Astronomy Cast Episode 195

Planetary Rings

Fraser: Astronomy Cast Episode 195 for Monday June 21, 2010, Planetary Rings. Welcome to Astronomy Cast, 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, and thank you so much for being a morning person! This is one of those times that we're cramming recording in between all my travel and your kids' summer breaks.

Fraser: Yeah, absolutely. I think I woke up 4 minutes ago... but I'm good to go! Ok, so Saturn is best known for its rings. This huge and beautiful planetary ring system is easy to spot in even the smallest backyard telescope. So you can imagine their surprise when Galileo first noticed them. But astronomers have gone on to find rings around the other gas giant worlds in the solar system. The differences are surprising. Alright, so let's start and tell the story of Saturn's rings because I think it's quite funny.

Pamela: Well, poor Galileo... he has a telescope... he's using it to look up rather than looking for enemy vessels coming over the horizon, which was it's original marketed purpose. When he looks at Saturn... because his telescope just isn't that good... it kind of looks like a very symmetric teapot—a big circle in the center with two handles off to the side. One of his original interpretations was that he thought it was three planets that were somewhat bound together in the ecliptic.

Fraser: Like a planet with ears.

Pamela: Yeah... exactly.

Fraser: And that was just because his telescope just wasn't good enough to really figure it... and I guess he... when you or I look through a small... even through the Galileoscope, right... we see the same thing, but we know what we're seeing. So, we're like... oh, look, you can see the rings! But if you have no idea what you're looking at, you can imagine... your brain is trying to wrap your head around this funny shape. It's not a ball, it's this ball with ears.

Pamela: And making it even worse, one of the things that we saw just last year, actually, is that as Saturn orbits, the angle at which we see its rings changes. Sometimes they seem to form a hula-hoop all the way around Saturn, allowing you to see the gap between Saturn and its rings all the way around the planet. And other times... well, it's not actually quite that dramatic... other times we view Saturn's rings completely edge-on. It was right after he discovered these rings that it went into this edge-on phase, and he was actually a bit concerned that Saturn had eaten its children, much like the mythical god it's named after.

Fraser: Right... I guess it's already weird enough that you're saying the planet has ears... but now you can't prove it to anybody.

Pamela: Right. Then, of course, the suckers came back. This had to be a rather confusing bit of notation in the margin for poor Galileo's logbook.

Fraser: Right, and then with bigger and better telescopes, it had a better view of the rings. So, what are the rings? We'll start with Saturn, but all the gas giants have rings.
Pamela: Yeah, that's one of the really cool things. We now have these four worlds with four very, very different ring systems. Saturn's are, quite literally, the shiniest. These are rings made primarily of ice particles... water ice that collides on a regular basis, constantly refreshing the surface, making them reflect a lot of the sunlight and making them highly visible, even in the smallest telescopes here on the planet Earth.
Fraser: Where did they come from?
Pamela: You know, that's one of those really weird mysteries. It was originally thought that well maybe these are transitory objects... only around for a few million years... that a moon got a little bit too close to Saturn, or perhaps two different moons in Saturnian orbit decided to collide with one another and shatter. The problem with these two different models is that as near as we can tell, Saturn's rings are stable. There is some evidence that they've been there for four billion years. So now we have to figure out how is it that they're getting replenished all the time because while they seem stable, we also know that they're constantly losing some particles. Particles collide and then in the collision one of them ends up running away with an escape velocity. Things get knocked about and instead of getting an escape velocity, they get too small of a velocity and fall into Saturn and get gravitationally consumed. So, as much as Saturn's rings appear to be ancient, they also need some source to constantly get new material. We think we have some answers for that possibility, as well.
Fraser: Well, ok... but how can we know... you say they appear to be ancient. How would a scientist know that?
Pamela: At a certain degree, you start running models. You start figuring out...
Fraser: So it's a calculation...
Pamela: It's a calculation. We don't have the ability to go out and say aha! this definitely formed at this particular day. So I've basically been going through different planetary model theory stuff, and there's lots of theories that show that these probably did form about four billion years ago. Now of course when they say that, the reason that they say 4 billion instead of 5.4 or 4.6, which are ages usually given to planetary formation, is the counter-formation model for Saturn's rings isn't that it's moons that collided or got destroyed by the Roche limit by getting too close and getting gravitationally disrupted... the other idea is that maybe this is just primordial material from our solar system... maybe this is just stuff left over that Saturn caught up. And the best reason to say that that's NOT what happened is the fact that Jupiter doesn't have giant rings... Uranus and Neptune don't have giant rings.
Fraser: Right... so if it were something that the planet caught up with, you would almost see planetary rings that were associated with the mass of the planet.
Pamela: Right.
Fraser: But instead, Saturn's got the biggest and most-massive rings by a long shot for no good reason. Now you said that they appear to be old, but there's some kind of source that's replenishing them. What would that source be?
Pamela: Well, there's basically two different sources that we're looking at. One of those two is really cool... and that's that some of the moons appear to have water-ice geysers... Enceladus in particular appears to have what we call cryovulcanism. This is where a planet for a variety of different reasons... and we can't identify what the true cause is

yet... builds up pressure and ends up, just like Old Faithful at Yellowstone throws water into the air, these throw ice into the air or perhaps just water that freezes very quickly up into the air. So it's this material getting ejected from deep inside the moon that's getting added in to replenish the different rings throughout their histories.
Fraser: And there's no question that this is happening... there's some beautiful pictures taken by Cassini showing these ice geysers spewing out of the bottom of Enceladus. It's quite amazing. No question that this ice is coming out and being ejected into Saturn's orbit. That could definitely be a source, but is it enough?
Pamela: Well, it could be. But, we know that there actually is a second source as well, that's simply known as "if you hit a moon hard enough, it throws stuff into space." This is true of planets as well. We've found meteorites here on the surface of planet Earth from both the moon and Mars, so we know that if you hit worlds hard enough they throw rocks into space that land on other worlds. It looks like with Saturn, and this actually works with the other planets as well, when you start hitting their icy moons with other icy moons... with other asteroids and chunks of inner-planetary rock and ice... you end up throwing off particles. Those particles... those centimeter-across or sometimes meter-across chunks of ice... those can also replenish the rings over time.
Fraser: Alright, we've talked about the biggest and best rings in the solar system, but it's not the only planet with rings. So, why don't we come in one world and talk about the biggest planet in the solar system, Jupiter, which was also discovered to have rings.
Pamela: And what's really cool about looking at Jupiter is that yes... it has rings... but its rings are radically different. This is a bigger planet. This is a planet that's more on the interior of the solar system. That slight change in distance from the sun actually seems to have a dramatic change on the composition of the rings and the composition of the moons. Where Saturn's moons are all of these icy bodies, Jupiter... it tends to collect the potato-shaped asteroids... it tends to collect rock. Then, of course, there's Jupiter's moon Io which is this molten world that resembles perhaps what you might think of in a Renaissance painting of Hades... all of these dusty rocky worlds orbiting Jupiter lead to it having dusty non-ice-filled rings as well. So here we have rings that just really don't reflect light with a completely different composition.
Fraser: Now you can't really see them in your small telescope, so how were they discovered?
Pamela: Here you need to send something out to go look. They were first observed in 1979 by the Voyager I space probe. You just can't see these suckers from the surface of the planet. They can be observed with the Hubble Space Telescope, and the largest available telescopes on Earth can start to just make them out. But in general the best way to observe them is to just send something. So Galileo spent a lot of time looking at them when it was out in orbit... the Galileo mission, not the Galileo person... yeah, they're faint... they just don't want to be seen.
Fraser: And what are they made out of?
Pamela: Dust. These are dusty.... hit a potato with a rock and you get dust thrown off of the potato... in this case the potato being an asteroid-shaped moon or a rocky moon.
Fraser: So, I could use Saturn's rings to cool my drink... I wouldn't want to do that with Jupiter's rings.
Pamela: No, not so much, not so much at all.

Fraser: And then Uranus and Neptune have rings, too, so let's talk about... and they're different, too... so let's talk about the ones for Uranus.
Pamela: Right. And here we're again into the realm of having these really dark moons. With Uranus and Neptune, these rings kind of have a weird discovery history. It was claimed with both sets of rings that there were old, old measurements, for Uranus in particular, William Herschel notes detailing the supposed rings in the 18th century. But, you know, no one else made any claims of the rings. It's quite likely like the canals of Mars, documentation of the rings of Uranus were just tricks of the eye.
Fraser: Well, I think an astronomer would do that just to be safe. If I discovered a planet around another star, I would say "...and I also found the Earth-sized world with life on it..." So if someone ever comes and finally discovers it... I got it first!
Pamela: Yeah, well no one really believes this so Uranus did... and remarkably, his documentation actually isn't that different from the actual sizes of the rings. So it does cause a lot of head-scratching, and we saw the exact same thing happen with Neptune where William Lassell, who discovered the moon Triton, also claims to have seen rings orbiting Neptune. No one really believes either of these, but it's worth at least giving the guys credit for thinking they saw something. And maybe they did.
Fraser: But Uranus is even further out.... very cold world... even the coldest world in the solar system... with icy moons around it. Yet, it has kind of a dusty ring, right?
Pamela: Well, we're not so sure if it's dust or if it's just dark material. The rings of Uranus... they only reflect a few per cent of the light that's hitting them... somewhere between 2 and 6 per cent. That really low reflectivity makes them hard to see. The best way to detect them isn't actually to look at them, but to look at how they block out light behind them. This is how the real final detection took place... they occulted background stars. It could be that they're made of icy materials that under the influence of solar radiation, under the influence of incoming cosmic rays they built up some sort of organic compounds on the surface... we're not saying life, we're just saying things that are rich in carbon atoms... that's what the organic compounds mean. We see this in other places in the solar system. So it could just be that this is ice that developed ooky non-reflective carbon compounds all over its surface.
Fraser: And Neptune's rings?
Pamela: Pretty much the same story as what we see at Uranus, but, again, these are very faint and diffuse rings. Now, what's kind of weird about the rings of Neptune is that they actually have these arcs in them. We're still trying to figure out what caused them. When you look at Neptune's rings there's actually a lot of... are they rings... are they partial rings... because they kept getting detected and not detected and then detected as just partial rings. It was all very confusing until we were able to get the Voyager mission out there to take a good solid look at them. The Adams ring, in particular... and all of Neptune's rings are named after the people who were involved in discovering it... the Adams ring actually has segments in the ring that are substantially brighter. So we're still trying to figure these things out. These are wiggles of some sort that change the amplitude of the ring tens of kilometers. It's all quite confusing. But again, these are icy rings covered in organic compounds that are just... you hit ice with radiation long enough and if there's more to the ice than just pure water, you're going to get organics forming.
Fraser: And is there any idea about the source of those rings? Is it formed with the planets or...?

Pamela: In the case of all three of these bodies... Jupiter, Uranus, and Neptune... we think that the formation process is probably very similar to what is sustaining the rings of Saturn. You start whacking the moons orbiting these planets, and we know that things collide, and the material that gets thrown off ends up tracing out rings that orbit the planets. Now where the rings end up actually has a lot to do with the fact that there are moons. There are lots of gravitational interactions that can lead to gaps, that can lead to material that might otherwise spread itself out and not be seen, ending up forming these really tight little rings that are easier if not easy to see. So the moons may be the source of both the material and the gravity needed to focus the rings into their shape.
Fraser: It does seem like a pretty big coincidence that there happened to be rings around all four of those planets. So something inherent in a planet that large with that kind of gravity and a certain number of moons just gets rings going. I mean, that would be my assumption, right?
Pamela: Yeah... and even looking at our own planet Earth there's some evidence... and by "some" I mean that no one particularly strongly agrees with what I'm about to say, but there are papers published that people look at and go "huh... neat idea..." that even our own earth might have in the past had a ring that had not very good effects on our planet. You can imagine that you take a ring... you attach it to the orbital space around the earth directly over the equator. Well, our earth is tilted relative to the sun, so if there were a ring it would actually cast a shadow on the face of our planet, drastically cooling those areas of the planet. And it's thought that if this ring existed, it probably existed about 35 million years ago and might have been responsible for extremely cold winters and mass extinctions including species like horses in Europe, and that maybe this was part of one of our planet's mass extinctions. Over time, just like satellites tend to fall out of orbit periodically, the ring fell out of orbit.
Fraser: There's some really cool pictures that were done about a year ago, I think. It was like "What if Earth had Rings?" and someone had done these really cool artistic recreation of what the rings might look like from different spots on Earth. So, if you're near the equator, you see more of a line; but if you're up near the poles, then you actually see the shape of the rings. They had pictures... there were some cities and there were rings up in the sky... and it looked quite beautiful and it was like ooh! and aah! but it sounds like it would be pretty devastating to the climate.
Pamela: We do not want a ring... unless global warming gets really bad, in which case we really do want a ring!
Fraser: It would just be a mess, right? Either way...
Pamela: But people who are trying to find solutions to global warming... putting little tiny orbiting bits... basically orbiting shrapnel up there to help reflect the sun's light before it ever hits our planet. That's one of the things that's being considered. Now, it makes communications satellites a bit treacherous to put up and manned spaceflight becomes even more dangerous, but an artificial ring... we know it can cool our planet... we think, based on the models associated with the idea that there was a ring 35 million years ago. We think this could cool our planet. Let's just hope it doesn't get to that stage.
Fraser: Now have planetary rings been discovered around any extrasolar planets?
Pamela: Well, we're not quite there yet. The types of resolutions needed to be able to say oh, there's a ring there... we don't have. We're at the stage of being able to see slight variations occasionally in the thermodynamic properties of other worlds; but while we

haven't been able to find rings around individual planets, we're starting to get a sense that other solar systems, while they may vary in where they store their planets, they're not that different from our own. We've found asteroid belts, we've found the moral equivalent of Kuiper Belt, we've found all the stuff needed to get moons around large planets... that appear to be needed to get rings around large planets. So in the future this is the type of thing that maybe we'll be able to find ways to detect, but not yet. Give us time.

Fraser: Yeah, and I guess with the methods that scientists detect these planets... with the transit method... it might be really hard to know, I guess... you've got the planet passing in front of the star and dimming it slightly... but it might be an ellipse that's passing in front of the star, right, when it's a planet and its rings, but you just detect an overall drop in the amount of light coming from the star... not the shape of the object that's passing in front of the star. But I guess maybe if they get better and better they can start to determine the shape. I know there was a scientific paper that came out actually suggesting that you could detect alien structures around other worlds because you could detect the shape of things that were blocking the light from the star.

Pamela: The way this works is if you can imagine slowly passing a giant tea kettle in front of a light, as the handle passes in front of the light... the first handle... you get this slow drop-off of light... you're moving the tea kettle very, very slowly. You get this slow drop-off as the handle goes from not in front of the light to totally in front of the light. Then you get this increasing but a slightly different shape drop-off as more and more of the handle passes in front of the light. Now as you start to get the actual solid teapot in front of the light, you get an even steeper drop-off in the rate of the light. So the changes, the inflection points in the curve of how the light from the background object diminishes... the shape of that curve can start to tell you a lot about how much profile is passing in front of the light over time. These different inflection points can start to tell you... oh, giant ring system. Now the resolution needed to do that... we don't have that. But it's something to think about in the future.

Fraser: And I think one of the things I go on and on about and I will do it again... here... now... today... is to remind everybody if you have never looked through a small telescope and seen Saturn's rings, get... get thee to a telescope. It is one of those things that just connects the concepts and the theories and the stuff we're talking about in this show with reality. You cannot believe what you're seeing when you look at a small telescope, a four-inch telescope, a good pair of binoculars, and you can actually see the ball and you can see the rings, it's the real deal. You're looking and seeing it in real time with your own eyeballs... it's really there. It's one of those transcendent experiences. When I show people Saturn for the first time, they cannot believe it. So if you are listening to this show and you have never seen Saturn through a telescope, beg, borrow, steal, find your friends, find a local astronomy club... make it a night out. Go find out where the local astronomy club is in your area... give them a call... ask them if you can show up, or just show up and say can I see Saturn and see if someone can show you because it's an amazing experience.

Pamela: And right now, the rings are getting better and better. They've gone through this edge-on apparition, which is just horrible, but they're coming back. Soon you'll be able to see the gap again... the Cassini Division. This is not a completely empty place in the rings, but it's a more empty place in the rings created by Saturn's moon Mimas. It's just cool to realize that you can make out structure in something that's only tens of meters thick that's located half-way across the solar system from us. It's a really amazing phenomenon that's been making astronomers scratch their heads since 1610, so get thee out and watch 400 years of head-scratching in action.

Fraser: Yeah, absolutely. Alright, well thanks a lot, Pamela.

Pamela: It's been my pleasure, Fraser. I'll talk to you later.

Fraser: Bye.