and understand the chemistry of the early Earth.

There's also the idea that if Earth was whacked hard enough (and I feel like I'm doing an episode of the Sopranos because I'm talking about whacking things)… There's a theory that if, after Earth had gotten covered in microbes, it was impacted by a large asteroid, it's feasible that chunks of Earth laden with microbes, could've got sent to Titan and we could've spawned life on this little moon. So people want to check.

Most of the science community is kind of pessimistic, but we keep finding life in places we don't understand, like deep in the arctic or Antarctica. There are Russians down in the Vostok Base digging and digging and digging and in these extremely deep ice cores they're still finding microbial life. The possibility is there, but most of us are pessimistic, and I'm identifying possibilities.

Fraser: To make things even cooler, we've actually landed a probe on the surface of Titan.

Pamela: Huygens Probe went down and landed in a field of icy pebbles. The fact that these are rounded pebbles indicates there's definitely weathering going on, on the surface of this little tiny moon – this moon that's bigger than Mercury in all truth. There's weather systems there.

The atmosphere is what's called a Hadley cell. Warm air at the equator rises and the comes down at the poles such that you have, at the high altitudes at the atmosphere, this constant equator to pole motion. Down at the poles you have the air coming back down, and then at the lower levels the cold air is coming from the poles back down across the surface of the planet.

There's this great weather system, and one of the outcomes of this system is you end up with this extremely dry equatorial region, but it actually rains methane in the polar regions and possibly even ethane (in the polar regions).

Fraser: This wouldn't be rain like we have here on Earth. We're not going to have water pouring down – it's good and frozen. But it's exactly the right temperature for liquid methane to rain down. It's gone into lakes and seas and rivers.

Pamela: They've found lakes on Titan that are bigger than Lake Ontario (I believe).

Fraser: And it's just liquid methane – you could go down, scoop it up and burn it.

Pamela: Yeah.

Fraser: Of course there's no oxygen – so you couldn't burn it.

Pamela: But oh my the smell!

[laughter]

Fraser: Yeah, I guess that'd be the problem if you did your gliding around on Titan… coming back inside. This stuff is all new too, right – basically all in the last year and a half they started to realise that there are bodies of liquid on the surface of Titan, and now they've mapped them out and they're just gigantic. It's amazing.

Pamela: It's definitely an interesting place we need to send more missions to.

Fraser: Yeah. I just think it's still so astonishing that we even sent something already – that there was a probe that came through, landed on the surface of Titan and took pictures of the surface. Every now and then there's little pieces of exploration that seem way beyond everything else. Now it seems quite natural that we could get nice pictures of the surface of Mars, but it's quite amazing that we've got pictures of the surface of Titan. I want more pictures of the surface of everything.

Pamela: (laughing) Between you and I, we could pretty much triple the budget of the European Space Agency and NASA if we were allowed to do all the science we wanted to.

Fraser: Yeah, yeah. Let's hope they're listening!

[laughter]

Let's move on to the craziest moon in the system (in my opinion): Iapetus.

Pamela: Oh, yeah. This is… yeah. My notes that I have, preparing for this show, I wrote "eek, this bugger's confusing!"

There's this ridge of material around the equator of this moon that makes it look kind of like a walnut.

Fraser: And it's shape – it's not a sphere. It's like a football.

Pamela: It's not round, it's flattened.

Fraser: Yeah. It really looks like a walnut.

Pamela: It kind of looks like a walnut that was allowed to grow mould. So what we have is a moon that we're still struggling to understand, but what we think is perhaps at some point in this moon's past, it had a ring and that ring plunged onto the surface of the moon creating this walnut-like equatorial ridge.

Then there's also this black and white side. In looking at this we have to ask, "is this intrinsic to the moon? Was it formed this way? Did it run into something that splattered all over it?" we think it might be a combination that's getting exaggerated over time.

One possibility (one of the ones that's leading right now) is that for some reason one side of Iapetus was a little bit darker than the other. It was a little bit warmer because it was a little bit darker – perhaps it collided with dust and got dirtier on that side, or perhaps it was intrinsic to the moon. Because it was a little bit warmer, when ice particulates collect on that side, they get heated up and vaporized and go over to the other side of the moon and settle down, constantly renewing the fresh, pure, white, highly reflective surface on the other side and leaving behind any dust that might've been on them.

So the dark side keeps getting darker and the light side keeps getting lighter, creating this amazing mottled surface that is primarily black on one side and primarily white on the other. It really looks like some sort of organic substance is growing across the surface, if you let your imagination go wild.

Fraser: But that's not what it is.

Pamela: That's not what it is.

Fraser: Just think of those letters…

[laughter]

I mean yeah – if you look at it, it looks like somebody splashed white paint on a black ball.

Pamela: Or like someone splashed black paint on a white ball.

Fraser: You decide which way that's going to go. There's parts where it's mixing. Cassini recently did a really close flyby of Iapetus and released a whole lot of pictures including it's strange walnut shape and the seam, the equatorial ridge that runs across it and really detailed images of some of these white and black speckled regions.

I can't even describe it, you have to see some pictures. It's all white and then there are pockets of black. It's not like they're craters. It's quite irregular looking, and the whole moon… parts of it are mixed up and the rest of it is all white or all black.

Pamela: It's just cool. Go to our website, check out the show notes and look at the images of this.

Fraser: Yeah. This ridge… it looks like the most unnatural feature I think I've seen in the solar system.

It doesn't look like something that would naturally form. It looks like aliens put a ridge on the moon. Don't say in the emails that's not what happened – but that's what it looks like.

Pamela: Just to imagine a moon that had a ring while orbiting a ringed planet. That's what we think this might've been – a moon with a ring, orbiting a ringed planet. The ring of the moon crashed onto the surface.

Fraser: That's pretty weird.

Pamela: Yeah. Kinda cool.

Fraser: And once again – there are some great images of the equatorial ridge taken at perspective as Cassini was flying right over top of it and you can really see the amazing shape to it. You can actually see a lot of craters on its surface, so it's quite ancient. But it looks quite amazing. I'm out of words for that. Whenever I write articles about Iapetus, I'm kind of breathless – it's amazing! It's really bizarre! I don't know what to say.

Pamela: Let's just move on to the next moon.

Fraser: Okay. I think this is going to be the last moon we're going to talk about, and it's also insane and bizarre looking: Hyperion.

Pamela: Hyperion looks like something that you'd find on the bottom-side of a mushroom. I clearly need to eat lunch before I record, because I'm going for all sorts of organic analogies right now.

Fraser: It looks like a sponge. It has these deep craters – maybe this is a Canadian reference, but when it just starts to get cold and it's still fairly wet, dirt will form this strange crunching, icy shape when you walk along it.

Pamela: Yeah.

Fraser: So you take a step into it and your foot crushes part of it, but part of it around it has these almost cells of ice and dirt lifted up. That's kind of what it looks like to me.

Pamela: We don't understand it.

Fraser: We don't understand it. Yeah.

Pamela: It's extremely low density. It's more like a pile of rubble that's been gravitationally held together than something that just formed gravitationally. It's beat up, it's not spherical, and it has all these weird craters that look like they went into it and carved a hold rather than creating a normal-shaped crater.

Fraser: Yeah, it looks like some of the impact objects didn't create regular looking craters with the blast around it, they just punched in and dug a little hole.

Pamela: These craters are not small. It's largest crater is more than 100km in diameter, and it's about 10km deep – that's big. It still held together, but that particular crater covers one entire hemisphere of this potato-shaped moon. It's all pockmarked. No one understands it.

[laughter]

Fraser: it's hard. This is where I wish we had a video podcast.

Pamela: Right.

Fraser: Trying to explain some of these things on audio is really rough. So make sure you check out the show notes for this week's show, because it's pointless to try and think about the stuff without seeing it.

Pamela: The best way to put it is 40% of this moon is empty space. If you think of a sponge or the bottom side of a mushroom or very airy, spongy dirt, with all those pockets of air in it, that's Hyperion. 40% nothing.

Fraser: That's the end of the show.

Pamela: And that's the end of the show.

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