Astronomy Cast Episode 201

Titan

Fraser: Astronomy Cast Episode 201 for Monday October 4, 2010, Titan. 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... a little bit of hay fever here. How are you surviving up there?
Fraser: It's great... it's great. We're having like a second summer. It's just roasting here... it's great... I love it. Ok, so... no chit chat today... we've just got Titan.
Pamela: Ok.
Fraser: Titan is Saturn's largest moon and the second largest moon in the solar system. It's unique as the only moon with an atmosphere. In fact, scientists think that Titan's thick atmosphere, rich in hydrocarbons, is similar to the early Earth and could give us clues about how life got started on our own planet. Titan! Alright, well let's go right back to the beginning... a little history lesson... we didn't always know about Titan. I guess humans always knew about Saturn but they didn't know about its gigantic atmosphered moon.
Pamela: No, no they didn't. In fact, Saturn was the second planet after Jupiter... I guess third if you count Earth... that had moons found orbiting it. It was in 1655 that Christien Huygens for whom the Huygens probe was named after...
Fraser: Right, because Galileo looked at Saturn... he discovered the Galilean moons around Jupiter... he discovered the "ears" of Saturn, but I guess he missed the moon.
Pamela: He did indeed miss the moon. So we had to wait a few decades until 1655 and then Christien Huygens... he started finding moons popping up around Saturn. So back then they started out with numbers. It took a long time before they started figuring out how to name these suckers. Initially Titan was fourth, and it stayed as Saturn IV for quite a number of years.
Fraser: Sometimes in research journals I've seen... it will just refer to Titan as Saturn IV.
Pamela: And what's interesting is the original numbering schema was to number them as you move out from the surface of Saturn, but as we keep looking we keep finding more and more new moons so this number is now pretty much completely irrelevant except for historical purposes.
Fraser: Right, right, of course. They're discovering moons well inside the orbit of the closest moon that they had thought of... and then well outside... then ones in between... it's all... somebody needs to shuffle those moons.
Pamela: In 1847 John Herschel, William's son who worked with Caroline, he was the one who figured out well, we're just going to start naming these things. He named the moons after the Titans. So...
Fraser: Ah ha... and one Titan. And so when we talk about...
Pamela: Mimas and Enceladus...
Fraser: Those are all the Titans of the Greek and Roman mythology.
Pamela: Yes.

Fraser: Now Titan is big... it's not... it's bigger than the Moon, it's bigger than almost every moon in the solar system... how big is it?
Pamela: Well, it is, in fact, bigger than Mercury, which is kinda cool to think about. It's not more massive, but its volume... its radius is bigger. It's 2576 km. in radius, on average. That's bigger than our moon and bigger than a planet. It ranks up there. Ganymede is still larger, but...
Fraser: But not by a lot... just a couple of hundred kilometers... And it is big enough, clearly, it has pulled itself into a sphere. So if it orbited the sun and had cleared out its part of the orbit, it would be a planet.
Pamela: That's true, and in fact one of the things that is more interesting about how they have the new definition for planet is they have the "it must orbit the sun." Part of it is... you have to start wondering... what do you call these crazy objects that are bigger than planets, have atmospheres... I end up usually just referring to them as worlds because world is kind of ambiguous... planet, moon, whatever. This is a system that isn't normally what you think of as a moon, unless you're thinking of Endor.
Fraser: Right... not really a forested moon, it's a... well, yeah, let's talk about its physical characteristics because it really is unique in the whole solar system.
Pamela: Yeah, it's this neat little hydrocarbon-rich world where, for reasons that no one can completely understand, it keeps generating methane. So via perhaps some sort of cryovolcanism gases that are stored up inside the planet are getting excreted, or some other process that we're still working to figure out is causing this atmosphere to constantly get replenished. The atmosphere has some neat thermodynamic characteristics. It's really, really thick, and the topmost layers have basically a reverse-greenhouse. They're opaque and reflective to sunlight so that the majority of the sun's heat that's trying to get to the surface of the planet can't make it through the thick atmosphere. But what sunlight does make it through this thick atmosphere then hits an actual greenhouse effect. Once it makes it through, the longer wavelengths... the infrared wavelengths that get reflected back off the surface of the planet... they bounce around just like in a normal greenhouse effect. So, you have a moon... a world... that's a whole lot colder than it could be, but if it wasn't for the lower levels of the atmosphere generating a greenhouse effect, it would be even colder than it is... which is just kind of weird to think about. But thermodynamics can do that.
Fraser: Yeah... and when you say it's thick atmosphere... you're not kidding. It's almost 1 ½ times thicker than the earth's atmosphere. So if you could stand on the surface of Titan, it would be horribly freezing cold and you couldn't breathe the atmosphere, but...
Pamela: Small problems...
Fraser: But... it wouldn't crush you like Venus would, and it wouldn't make your blood boil the way Mars does. So, you know, there's that.
Pamela: And it's kinda cool because you could actually fly with wings! The gravity on Titan...
Fraser: Oh, with the low gravity!
Pamela: Right!
Fraser: That is cool.
Pamela: So, with a thick atmosphere and...
Fraser: We've got to go to Titan!

Pamela: Yes! And what's more is this lower gravity combined with the thicker atmospheric pressure... it leads to some really neat geophysical characteristics. Here on the planet earth we have a water-based meteorological system. Water evaporates... forms clouds. We have water vapor in the atmosphere... you get too much water vapor—it rains. We have this entire water cycle. And then the water going across the surface of the soils ends up leading to rivers and deltas and weathering of our planet—fluvial processes... the fancy word for it. Well, the reason that geophysicists use the word "fluvial" instead of something that's more water-specific is there's other liquids than just water. One of the liquids that we don't think of very much here on Earth is that you can actually have methane form a liquid. On Titan, where you have less gravity, methane... even though it's lesser liquid than water in many ways... it's able to exist as a liquid at this high pressure low gravity extraordinarily low temperature where water ice doesn't even bother to sublimate. Water ice just sits there going, "I'm cold! I'm not moving." So the methane liquid is able to create this entire fluvial system where you have rivers, you have lakes, you have deltas, you have methane rain, you have methane clouds. So Titan is undergoing all the same processes we see on Earth but with a different liquid. And that's just cool.
Fraser: Yeah, and that is all brand new science. This stuff is probably within the last five years of when we're doing this show... less even. Before that we had no idea. But thanks to the Cassini mission they've been taking better and better images and they keep firing Cassini past Titan and each time they do a much better job of finding some of these features.
Pamela: We've known that there was a thick atmosphere since Gerald Kuiper—same person of the "Kuiper Belt"—did observations back in the 1940s. He used spectroscopic technique that allowed him to basically see light passing through the atmosphere. He was able to start measuring the pressure of methane in the atmosphere and measured it at 100 milllibars. So we've known for a long time that the atmosphere was there. What's new is just this whole "it rains methane" part of the problem.
Fraser: Well, let's talk about the exploration of Titan because it's actually one of the most explored places in the solar system as well.
Pamela: That's true.
Fraser: It's had a few visitors. Beyond the actual telescope observations that have been made, it really wasn't until the spacecraft started arriving...
Pamela: Right. So, we had both the Voyager probes visit it. That was really the start of detailed observations where they both flew by, took a good solid look. We had Voyager I actually changed its orbital path to get an even better look.
Fraser: Right, but with a terrible cost... we talked about that a couple of episodes ago.
Pamela: As a result of that, it wasn't able to on out and explore the outer planets as had originally been hoped. But it gave us this sense to go wow... seriously thick atmosphere here... and to start noticing all the rich hydrocarbons in the atmosphere, as well. Those weren't at all a surprise... sunlight hitting methane creates complex molecules. But we got to study them in more detail. Now scientists can't ever settle for one set of images... we always want better and better data. This is where the Cassini spacecraft comes into play. In 2004 the Cassini-Huygens mission set off to work together to get direct images of the planetary surface where Huygens dropped itself through the atmosphere, went in

for a landing, and discovered that it was someplace extraordinarily dark, extraordinarily hard to get good pictures.
Fraser: There's some amazing animations that you can find where Huygens was snapping pictures as it was descending through the clouds and after a while you can actually see the landscape sort of spinning underneath the probe as it's coming in for a landing, and the ground just gets closer and closer and closer, and then it lands. It's pretty amazing. I mean, unlike things like Mars or... the atmosphere is so thick that it was just able to use parachutes and just land.
Pamela: And you've probably had this experience living in the Vancouver area where there's days that it gets so foggy and so cloudy that you know the sun's up there somewhere, but you just can't figure out where in the sky it is. Well, that's what it was like for Huygens as it descended. This little spacecraft was trying to figure out where the sun was located and just couldn't do it as it fell through this thick atmosphere.
Fraser: Yeah... yeah. And that's why, I mean, when you do see the images they don't look great. They're definitely not the kinds of stuff that you would see with the Mars landers and imagers. And that's because it was so dark and so foggy and was really hard to see. They had to use special instruments to be able to even make out the landscape at all.
Pamela: One of the things that always gets me in astronomy is we talk about methane-rich and how it's the hydrocarbons in the atmosphere that are the bane of everyone because it prevents us from seeing the surface of the world and things like that. But when we say it's methane-rich, it's only between one and two per cent methane. Most of this atmosphere, like most of our own atmosphere, is made up of nitrogen. That's another defining characteristics is Titan, aside from the earth, is the only place in our solar system that has a nitrogen-rich atmosphere.
Fraser: Right... right. And I know that... this is probably a long-shot but.... some of the theories with Mars is that there could be life that's generating the methane. Do scientists think that's maybe the same cause with Titan? Or are they fairly certain it's volcanism?
Pamela: No... that's the thing with Titan is that Titan has even more confusion in the sense of "data that wants to tempt you with the fact that there could be life" than even Mars does. As the Cassini probe and Huygens probe have been repeatedly... well Huygens had one shot... as Cassini has been repeatedly observing this moon and as people have been carefully analyzing the Huygens data, what we're finding is that the atmosphere isn't in the chemical equilibrium that was expected. In general, when you have a certain set of chemicals and a certain temperature and a certain pressure, you expect to see chemicals in specific ratios. If you have this it reacts with this and produces that, and as you move through the atmosphere, you have differences in pressure and therefore you see differences in the chemical composition... you have differences in light and therefore differences in the chemical composition... and people who like chemistry more than I will ever like chemistry, have figured out all of these things and predict what you should see. And others... astrobiologists... have also sat down and said, " ...and if there's life, we predict you'll see this other set of things." And what's amazing is that that other set of things specifically hydrogen and acetylene... they don't appear in the expected ratios. The deficit of these two chemicals can be explained by the presence of methanogens. So there's this interesting... huh, that's not quite right... and that matches the predictions for life. But the thing is it's nothing certain. Like Carl Sagan said,

“Evidence for life requires extraordinary evidence.” This isn’t extraordinary yet. It means that there’s got to be a chemical process we don’t know, but that happens.

Fraser: But from what I understand, the interior of Titan is thought to have a layer of liquid water because the same sort of tidal forces keeping the interior... part of the interior anyway... warm and liquid. So who knows? There could be a whole layer of life and this is it escaping... outgassing through cracks in the moon’s surface. Or, there’s some kind of process, some vast repository of hydrocarbons, and it’s just somehow escaping and it’s just happening to match that profile but it’s not really life at all. More data is necessary!

Pamela: Right. And so it could be problems with our detections, it could be there’s some sort of catalyst we don’t know about that works at extremely low temperatures... which is also a very exciting result. There’s all sorts of things, and we don’t know. One of the frustrations for the planetary science community is that there are these two amazing worlds that we desperately want to understand better. There’s Europa orbiting Jupiter, there’s Titan orbiting Saturn. We don’t have enough money to go visit both. We don’t have enough nuclear fuel cells to conveniently explore everything we want to explore. Right now I think everyone’s kind of holding their breath, waiting for the planetary sciences decadal survey, which will come out in March. When that comes out, currently people are planning for a visit to Jupiter... a chance to explore Europa. But there’s also plans, they’re just not yet funded, to go to Saturn, and so hopefully we’ll find a way to go to Saturn and get to explore Titan some more as well.

Fraser: Now, in the intro, I talked about how Titan is similar or is thought to be similar to the earth’s early history. So what is that similarity... I mean Titan is really cold compared to Earth, so how are they similar?

Pamela: Well, the early sun wasn’t as warm as it is today. So, our own planet... it was not as cold as Titan, but our planet was colder. But more to the point, the comparison that gets made is the chemical compositions of the atmosphere. Early in Earth’s history, we had no oxygen molecules running around in the atmosphere. It was a carbon-rich atmosphere with methane, with carbon monoxide, carbon dioxide... we still had the nitrogens. It was this lack of oxygen and the existence of this methane that allowed our planet to be a little bit warmer because methane is a much more effective greenhouse gas. This is one of the problems we’re trying to deal with today is that methane is a more effective greenhouse gas and we’re giving it off. Well back in the past, with this methane-rich atmosphere, it also led to the production of UV-light from the sun, hit the methane, produced hydrocarbons in the atmosphere, as well, which shattered the planet somewhat. These are all similar things to Titan. The chemistry... the methane-rich atmosphere, the nitrogen-rich atmosphere, that chemistry which we know methanogens thrived in early in Earth’s history, is similar to what’s going on in Titan. Again, Titan is much colder than Earth was, but it’s still interesting to think about what can happen from the chemistry perspective. Many people hear about the Urey-Miller experiments to try to create life in a beaker... or at least to create amino acids in a beaker. They mixed chemicals up, zotted it with electricity, and looked to see what had happened. And for a long time, and in fact this is what you and I both probably learned in our school books, it was thought that life was created in volcanic pits and other high temperature environments. But, there’s evidence to say that... in fact from Stanley Miller of the Miller-Urey experiment... you can also get life forming in ice, perhaps.

Fraser: Right, so there could be like a whole cold-based process for life to get going. It doesn't need these volcanic vents and electricity at all.
Pamela: No, it's just a lot slower. So back in 1972, Stanley Miller... he mixed ammonia and cyanide and then froze it and kept it frozen for decades. When he finally opened it up, 25 years after he put it all together, he found that at dry-ice temperatures it was able to form complex organic molecules. So we now know for certain that if you mix the right stuff and freeze it, you're still going to get chemical processes.
Fraser: Wow. Yeah... you know, before we were even going to have this show today, I had sort of not written Titan off, but I had sort of really thought about it as amazing for the liquid processes that are happening on the surface. But if I were going to choose, I would go Europa, Europa, Europa. But I gotta say I am actually a lot more intrigued about the possibilities for going to Titan. What kind of a mission is theorized that might go back and explore Titan?
Pamela: The most common mission ideas I've heard... and every nation has their own slightly different variation... is to go and drop balloons in the atmosphere that then orbit around and around this moon taking data for perhaps six months at a time...
Fraser: Like hot air balloons... or hot gas balloons...
Pamela: Yeah... so basically putting some sort of hydrogen balloon, perhaps... I haven't looked into that level of detail... but nonetheless, putting balloons in the atmosphere that float around and are able to take long-term samples and make long-term measurements.
Fraser: Right, because you could go up and down... you could change your gas levels and go up and down in the thick atmosphere and just ride it out for years at a time, or months at a time.
Pamela: Right now they're looking at months at a time. Going up and down requires you to carry stuff with you that takes up space that... well, you'd rather take more probes. One of the interesting things that I saw over and over at a meeting I was at in Rome last week was different explorers... different planetary scientists... are looking to build probes that are essentially lawn darts that you drop through the atmosphere and then they embed themselves in the surface of a planet and take data. So I saw this planned for Mars, for Venus, and I bet if there's a Saturn mission put on the books, we'd be seeing lawn dart type instruments getting dumped through the atmosphere of Titan to take data on its surface.
Fraser: What about a boat or a submarine? Can you imagine the engineering involved to make a submarine that could go down through the methane... liquid methane?
Pamela: Well the problem that you run into with the submarine-type idea is... well, balloon to get to the surface, but the liquid water if it's there is really, really deep. So that's more like trying to dig to China here on the planet Earth.
Fraser: No, no... just going to the pools of liquid methane and seeing if there's anything at the bottom. Just explore them.
Pamela: That becomes more challenging because it's not all liquid on the surface, so you have to find it and aim properly, and that starts to become difficult when you're dealing with tens and tens of minutes lag in your communications.
Fraser: Not in my imagination!
Pamela: That's true...
Fraser: That's easy!

Pamela: Your imagination would be more successful building something for Europa, though.
Fraser: Perfect. Yes. Absolutely. Yeah, I guess I'm still going to go for Europa. That is all very cool. So the decadal survey for the planetary scientists is in March?
Pamela: That was just announced. It's going to get announced to the world in March 2011 at the Lunar and Planetary Sciences conference down in the Woodlands, which is part of Houston in Texas. I'm going to try to be there and report all that happens.
Fraser: That sounds great. And then we'll find out if they're going to send a probe to Titan... or not.
Pamela: Or not. We'll see.
Fraser: Cool. Alright, well, thanks a lot, Pamela. That was great.
Pamela: Sounds good, Fraser. I'll talk to you later, and I'll be seeing you at the US Science and Engineering Festival later this month.
Fraser: We'll have a big announcement about that next week, I think.
Pamela: Sounds great.
Fraser: Ok, good-bye.
Pamela: Bye-bye.