Astronomy Cast Episode 59:
Saturn

Fraser Cain: Let's voyage away from the largest planet in the solar system to the second largest, Saturn. Once again, we'll break up our visit into two parts – I don't even know if two parts will be enough. I'm thinking about the moons and there are so many interesting moons that do so many cool things, it could be three shows – we'll just play it by ear.

This week we'll talk about the planet itself, and next week we'll talk about its collection of fascinating moons, so here we go. All right Pamela, why don't you give us an introduction to Saturn?

Dr. Pamela Gay: Saturn is this blob that would actually float on water if there were a big enough ocean available. It's just a nice, big, chunk of gas – it's about 93% hydrogen, a little bit less than 7% helium and then it has very small amounts of other things – a little bit of ammonia, a little bit of methane, acetylene, all sorts of little, trace amounts of chemicals. It's those trace amounts of chemicals that help give it the spectacular watercolour appearance of different oranges, yellow stripes and occasionally even creeping over into the blues. It's just a very pretty little world.

Fraser: We talked about Jupiter last time as a failed star. Is Saturn an even more failed star?

Pamela: There you're starting to get into the really failed start category. It's only 95 times bigger than Earth, so yeah – it had no hope of becoming a star, but it definitely isn't a rocky world. It's definitely very much a gassy world.

Fraser: All right, and of course the most distinguishing feature of Saturn is those rings. What are those?

Pamela: They're bits of ice that became knocked off from different things. It could be in some cases comets that got disrupted, moons that got disrupted because they got too close to the surface of Saturn and got shredded by tidal forces (we talked about those in an episode a while back). Some of the material in the rings comes from water geysers in some of the moons (which we'll talk about more hopefully next week).

So you have these volcanoes that are blowing chunks of ice into orbit around Saturn. You have moons that are very low density, and when they get hit with micro-meteors – or just plain old meteors – the material that gets knocked off also helps to feed the rings.

Fraser: So what's the history of Saturn? How did we first come to understand it?

Pamela: Saturn's been known pretty much forever. It's one of the easily visible to the naked eye planets. Galileo first observed it back in 1610 through his telescope, and it confused him because it looked, to him, like one round planet and then two other small ones touching it. His telescope just didn't have the ability to fully understand what the rings were.

It wasn't actually until 1655, 45 years later, that Huygens became the first person to really look at the rings and go "Oh, that's not Saturn having two handles on it, that's Saturn being surrounded by a disk" They didn't know it was a disk of chunks of stuff at the time – they thought it was a solid disk. People kept looking at this world, making a quick succession of discoveries.

So we now know who the Huygens Probe was named after – it was the person who figured out the rings. Giovanni Cassini, in 1675, was the first person to be able to figure out with a telescope that the rings aren't actually one large ring, but rather they're a series of rings that have gaps between them and slightly different colours. That's who the Cassini Space Probe is named after. There's also one of the gaps in the rings, the Cassini Division is named after him.

Fraser: I think one of the most transformative astronomy activities you can do for the first time, is to see Saturn through a small telescope. I've gone on about it lots in the past, but seriously. If you out there are listening to this show and you've never actually looked in a small telescope and seen Saturn, this needs to be at the top of your to do list. I don't care how, find a telescope, find a friend, go to a local astronomy club – ask someone if you can see Saturn.

You really see the ball with the rings on either side, and it's quite eerie to see it through a telescope. You can just imagine what Cassini and Huygens and Galileo were seeing when they looked through their telescopes for the first time. You'll see it too. It's just amazing.

Pamela: It was a total paradigm shift from thinking this object was just a disk to realizing it's a disk with a ball in the centre – and that the ball in the centre is the planet. It just completely changed how they thought about this little world.

You're so right about seeing it through a telescope. I've had people with just a 4" telescope where they're like, "Is that a slide? Do you have a camera in there that's projecting it?" They think there's a practical joke being played on them in some cases, because that can't possibly be real.

With just a 4" telescope, you can really see the rings. You can even start to see banding on the surface of Saturn if you have a steady night where the air doesn't have the jet stream going through it or anything. It's really amazing to look at.

Fraser: Now, with advancing technology, we've got a better and better view of Saturn, so how good has the view gotten from the ground?

Pamela: So here's some examples of the things we can see. From the planet Earth, we can start to study the fancy features at the two poles of Saturn, depending on which pole is facing toward us at a given moment. We can make out individual storms and watch the evolution of things like every time it's approaching the solstice; Saturn grows a big white oval. It grows this specific type of storm roughly every 15 years. We can watch these kinds of changes.

Now, from the planet Earth, we have been able to identify at least 60 different moons of progressively smaller and darker forms, orbiting around Saturn in the midst of all the rings.

I think the most exciting thing we're doing from the planet is trying to understand the storms at Saturn's two very, very different poles.

Fraser: I'll bite. What's exciting about the poles?

Pamela: They're different, for one thing.

On Saturn's south pole, there's this amazing hurricane. Just like a hurricane on Earth, it has a well-defined eye. You can look down the eye and see to much deeper layers. Here on Earth, when we have a hurricane, it's a cloud cluster over the ocean or over land. We can see the water around the storm and then we can look through the eye of the storm in a really big storm and see the ocean beneath.

Saturn is just clouds – the whole thing's clouds. But on the south pole – and only the south pole, the north pole's different – there's this amazing hurricane that has this well-defined ring that it's actually kind of creepy to look at because they're rotated some of the images they've taken of it so it looks just like you're looking into some black and white eye. They had too much fun with the image.

Fraser: Is it the same thing with Jupiter, where these storms are digging down and dredging up material?

Pamela: The thing is, the storms on Jupiter don't have this well-defined eye wall as on Saturn. The vortex on Jupiter, the vortex on Venus – they're dredging up materials, but they don't have this eye. What's unique about the eye is it lets us look down into deeper layers of Saturn's cloud structure than we've been able to see in any other way on Saturn.

So it's like the storm is letting us take a visual core-sample of the clouds on Saturn.

Fraser: Because the storm is very stable, you can just keep coming back and looking at it time and time again.

Pamela: As we develop new imaging techniques, we're getting thermal images of the different layers. We're getting spectroscopic images to determine the content of the different layers. We can look at it and determine the wind speeds. It's one of the most fascinating things to watch the storm spiral. The winds in it are going 350 miles/hour. That's significantly faster than your average hurricane here on Earth.

Fraser: The storm on the south pole is plenty weird, but the one at the north pole is even weirder.

Pamela: Yeah, that one you look at and wonder if the image is real. In fact it is.

The north pole is a hexagon – honest-to-god straight lines on six-sides, with equal angles, hexagon.

Fraser: There are animations you can see that we'll link to in the show notes, where this hexagon is turning and staying perfectly stable. It's the strangest thing.

Pamela: Looking at it, there are rings of structure around it that you can see in different thermal images. It's like this honeycomb of cloud structure. We don't know why it's there.

There are people who've worked on it who think it's some sort of standing wave phenomena. It's sort of like if you tap a bridge just right, in theory you can get the entire bridge oscillating. In theory, if you hit any liquid, any substance that's capable of motion, you can generate waves that will, with very little energy going in, just build and build and build.

So there are people who are thinking this is some sort of standing wave phenomena on the north pole of Saturn. It's just creepy. Again, we'll show you images. And we don't know why.

Fraser: We don't know why.

Now I've got a trick question for you.

Pamela: Uh huh?

Fraser: How long does it take for Saturn to complete a day?

Pamela: Oh, that is a trick question. So exactly what part of Saturn do you want to know about? Different parts actually go around the axis of Saturn in different periods of time. This is differential rotation, and it makes giving an answer difficult. We don't know how fast the core is moving – we can tell you a cloud on the equator is moving at one speed, and the rate at a given moment that the radio emission is rotating. That's another weird thing – the days change.

Fraser: Hold on a second here – you're got some different methods, right? There are the radio emissions from the planet that turn with the planet and that gives you a way to tell what its day is. The clouds are rotating, and all this is different?

Pamela: Yeah. It averages out to about 10 hours and 30 minutes, but at the equator, you have things going at one speed, and things going at a different speed at the poles. The radio emission that we thought was a true indication of the rate at which Saturn is rotation, but it's not. It turns out that the radio emission, which is tied in part to the magnetic field, can get slowed down by interactions with particles in orbit around Saturn, specifically stuff that's being spewed out by Enceladus (we think), is able to get caught up in the magnetic field, creating a drag force on it and change the rotation rate of the radio emission.

So yeah, one of the great mysteries of the solar system is how long a day is for the rotating core of Saturn. We don't know how to answer that. It's cool to have these questions.

Fraser: That's funny. It's great when you still have questions that we just don't know. Sorry – ten days or so, that's all we've got.

Pamela: it's about 10 hours

Fraser: 10 hours, yeah. That's about as precise as we can get.

So now, beyond ground-based observations, we've actually (of course) sent a fleet of spacecraft out toward Saturn. Tell us a bit about those.

Pamela: The mission out there right now is Cassini, but it's by far not the first mission to get itself out to those planets. We've been studying Saturn for a long time. Pioneer 11 went past in 1979. We had the Voyager flybys in '80 and '81. These missions all just imaged and imaged and imaged.

It was actually during the Voyager missions that we first noticed the coolest structures in the rings, and those are the spokes that are apparent in the rings. Then Cassini got out there and there were no spokes, initially (but the spokes returned).

Cassini is out there; it just hit its 10 years from launch anniversary. So we have this amazingly successful mission that is going out and doing flybys of the moons, going through the rings, up over the planet, down under the planet, getting all sorts of different images. It's just a great mission that's returning amazing science.

Fraser: I guess that's the point of Cassini being different than the other ones. Cassini was sent to actually orbit the planet, while the Voyager and Pioneer missions all just did flybys – a quick view and away they went. So if there was a moon nearby they had a chance to see it, but otherwise we got what we could get. This time around, Cassini just orbits and orbits and its seen it from the equatorial side, looked right down the pole, it's gone past every major moon, in many cases multiple times – it's thrown down a lander onto Titan (that's the Huygens probe, and we'll talk about that next week).

Pamela: It's been the most amazing orbital mechanics that they've done, basically. They've been very carefully figuring out how to use the different moons to boost their speed. This is part of why they keep going by Titan. Titan has a lot of gravity they can use to fling it around the Kronian system (Jupiter's the Jovian system, Saturn's the Kronian system – makes no sense, but that's what it's called). They use the gravity of Titan to fling Cassini around more effectively, and they're doing amazing orbital mechanics to get repeated views of targets of interest.

The stuff we're learning, the images of Iopetus that we'll talk about next week, are just amazing. To be able to see the evolution of this planet from parts of its year to other parts of its year, to see how things come and go with the equinoxes, how they come and go with the solstices… these are things that Cassini and its long life are allowing us to study.

Fraser: Let's go back and talk about the rings for a bit, because we just brushed by them fairly quickly. Can you give us a sense of scale of these rings? How big are they?

Pamela: Saturn's rings aren't as thick as you might think. I always imagined – and maybe you didn't have this problem – that here's this giant planet out in the middle of the solar system with these amazingly solid looking rings. They must just be huge – take the Moon and smear it out into rings or something, I don't know (crazy imagination).

It turns out the rings are only about a kilometre thick, which on cosmic scales isn't that big. These rings are about one kilometre thick and they extend from about one Earth diameter above Saturn's surface, out to about 120,700 kilometres from the surface.

Fraser: So there's a gap right in the middle between the planet and the beginning of the rings, about the size of the Earth.

Pamela: Yeah, there's this Earth-radius gap in there.

Then you have these spectacular rings that stretch out and out and out. The rings are about 93% water. There's other stuff mixed in there; there's bits of carbon (these are part of what add some of the colour), and other impurities in there.

The particles themselves range in size from dust grains to blobs the size of an average bedroom. Then you get these moons in there, and the moons are part of what give the rings their structure. They gravitationally shepherd the rings to help keep them locked in and get all of these structures, all of the gaps. It's just an amazing system to try and figure out how it works, how it's interacting, and how it's a persistent system.

In time, it's quite possible that the rings are going to go away. They are getting refilled; they're getting more matter added into them as Enceladus' volcanoes go off. We think there are probably some other moons that have cryo-volcanoes as well, ice volcanoes as well. They're, in some ways, probably getting refurbished, by comets every now and then (on cosmic timescales).

At some point, we're going to run out of new material. Enceladus is going to run out of stuff to erupt into the atmosphere. The number of comets coming in isn't going to be enough to replenish what's going on. Saturn's rings are eventually going to dissipate. They'll gravitationally fall in and be no more.

We're very lucky to be around to get to see these phenomena.

Fraser: Now, what's the source of the rings? You see them right now, and as you say they're chunks of ice. What do scientists think is their original formation? I know they think Enceladus might be spewing out from some of its ice volcanoes, but there must be something that provided ice early on.

Pamela: We think it was probably a moon that got disrupted. This is a theory that's been around for a long time: it came out on the 1800s, and is part of the idea of the Roche Limit we talked about when we were doing tidal forces. So you take an icy moon and let it creep too close to Saturn. This can happen if the moon is orbiting the planet in either an unstable orbit or if it's orbiting it and gets captured too close to the surface, it will eventually get shredded. This shredding could have initially formed the rings.

The other idea is that maybe this is just material that was left over when Saturn formed. That's not a generally accepted theory, just because the rings should've been disrupted by now. They should only have lasted for a few million years, and the solar system has been around for longer than that.

So we really think it was a case of a moon getting too close and getting disrupted. Other moons are now in there shepherding the material from that destroyed object.

Fraser: So it might only have happened within the last few million years.

Pamela: It could be that when the first humans were walking on the surface of the Earth, had they had telescopes, they wouldn't have seen any rings on Saturn.

Fraser: Into the far future, we may not see them again either.

Pamela: Exactly.

Fraser: Whoa.

Pamela: So we're here. This is one of the few times we can say we do live in a special time.

Fraser: We talked about the hexagon, but I think one of the other most amazing images of Saturn are images of these shepherd moons drawing material from the rings. You can actually see the tiny little moon and a stream of material moving toward the moon, pulled by its gravity, almost like a wake. It's hard to describe. We'll link to it. But you look at it and understand right away what's going on here.

You mentioned as well about the spokes and went over that quickly. What are these spokes?

Pamela: We don't know. We know they're related to the seasons.
Fraser: What do they look like?

Pamela: Back in '80/'81, when the voyager missions went by, they saw patterns in Saturn's rings. They looked like spokes going out perpendicular to the direction of the rings, going out from the surface of the planet toward the solar system. These dark lines.

We couldn't figure out what they heck they were. When Cassini got back out there, they weren't there. So the prediction was made that maybe this is a seasonal phenomena, and it will occur around the equinoxes.

Fraser: But what is it?

Pamela: We don't know.

We're still learning. It takes time to figure out all these cool, different things that are going on. It's some sort of seasonal affect in the rings that causes, around the equinox, these dark lines to appear. They appear to be some sort of dust particles getting suspended in the ring, maybe through electrostatic repulsion or some sort of magnetic effect – we're not entirely sure. They're absolutely amazing.

We have theories, and we're going to watch. We can actually see the spokes with the Hubble Space Telescope, and if we have future optical telescopes we should be able to follow up and see how these things come and go over time, and try and study them.

Fraser: Now, Cassini arrived a couple of years ago, and I know its mission is supposed to last until 2008. I'm sure they'll extend it like the Mars Rovers, but there's nothing else in the works for Saturn, is there?

Pamela: No. Currently there's nothing in the works for Saturn or Jupiter, really.

The United States is putting a lot of its energy into Mars. We have a presidential mandate to get people to Mars. Before we get people there, we really want to have weather satellites in place, and basically have imaged the tar out of the surface so we understand how the surface is evolving with time. We want to make sure we can get there successfully by landing robots and rovers and laboratory platforms and everything else.

There are worlds we don't understand that well, so we're sending things off to Mercury, and things off to the non-planet, Pluto. But other planets are getting scientifically set aside for the time being. There's just not enough money to go around.

We also want to invest recourses into studying extrasolar planets to see how our planets fit into the greater paradigm of all the different planets in the local galaxy. NASA doesn't have enough money to do everything at once. Currently, Jupiter, Saturn and missions to study extrasolar planets have all been set aside, but we do have European programs to study extrasolar planets – they have their Darwin mission coming up, and Kepler's another one.

Fraser: So let's hope that Cassini can go for a long, long time.

Pamela: Yeah, yeah. At least we don't have the same worries about disrupting life that we have with Europa. Hopefully they'll be willing to keep it going a bit longer since we don't have to worry about contaminating things.

Fraser: Except that (and we'll talk about this next week), they might've found water on Enceladus. I'm sure that, when it's time, they'll crash it into Saturn.

Pamela: Yeah, they might be more willing to take risks. Some day they'll be making these decisions.

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