Astronomy Cast Episode 229 for Monday, April 18, 2011:
The Cassini Mission

Fraser: 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. How are you?

Fraser: I'm doing really well. This is still the worst summer ever, although again, because we're recording in July, but it's really the April, people will wonder why it's a bad summer, but yeah, it's a terrible summer.

Pamela: We're just prognosticating the weather.

Fraser: Yeah, I predict that in July 2011 near Vancouver Island the weather will be horrible. Yeah, did you have any more reminders? We're going to be doing the live episode of Astronomy Cast at Dragon*Con Labor Day weekend.

Pamela: And we're going to be doing a special Astronomy Cast with Chloe, with your daughter.

Fraser: We are. Right.

Pamela: Yeah.

Fraser: O.K…at Dragon*Con

Pamela: Yeah, we're going to do a half-hour show with Chloe.

Fraser: "Questions from a nine-year-old…" She's got all kinds of questions, but there's going to be…lots of our friends are going to be there: Phil…um…

Pamela: Kevin Grazier

Fraser: Kevin Grazier …so we'll probably do a live show with all of them as well.

Pamela: And we're also going to do… Matt Lowry and I are going to do a physics demonstration show where we attempt to not kill each other with things like beds of nails.

Fraser: Cool! That sounds great!

Pamela: So…yeah, come out, come watch us be nerdy dorks doing pressure shows, and playing with lasers and blowing up balloons inside of balloons 'cause we can, and uh, stuff like that.

Fraser: That's cool! I'm trying to think how you do that. Is it like a black balloon inside a white balloon?

Pamela: You get one of those transparent balloons like they have at floral stores that you put teddy bears inside, and you fill with either dark purple or dark blue or one of those really dark sets of small balloons, shine a green laser through the clear balloon and shine it on the dark colored balloon, and the dark colored balloon will expand and explode -- and it's a glorious thing.

Fraser: That's really cool. I want one of those blue lasers. I hear they're terrifying. I'm already scared about my green laser, so I can't even imagine having a blue laser. Alright, let's get on with the show. So last week we talked about the Italian astronomer, Giovanni Cassini; this week we'll talk about the mission that shares his name: NASA's Cassini Spacecraft. This amazing mission is orbiting Saturn right now sending back thousands of high-resolution images of the ringed planet and its moons. Alright Pamela, let's talk about Cassini, and I'll just go like right from the beginning: Cassini is like the highlight mission of my life.

Pamela: Really?

Fraser: Yeah, I think so. I think of all the missions I've been most excited about, reporting *Universe Today* -- you know, it launched around the time that I started working on the site and got to Saturn…what 2004? And I've been…it's like followed pace of my entire career, so it's uh yeah, I'm really excited about Cassini. And it's got a really long history. It goes back to like before we were born, I think.

Pamela: [laughing] Not quite…it goes back to elementary school.

Fraser: Perfect. Yeah, what's the beginning of Cassini?

Pamela: Well, back in 1982, folks were trying to figure out: "What next? What do we do?" And this was when we were still working off the Voyager probes…were out there still sending back data. We still had the Mariner missions, and this was supposed to be part of the Mariner Mark II set of missions. It was going to be…it wasn't called Cassini back then -- it had a long complicated name involving, as you might guess, Saturn, and then there was also a sister mission, a comet rendezvous asteroid fly-by, and the idea was that these were both going to be Mariner missions, had very similar hardware, have basically…save money by doing two things that were very similar, except then there wasn't money to do two missions, and well, with only enough money to do one, the decision was made that Saturn was the much more interesting target, and Cassini became a stand-alone, highly-specialized mission that was optimized to learn as much as possible about Saturn.

Fraser: Right, and this is the first time…although missions had been sent toward Saturn before then…you'd had the Pioneer, and the Voyagers -- they were fly-by missions, and so the goal with Cassini was not to fly past the planet, but to actually go into orbit and then get…do fly-bys of all the moons and gather a lot more science really close up,.

Pamela: Right, and so there was this really nice laundry list of science missions where we were trying to better understand the dynamics of the rings. Are things like the spokes that had been seen real? We were trying to figure out what is the surface history of all the different moons. Do they share the same history? Do they have different histories due to differences of origins. Then, there's just the weird things like Iapetus being a two-colored object, and well, we didn't even really know before Cassini how long it took Saturn to rotate on its axis. So all these different things about all of the different moons and about the magnetosphere, and about, well, Saturn itself and its clouds -- all of these different things got piled on to the future of Cassini, but along with piling on the goals, they piled on the instruments, and this is a mission that had a healthy enough budget that it was able to do all the things that it wanted to do. It came in at 3.26 billion dollars, which is a hefty price tag, but it worked.

Fraser: It's a big spacecraft, and so it's really well-equipped to do this work. So when did the mission finally come together then?

Pamela: It finally launched in 1997, so you were getting *Universe Today* started, I was contemplating my first year of graduate school and was completely oblivious to the entire thing. What's interesting though is it almost died many times between its 1982 conception and its 1997 launch. Congress kept trying to kill it off in the 90s and what saved it is this mission, while a sweetheart of the U. S. space program, and while largely funded by the U. S. space program, was actually one of the missions that helped really heal our relationships with the European Space Agency and its different member nations. In the late 80s/early 90s, we worked to make this a really solid collaboration, where the Huygens probe, for instance, came from the Europeans, and many of the instruments came from the Europeans, and every time Congress tried to kill off this little mission, this really huge, giant mission actually, NASA was able to step forward and say, "you probably don't want to do that. We like the Europeans and we want them to like us back."

Fraser: It's interesting as we're going through this, as we're recording this -- it's the same story, you know, about the James Webb, and now the space shuttle is closed, but that's been the ongoing stories: missions almost killed. So when a mission actually makes it off the planet and you can't take it back, you know, then that's, you know, that's when you've finally arrived. So yeah, launched in '97, but it had to take a pretty circuitous route to Saturn, right?

Pamela: Circuitous – I'll go with that. Right, so it didn't have the most powerful engines any satellite has ever had, and so it got gravitational assists from Venus more than once, it whipped past the Earth, got some good images of Earth as it went by, and finally

headed out toward Saturn via Jupiter, and got some pictures of Jupiter as it went by that, so we have a spacecraft that basically took a full tour of the Solar System on its way out.

Fraser: And there was a big controversy if you remember when it was about to launch, there was this big controversy because it had that big plutonium reactor on board, and so it was actually, you know, kind of filled with poisonous plutonium, and people were worried that, you know, when it would launch if there was a problem -- a launch disaster -- it would spread plutonium around the Earth. And as well for the subsequent fly-bys when it had to go past the Earth, there was another, you know…people were kind of freaked out.

Pamela: Right. So this mission has…you can't use solar panels when you're out at Saturn, there's just not quite enough sunlight out there, so it has roughly 70 pounds or 32.7 kg of plutonium 238, which is a nicely radioactive, producing-heat-as-it-decays element, and it's from that heat that they're able to generate electricity, and the concern was that it could either blow up on launch and release all of that radioactive material into the atmosphere, or…on its one lone fly-by they ran models, and in a worst case scenario, if the mission came through at just the right perfect, absolutely-miraculous-shouldn't-actually-have-much-probability-of-happening-if-it-came-up-at-just-the-right-angle, it could completely burn up in the atmosphere and distribute all of the plutonium through the atmosphere and cause an additional 5000 cases of cancer per population of the planet Earth.

Fraser: But it didn't happen, so…

Pamela: It didn't happen, and they took the risk because the probability said it wouldn't happen.

Fraser: Yeah, but you can imagine that being the ongoing controversy for any of these flights that are going to be going out, you know, beyond the warm embrace of the Sun. You're going to have…you're going to need something like plutonium.

Pamela: We might actually be avoiding that problem due to current Senate cuts. We actually aren't currently producing plutonium 238, and we're running out of these engines. I believe there's less than five left, and they're all allocated to projects already, and so if we want to continue building into the future, we need to turn back on the plutonium 238 production, and that was part of the upcoming budget, but it's one of the items, along with the James Webb space telescope, that's currently axed.

Fraser: So Cassini makes this…you know, fly-bys of Earth and Venus, and then made this wonderful fly-by of Jupiter and sent back amazing images…and what was great was the Galileo spacecraft was at Jupiter at the time, and so the two sent back these amazing images in concert together, and they actually were able to sort of combine science from these two spacecraft. It was quite a time.

Pamela: Well, it's one of those rare instances where you can get the up-close view of the spacecraft that's in orbit, and get the big picture view that allows you to see all the context from the further away spacecraft, and so if you've ever done the going back and forth between binoculars and eyepiece, or binoculars and your eyes…well, they were able to do that going back and forth between two satellites.

Fraser: Yeah, and so if you do a search for Jupiter, like Google images and stuff like that, a lot of the full pictures you'll see of Jupiter were actually taken by Cassini, even though Galileo spent so much time at Jupiter. Galileo was up a lot closer, so it didn't just get as much nice views from afar, and so they still really rely on those images from Cassini, when they're showing images of Jupiter. So Cassini then made it all the way out to Saturn in…what was it? 2004?

Pamela: It made it out in 2004, and on its way in as it started what was one of the scarier orbital insertions ever because you're kind of dodging moons, dodging rings, trying to get yourself into all of it…they had to first rotate the spacecraft so that its large dish would basically protect all of its instruments from the dust and debris of flying through the rings, not through the rings, through a gap, but then they had to turn the spacecraft around so that it could fire its engines in the direction of its motion to radically slow it down for orbital insertion. So this was all sorts of crazy maneuvering, and the spacecraft just took it all in stride, and it was able in June 2004 to send us pictures of the little battered moon, Phoebe, and in July zip through and put itself into orbit because NASA likes to do everything on national holidays, and Fourth of July seemed like a perfectly good time to celebrate another orbital achievement.

Fraser: It's not Canada Day…I don't see what's happening then. Anyway, and the images coming back from Phoebe were just amazing. As soon as you saw those images, you knew we were dealing with something…you know, this was a whole new way of seeing photographs from space, I mean, they were so good…and then?

Pamela: And then, well, the entire time this very large spacecraft was carrying a parasite with it. So the Huygens mission was latched on and sucking power from its plutonium drive and was carried all the way up until December, and on December 25, the European Space Agency separated off their Huygens probe from Cassini, and it began its long journey to Titan, and it was on January 14 that we were finally able to see the surface of another world that had active geology from atmospheres, from weathering, from rivers, from deltas…and so that symbiotic relationship with the European Space Agency allowed us to basically get two major scientific missions for the price of one.

Fraser: Yeah, and there are some amazing videos now -- after the fact. I remember when it was first coming out, the images were pretty rough, and it was really hard to really get a sense of what you were seeing until you actually saw the images on the ground, but since then people have gone and done a lot with the images and sort of built these really neat animations you can see the [missing audio] from space, watching the [missing audio] or from a really high altitude watching what Huygens was seeing as it was descending through Titan's atmosphere all the way pretty much down to the surface of the moon, you

can see just these great, you know, the sort of spinning vistas of the surface of the moon until it actually plunked down into the -- what was it…mud on the surface of Titan. It blows your mind. You're seeing these kind of rolling hills with boulders of rock and muck with ammonia and…

Pamela: It was like Dagobah with no vegetation.

Fraser: Yeah, yeah, just astounding to think what had gone through to make that happen. So then Cassini no longer had Huygens, but it had done a really nice fly-past of Titan, still had gotten rid of its parasite you know and then kept moving, right?

Pamela: Yeah, and one of the amazing things about Huygens is they realized after launch, after the mission was good and far away from the planet Earth, that Huygens had a rather fatal flaw and they were able to figure out how to compensate for that in real – well, not in real time, they figured it out ahead of time, but they figured out how to compensate in mid-stream. As we've talked about before on this show, when an object is in motion, its light its radio, its wavelengths get Doppler-shifted, and they had tuned Cassini to listen to Huygens as it dropped through the atmosphere of Titan and the firmware forgot to take into consideration that there'd be this Doppler shift of the signal, and so when they tested things they realized, "(many expletives), it won't be able to catch the signal!" and they figured out how to change the way things were aligned, and they were able to figure out how to make it work so that they could catch all of the data and nothing was lost in the end.

Fraser: Yeah. In this…this is around a string of problems. Remember, there was the… What were the other ones? The polar…

Pamela: Mars Polar Lander?

Fraser: Polar Lander? No, yeah…there was one that just smashed into the atmosphere and disappeared, there's the Beagle II that just disappeared, and there's another that they had used the wrong imperial metric system, so there was just a string. That happened right during a string of big problems, yet there was a lot of great engineering successes as well, where people had figured out how to make other missions run on like a single gyro, things like that. Now, how come…? You know, there's a lot of those missions where like with the rovers, where they keep going and going and going, but like pretty much once Huygens was done, that was all we saw of it. Like it sent back a couple of images and then we didn't hear anymore news from Huygens.

Pamela: Battery life? So Huygens was a happy little parasite on Cassini drawing energy off of its plutonium thermocells basically up until that December 25 launch separation moment, and once it separated, it wasn't carrying its own nuclear fuel cells, so it was working on chemical batteries, and the chemical batteries had a finite life and the mission had a finite life and they weren't sure it would even survive impact, but it lasted a couple of minutes past impact, and it just wasn't designed to keep going and going and going. You have to cut weight somewhere, you have to cut costs somewhere, and in the end, not

knowing what they'd land on, they budgeted to get as much data for the parachute ride down as they possibly could, and it then ended, so…

Fraser: Yeah, yeah, I can kind of imagine if they'd used some of the newer technology, right? Can you imagine if they'd made some of the Rover technology, or had done something like that then that would have been a much better way to…you know, some of the newer technology with the Spirit of Opportunity -- that would have been amazing.

Pamela: Well, the problem they ran into was they had no way of knowing if they needed a dust buggy or a swamp vehicle, and when you're not sure if you need to float, or if you need to roll, it's hard to plan for that.

Fraser Yeah. Alright, so we got the cool landing at Titan, and if you want more detail, we've done a whole show on Titan, we've done a whole show on Saturn, we've done a whole show on Saturn's moons, so, you know, we're more talking about the mission than actually about the discoveries on the moons and the planet. So then we…and, I mean, that was like the first fly-by of Titan, but they did Iapetus, they did…so many fly-bys.

Pamela: And with Enceladus we were able to, for the first time, start to get a sense of what's rejuvenating the rings by the discovery of the geysers coming off of that water-pressurized moon. And what's amazing is just like the Mars Exploration Rovers, this is the spacecraft that also won't die. And so here it is, it's in its second mission extension at this point. They decided to extend it through the equinox that occurred in 2009, which is where we saw the rings completely edge-on and seemed to disappear into the starlight, and they're now extending it into the next solstice period, so we'll get to see the other pole of Saturn from Earth while Cassini gets to watch how does the atmosphere of Saturn change as the sunlight changes. And what's neat is one of its discoveries was this rather terrifying vortex on the pole of Saturn, and it'll be neat to see are there any changes in that eyewall as the thermodynamics of the system changes.

Fraser: They found that strange hexagon-shaped storm, right?

Pamela: Yeah.

Fraser: In fact, we added that to one of our "Mysteries of the Solar System" show, I think.

Pamela: Right. So there's this strange vortex on Venus, the strange vortex on Saturn -- I'm kind of glad we don't have a strange vortex on Earth. It's just kind of amazing and the only thing that's scary right now is while it has been extended out through the next solstice, there are concerns that right now they're doing senior review of all of the NASA missions that are on extended missions. There's limited funding and the fear is that maybe this, Maybe LRO, maybe…who knows? All of these different missions that are up for an extension are being reviewed, and they could die as part of the 2.2-3 trillion dollar budget cuts in the U.S. government.

Fraser: Uhhh…

Pamela: Yeah, so here's to hoping LRO survives, James Webb survives, Cassini survives…uh, we want our missions.

Fraser: But as we alluded to earlier in the show, this is the story, its almost like no mission ever gets out alive, you know? They all get beaten up at some point and really just the toughest ones… it's like some kind of gladiator fight to get a mission launched. So what would say are some of the big highlights, what are some of the big discoveries Cassini made as part of its mission at Saturn?

Pamela: So, I have to say my favorite is realizing what the heck happened to Iapetus to cause this two-toned moon to exist and look chewed-up the way it does. This is the moon that when you look at it, it has one face that is black, black, black, black, and the other side is this shiny, white, highly-reflective ice, and what they were able to figure out is at some point in the past -- this moon, it's rotating so slowly that it has one edge that tends to lead around the orbit, and that edge just collected dust and that dust made the surface darker, and the darker surface heated up, and the ice didn't melt, it sublimated, but any dust and gas that was trapped in that sublimating ice was then revealed and it became this feedback system where the hotter the surface got, the more it sublimated, the darker it got as more dust was revealed, and it's now thought to be several centimeters deep in this black, carbonaceous, gross substance that does not like to reflect light.

Fraser: And it's got that really weird seam. I don't know if they've really closed the book on that yet, have they?

Pamela: No. That one they're still trying to figure out. I mean, at a certain level it's part of the outer solar system that's had the tar beat out of it, but exactly what caused that we don't know.

Fraser: Right. So we got a handle on why Iapetus has that strange two-toned color – thanks, Cassini, and we found the Hexagon – thanks, Cassini.

Pamela: And we found some new moons. It's always fun to find new moons, hiding out in the rings. Titan just…we keep getting awesome new ideas on Titan. This is the moon…you know, if I was given a choice of Europa or Titan to send real exploration vehicles to, I'm not sure which one I'd choose.

Fraser: Europa -- submarines looking for life…

Pamela: Yeah, but then the back of my head is like…but Titan is so much more likely to be successful. Yeah, I agree the return on Europa is likely to be much greater, but we're learning so much about Titan, and the mission is planning to do actually one terrifyingly close fly-by that will then send it on an orbit that makes it just a few thousand kilometers above Saturn's clouds, and it's going to do two of those close fly-bys, and the second of those close fly-bys will actually send Cassini on a death orbit into the atmosphere of

Saturn. They don't want Titan or Enceladus or any of the other moons that have liquid to potentially get polluted with Earth goobers, and so rather than let our bacteria get to the surface of one of those moons, they're going to suicide the satellite.

Fraser: They get pretty reckless with these missions near the end; they did that with Galileo as well. "Now, let's get some extreme science," and then they send it closer and closer and more radiation and then finally went, "oh well, we can't kill it this way, let's just drop it in," but a big part of it is that whatever they do, they don't want to infect any part of the Saturnian system with microbes from Earth, so in the end, Cassini is going to be shut off, and it's going to be shut off, or it's going to be crashed into the planet when they still can talk to it. If it suffers some kind of big damage, or its system runs out of power and they can't control it anymore, then it's too late, so they're going to shut it down sooner than they have to because it's not working anymore. We talked about some other discoveries, right? The discovery of liquid on Titan…

Pamela: Right. Methane rain, methane lakes -- it's a completely different geology than we're used to, and it's absolutely amazing. Yeah, there's just so much stuff.

Fraser: The ice geysers on Enceladus, the tiger striping…

The rings were confirmed to have spokes, and have these weird gravitational interactions. They're not as symmetric as you might expect them to be, and so we're slowly learning more and more about the dynamics of the rings, finding twists and ropes in the rings.

Fraser: Yeah.

Pamela: And uh, what's kind of amazing is as well as doing all this science, NASA has reached out through the forms of unmanned spaceflight and said, "Hey, we'd also just like to get some beautiful Kodak moments," and they've asked the public to contribute what are those times that we should try, and I heard Carolyn Porco talking once how they've had to do these crazy maneuvers. As they're flying past a moon they're rotating the spacecraft and accelerating and imaging and doing all of this stuff at once, but the result is being able to do some absolutely amazing videos and almost everything can be found on Emily Lakdawallas' blog, the Planetary Society blog, and what's amazing about what Emily does: if she can't find the image she wants, she gets into the planetary data system and she downloads the images and she processes them. So she has some really amazing stuff.

Fraser: Yeah, you gave three quick shout-outs there, we should slow them down, right? Unmanned spaceflight is a fantastic forum for talking about various missions, um I highly recommend it as well. Carolyn Porco, she is the primary investigator, science investigator, for the Cassini mission, and has done a better job than pretty much anybody in the whole industry in getting the word out about her mission. I mean, even when I started *Universe Today*, way back in the day, if I made a mistake, Carolyn was sending me an email right away, saying, "Oh yeah, you missed this, you made a mistake there," but she was also really good about helping me get the word out about things that we were

doing for her missions, so I think anyone else who's going to be involved in this kind of a public affairs mission, look at what she's done, she's done TEDtalks, she's just been fantastic.

Pamela: And she's done a Star Trek, you can't leave that one out, that's just kind of full of whim.

Fraser: And then Emily Lakdawalla, she's the one at the Planetary Society who's the hardest working person in space media. As you said, she's fantastic. She will produce images that nobody else has, and she just does a fantastic job, so…groovy! I think we're kind of reaching the end, so when will Cassini end? Where are we at right now?

Pamela: Well, right now we're waiting for the U. S. Congress to get its act together, so barring that, it's going to keep going until 2017 and allow us to see well the next solstice.

Fraser: Right, and that's six more years from when we're recording that, and that's like for sure at that time they'll have to de-orbit it.

Pamela: Well, nothing's for sure, they have to look and see how the spacecraft is doing, how the spacecraft is behaving, but like you said, if there's the slightest hint of something going wrong, they're going to pull the plug before it has to…you just can't risk a mission that you know has bacteria on it potentially landing on Titan where, as we've talked about in earlier episodes, there is hints of not statistically certain, but hints of evidence that there's potentially bacteria there, so just no risks allowed.

Fraser: Yeah. Yeah. Alright, well, thanks a lot, Pamela. That was great. We'll talk to you next week. We're going to do the third part in the series. We're going to do the discussion of Christiaan Huygens, right?

Pamela: Yep, Huygens.

Fraser: Yeah. Awesome. Well, we'll talk to you next week.

Pamela: Sounds great! Talk to you later, Fraser.