Astronomy Cast Episode 174

Mysteries of the Solar System, Part 1

Fraser: Astronomy Cast Episode 174 for Monday January 25, 2010, Mysteries of the Solar System, Part 1. 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're you doing?
Pamela: I'm doing well Fraser, how are you doing?
Fraser: I'm doing great! So this week... well, we know a lot about our solar system, and there's an awful lot that is a complete and total mystery. Today we're going to begin a series of unknown length examining some of these mysteries and explain the best theories that astronomers have so far. So I think that one of the problems that we do is that we kinda come up with an idea for a show, and we have a schedule, and I'm often rushing Pamela to kind of meet the schedule, meet the time. Well, I'm not going to be time's slave anymore... so we have no idea how many part series this is going to be. Could be a one-part series... but, you know, more likely no... it'll probably stretch on further. But, it's so cool... and you know what's kind of interesting is... now, I'm kinda going off on a tangent--sorry... my daughter is studying space and astronomy in her school, and I'm going to come in and give a presentation to her class that is essentially the podcast we're going to do today, which is a collection of crazy mysteries in the solar system and the best ideas that we have. But I get to show pictures to the class... you'll just have to use your imaginations... or follow along on the web as you go... so, let's get on with it! These are big mysteries in the solar system... in some cases astronomers have some idea of what we're talking about... in other cases--no idea. Should we start with the Pioneer anomaly?
Pamela: Let's go ahead and start with that. It's kind of the oldest of the mysteries, I think.
Fraser: Alright, let's do it. So, in case you weren't aware, there is a weird situation where the Pioneer spacecraft aren't where they're supposed to be. So what's going on?
Pamela: Well, as they're moving out towards the edge of our solar system, as they move out towards leaving our solar system we have calculations on how much they should be slowing down as they go because the sun and the solar system's gravity is pulling on them, we have calculations on... ok, we fired the rockets here this amount... We should know everything about how these suckers are moving through space. We know that there might be some factors to correct for... they fire off radio transmissions toward Earth--that might have an effect. They get heated up by the sun--that might have an effect. And when you put all these pieces together and you figure out where they should be--they're not there. It turns out that for reasons we can't really explain--and this is true for Pioneer I and Pioneer II--both the missions seem to be slowing down more than they should be, and we can't explain it.
Fraser: So, they're not as far from the sun as we would expect them to be.
Pamela: Right.
Fraser: And even when you plug in Newton's formulas for gravity and then you try Einstein's formulas for gravity and you include all that stuff--the additional push of them

using the radio transmitters... that's a pretty weak amount of push that they must be getting--they're still slowing down too quickly.
Pamela: Right. And the thing is, all of these things that we've tried to blame the Pioneer anomaly on--the fact that that they are using their antennae to blast radio signals... that should be accelerating them away from the solar system, the fact that the sun is heating them on one side and not the other... that should be pushing them away from the solar system... So, for some reason those things aren't pushing them out of the solar system, or at least there's something else keeping them in the solar system with an even stronger force. And all we can really do is go over the numbers again and start scrutinizing how we built the missions. And the crazy thing is, within error, it looks like we might have the exact same results for the Cassini and Galileo missions as well on their way out to Jupiter and Saturn.
Fraser: What about the Voyagers?
Pamela: The Voyager missions... and now we're going to hopefully have New Horizons as another case study to look at. But we're not sure how to explain how these different missions all have, with their different architectures, seemingly the same anomaly. Now the thing is so far, Cassini, New Horizons, and Galileo haven't gotten that far out and we have a completely different design for those missions than we have for the older ones. And we also, more importantly, have a different way of transmitting and storing the data. And one of the things that's being scrutinized is are changes in how we look at the data... are those differences over all the years and all the different format changes--are those the responsible party? Or does it actually have something to do with the spacecraft and its fuel cells perhaps giving off heat in one direction but not the other.
Fraser: And so it's either a measurement error...
Pamela: Yep.
Fraser: It's an unknown... sort of something going on with the spacecraft, some interaction that we're not thinking of, like...
Pamela: One side is hot due to the fuel cell, and that side is the one that's away from the sun and that heat from the fuel cell is creating a force.
Fraser: Or, it is deep and fundamental... that there is some understanding of basic physics of about how things move in space over long distances that we just don't understand.
Pamela: And that's the most painful one to deal with because when we look at the orbit's of the Kuiper Belt objects---they make sense. When we look at the orbits of Uranus and Neptune--they make sense. When we look at the orbits of even all of their moons--they make sense. So, whatever it is, if it is fundamental physics, is only working on this radial axis from the sun, and it's not affecting things orbiting the sun. And that just seems crazy.
Fraser: So, things moving away from the sun experience this thing... whatever it is. And it could be, you know...
Pamela: Just the way we built the suckers causes them to behave differently... that could be it.
Fraser: Right. And this is one of those things... it's so great because it's so simple. It could be either... oh, yeah, we have a slight modification to our math... oh, we wrote down the numbers wrong, or we don't understand gravity... you know.... It's quite a wide range of possibilities, so... anyway... so that's it--mystery! We don't know... stay tuned!

So, mystery number two--the strange axes of Uranus and Venus. So, Venus is flipped completely upside down, so...
Pamela: 177.3 degrees off of normal.
Fraser: Right, so imagine you take the earth spinning... you flip it upside down but still keep it spinning in the same direction... from your perspective looking at the planet now... it's going the wrong direction. Venus rotates backwards to all the other planets in the solar system. Uranus has just been rolled only onto its side, so, you know, sometimes it's pointing its south pole at the sun, and other times it's pointing its north pole at the sun, and... you know... is spinning on its side.
Pamela: It's tilted 97.7 degrees. So neither of them are quite dead on... but, wow they're close.
Fraser: So what is up with that?
Pamela: Well, we don't quite know.
Fraser: Right, the earth has an axial tilt of 23.5 degrees... Mars is kinda similar... Mercury is kinda similar... Jupiter, Saturn, they're all close to that.
Pamela: So, we have two different mainstream theories. The first is that in both cases... take a planet, whack a planet with another planet, and it flips over. With Uranus, that starts to get a little bit troubling because you need to get things really big to hit it, and we just don't know if there was anything that big hanging out doing the colliding back then.
Fraser: But couldn't just time do the trick for you? You hit it with something... I don't know... Mars-sized, and then you just give it 4.5 billion years to roll over?
Pamela: No, because these things tend to either keep rolling once set into motion--it's "things in motion stay in motion" that's a problem--or, once you whack it, it just stays put. That's the way it normally works out is you just whack something into a new stability. Rotating objects are very consistent in keeping their axes pointing in one direction--this is how gyroscopes work on space stations, on spacecraft. Without this characteristic of spinning objects, we wouldn't be able to move spacecraft around. Planets are just spinning tops, they're their own form of gyroscopes so they're spin-stabilized is one way to think of it.
Fraser: Right, and here on Earth we have the precession, right... where we have a bit of a wobble, but that wobble stays within that very specific range, and so you still have the wobbling of the top but it's not like it wobbles over to one point and then just stays there... it's always kind of moving back and forth and back and forth.
Pamela: And so here... it could be that we played "Whack-a-World" but the other option is.... well, maybe this is just tidal effects, maybe this is resonances. One of the things about the formation of the solar system that people are playing with is it's hard to explain how to explain how Uranus and Neptune could have formed where they are located today. But, what is easier to imagine, is that all of the gassy planets, all of the two ice giants and the two giant gases--Jupiter and Saturn, Uranus and Neptune--what if they all formed closer to the sun but Saturn and Jupiter hit a resonance where their resonance caused all sorts of crazy things to happen. There are several different ways of modeling this that start out with all four planets basically tumbling in a gas-giant ball and then moving apart and you basically end up flinging Uranus and Neptune out to the outer solar system. Other cases they start out as four distinct orbits but Saturn ends up on a more and more elliptical orbit over time due to a resonance with Jupiter until it finally settles into

an almost circular much larger orbit and in the process also flings Uranus and Neptune out to the outer solar system.
Fraser: So it's almost like you need one process to start the movement and then a second process to stop it. You need the start, and then you need the brakes... to kick on the brakes again to make it stop.
Pamela: And this is where ending the resonance is essentially putting the brakes on.
Fraser: Right, right. Because, I mean, we have examples of asteroids that are tumbling in two directions... they're rotating and they're also tumbling because... and they'll never stop because nothing's ever stopping them from doing the tumbling part.
Pamela: Right. And with Venus it's thought that maybe some sort of a chaotic process where it was getting gravitationally beat up by the planet Earth in some ways was what got it into its situation. If you look at how long its day is... it's a resonance with how often Venus and Earth and the Sun all line up into a nice straight line. So it's possible that this is just the pull of gravity over time gradually tilting and tilting and flipping through all the different resonances in the solar system. Venus just happened to be the one that was susceptible to being put on its head.
Fraser: So why are Uranus and Venus... they're axial tilts off the plane of the ecliptic? It's a mystery. Alright, mystery number three... what is underneath the ice on Europa?
Pamela: Hopefully water.
Fraser: Hopefully water... right, so once again, we've got the situation where Jupiter has its four Jovian moons: Io, Europa, Ganymede, Callisto, and the tidal flexing from the gravity of Jupiter is kinda squishing these moons and then... keeping them softer than they ought to be. With Io, it's full-blown volcanism with huge... magma and lava coming out, with Europa it's not quite as devastating, but you can see... astronomers are pretty certain that there's a shell of ice and underneath that is a great big liquid water ocean... maybe?
Pamela: Maybe. And this is what we're hoping. What we do know is that when you look at images of Europa, it's one of the most beautiful moons in the solar system, I think, it in many ways looks like some sort of a blown-glass ball covered in cracks in the glaze. It highlights in blues and in oranges in many of the different Galileo images. This strange little icy world is actually the reason that we plunged Galileo into the Jovian atmosphere. This moon, through cracks in its surface, is constantly resurfacing. What this means is craters that form on Europa don't get to stay there. They instead get filled in. Basically, a geophysical Zamboni is constantly clearing the ice of Europa.
Fraser: I was going to use the Zamboni reference! That's exactly what it is, right? Every now and then the ice gets all smoothed over again.
Pamela: Right, and the easiest way to explain this is the Zamboni method.... you just spray the sucker with liquid and the liquid refreezes and you're back to a nice smooth surface.
Fraser: And where's the spray coming from?
Pamela: And that's the question... we don't see it directly, but more likely we simply have this slow coming-up, this slow puddling... more like what you see if you go to Yellowstone and visit the bubbling mud pots than if you go and visit the geyser of Old Faithful. So somehow liquid is coming up to the surface, and if liquid is coming up to the surface, that means there is liquid below the surface.
Fraser: Right.

Pamela: And the models... some of them say the ice is a kilometer deep, some of them say it's tens of kilometers deep... but no matter how deep it is, there's probably an active rocky core underneath that's doing the heating.
Fraser: Io... what's happening to Io is happening to the core of Europa... it's being flexed and heated, and putting out heat, but it's not turning into great big plumes of lava... it's just keeping this ocean warm.
Pamela: And the amazing thing to think about--and there are a few papers related to this--is it could be that you have mid-European ocean volcanoes and basically lava plumes just like you find in the deep trenches here on the planet Earth. And it's those deep ocean plumes that are so rich with life that never sees any sunlight, so we know that this form of volcanism under water is capable of supporting life. This makes people wonder, very honestly, could there be life supported under the ice on Europa?
Fraser: Yeah, people don't realize you could destroy the sun and there would still be life on Earth.
Pamela: Until it cooled off...
Fraser: Until it cooled off, but for billions of years you would have the geothermal heat heating the oceans, keeping life going... no problem. So, who knows what's under there... Now, is there going to be any way that we're going to know? I know there were ideas to send a probe that could melt down through the ice and try to make its way down to the ocean.
Pamela: Like so many problems, this is one that comes strictly down to money. There are robots being designed and tested right now that, if you drop them into an underground lake, are capable of going down and on their own exploring and mapping what exists down beneath the surface of the planet Earth. Then they come back and they radio their results. So what we need is to develop a robot that takes this one step further and digs a hole for itself through the ice and drops itself into what is hopefully not too far down... liquid water, and then digs itself back up to the surface and beams its results back.
Fraser: Or, leaves a tether behind, right... some kind of communication tether... it leaves that up on the surface, melts its way or bores its way down through the ice, gets down to the ocean, leaves that as a way to communicate and then travels down into the ocean to see what's below. It's a monumental engineering challenge to make that work.
Pamela: And beyond just the budget difficulties, anything that's swimming around underneath the ocean of Europa... or underneath the ice of Europa, rather... won't be able to use solar panels. To continue exploring the outer solar system, and to explore places where literally the sun doesn't shine, we need to use radioactive fuel cells, we need to use radioisotopes. Right now, here in the United States, we have a shortage of these. We're simply not developing the fuels that are needed to power spacecraft. A lot of international treaties govern what nuclear isotopes you develop and you process and you refine and all those other different things. And under treaty, it's unclear if we can create fuel cells we need for our space program.
Fraser: So, who knows... this is one of those situations where I'll bet you someone's going to come up with a clever way to analyze the ice on the surface and detect evidence of life's outputs... right? Micropoop in the ice on Europa... so we'll stay tuned on that one...
Ok, so next... mystery number four... what is creating the methane on Mars?
Pamela: Yeah, we don't know that one either...

Fraser: No, I know... but this is huge!
Pamela: This is one of those amazing discoveries!
Fraser: Yeah, so once again, to set the scene... the European Space Agency's Mars Express spacecraft discovered the faintest whiff of methane in the atmosphere of Mars. This is really shocking and surprising because methane is destroyed by sunlight in a very short period of time so there has to be some source replenishing the methane. What's creating it?
Pamela: And during the northern summer, they were actually finding as much as 30 parts per billion of methane in the Martian atmosphere, and methane is something that gets actively destroyed by the sun. Sunlight... ultraviolet light hits methane... methane stops being methane, it's happy to do that. So this is something that's being actively produced, and we only know of two sources of methane.
Fraser: Source number one?
Pamela: ...is lava, geophysical activity, something indicative of the planet being alive geophysically.
Fraser: And that would be very exciting to discover... we could see Olympus Mons erupt again...
Pamela: I'm not quite sure we could go that far... but it does mean that there is some sort of process going on that--well, it's always cool when rocks are alive--but the other process is... well, life produces methane. Meet a cow--you've met a methane-producer. Small biological entities, bacteria, single-celled organisms in all their different forms, there's many different ways to produce methane and so if Mars is as geophysically dead as we've been teaching for, well, as long as I've been alive, that means that there's methanogens or some other form of methane-producing life in Mars.
Fraser: And, I mean, if they can find that, the ramifications of that are gigantic. That means that there's life on Earth and there's life on Mars. And if there's life on two planets, then life could be all over the place in the universe. And you would, in theory, eventually be able to find the source and be able to study it and see if the two are connected. Did life begin on Earth and separately on Mars, or are they somehow interconnected? Do they share a common ancestor? The ramifications of this are mind-boggling. Now there are plans to get to the bottom of this mystery.
Pamela: Yes, and everything from the upcoming Mars Science Laboratory to most of the plans for the future for Mars all include going and digging in the surface and looking for signs of life. One of the most exciting ideas that I haven't seen any missions attached to yet, is going and... there's several different places that we've seen along the volcanoes on Mars skylights into deep dark caves that are likely completely protected from radiation. If we can go and explore in those caves... those caves may represent our best bet for places capable of supporting human colonies and supporting life that exists in the dark.
Fraser: And there's also been some orbital missions proposed that will map out the methane concentrations with more accuracy and try and even find out exactly where it's coming from.
Pamela: And everyone just wants to go dig... because who doesn't like digging in the dirt?
Fraser: Oh, for sure... but I mean this discovery... this could change everything.
Pamela: Yes.

Fraser: So if there's one mystery that we've really got to get to the bottom of... it is this one. But, let's move on... so, mystery number five--where did Titan's atmosphere come from? Titan is Saturn's largest moon... second largest moon in the solar system... and it has an atmosphere that is thick... like as thick as Earth's... and rich in hydrocarbons which scientists think is a very similar environment that we had here on Earth early on. How on Earth... ha, ha! How on Titan could you get an atmosphere like that so far out in the solar system orbiting Saturn? It should just be a block of ice, right? A ball of ice...
Pamela: Right, right... and this is where Titan gets to be a really interesting planet to look at.. it's not even a planet, it's a moon... it gets to be a really interesting object to look at from a geophysics perspective because it doesn't just have a thick atmosphere, but it has a "insert the expletive of your choice" thick atmosphere. This is atmosphere that is 1.5 atmospheric pressure--or atmospheric bars, rather. That's thicker than the atmosphere on the planet Earth.
Fraser: You could take off your spacesuit and not freeze-dry... you would merely freeze!
Pamela: And the thing about having an atmosphere this thick is... I love this... it's a low-gravity world. It's a tiny, tiny moon--compared to the size of the planet Earth--and so with this low gravity, if you attached a pair of Icarus' wings to your arms, you could actually fly around in this really thick atmosphere. Now, the majority of the atmosphere is nitrogen--it's 98.4% nitrogen. But, along with that nitrogen, there's another 1.6% composed of methane and other organics, and like I just said about Mars, methane is destroyed by the sun. So, somehow there's something about Titan that's causing it to constantly generate methane that's getting replenished in its atmosphere. People have looked to see... well, maybe it just captured the methane and it still hasn't had enough time to all be destroyed from the solar nebula. No, that model doesn't work. Well, maybe it just comes from getting clobbered by comets. No, that doesn't work either... the composition ratios are all wrong. Somehow, something inside Titan is generating this, and one of the really awesome things about the combination of Titan being really cold, really tiny, and having this carbon-atom rich environment, is it can have geophysical processes that carve rivers, that carve canals, that in many ways look just like the processes that we have with water here on Earth. So, for Titan, the methane in the atmosphere is like the water in the Earth's atmosphere. It can rain, it can form rivers on the surface, it can freeze, and so you can have an entire environmental cycle built out of methane... but we don't know where it's coming from.
Fraser: Right. So, methane is too short-lived to have been left over from the solar nebula, so some thing is either protecting or replenishing it on Titan.
Pamela: Exactly.
Fraser: Crazy. Alright, well I think we're actually out of time. We've gotten through five, and we've got more. So this is going to at least be a two-part series, so stay tuned for next week. Thanks Pamela!
Pamela: Sounds good Fraser.