Astronomy Cast Episode 203

Europa

Fraser: Astronomy Cast Episode 203 for Monday October 18, 2010, Europa. 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. It's fall... leaves are falling off... How are things there?
Fraser: It's good, it's good. No leaves falling yet... but we've got a big piece of news. We're going to be in Washington in just a couple of weeks.
Pamela: Yes, we're part of the US Science and Engineering Festival, and we're going to be performing at 4:00 on Saturday October 23 and come find us... say hello. We'll also be, all weekend except when we're on the main stage or otherwise getting a drink or something, in general, we're going to be at the Galaxy Zoo booth the entire time and your program will have a map of how to find Zooniverse, Galaxy Zoo, Moon Zoo, and all the citizen science goodness.
Fraser: Yeah, we're going to do an hour show on why Pluto isn't a planet. The rest of the time we'll be around to hang out and talk science.
Pamela: So come say "hi!"
Fraser: Ok, on to the show. Europa is the smallest of the Jovian satellites, but it might be one of the most exciting spots in the solar system. When NASA's Voyager spacecraft flew past the moon, they discovered huge cracks in its icy surface. Is it possible that Europa has a huge ocean of liquid water and maybe even life? This is a world that needs more investigation. Alright, Pamela, I'm going to guess who discovered this Galilean moon?
Pamela: Well, I think maybe it might be this dude called Galileo Galilei, but you know there's actually a little bit of debate on this one. So even though it's called a Galilean moon and you'd think that it's 100% obvious that full discovery credit should go to Galileo, it looks like it might also have been independently discovered by Simon Marius. So this Galilean moon may have been discovered twice and might need a little footnote pointing to Simon, but then there's also controversy saying he just plagiarized, so...
Fraser: But anybody pointing a 20-power, 30-power telescope at Jupiter would have discovered Europa, I mean, as soon as you have the tool, the discovery is right there. You could make that discovery right now today with a small telescope or even a powerful pair of binoculars.
Pamela: What's interesting is that as easy as this thing is to see, it occasionally lines up just right so that you don't see it. So yes, you can go out, you can see it with binoculars, you can see it with the cheapest dime-store telescope you can buy for more than a dime. But Galileo himself discovered it on his second night of observing because on the first night he was observing it, it was merged with a different moon.
Fraser: Oops!
Pamela: Well, yeah.
Fraser: And then where does it stand in orbits compared to the other Galilean moons?

Pamela: Europa is the second out from Jupiter of the Galilean moons. It went by the name Jupiter II for a long time because people didn't want to use the name Europa.
Fraser: Boring!
Pamela: Yeah, yeah, yeah, I know. We're astronomers... we crave the boring! So it goes Io... which is grabbing all sorts of energy out of Jupiter... then Europa, Ganymede, and Callisto's the furthest out of these four giant moons.
Fraser: And before the Voyager spacecraft, what did we know about Europa?
Pamela: That it was shiny.
Fraser: So like icy? Maybe?
Pamela: Well seriously what we knew was it's shiny, and ice is what we always assume, but this object was reflecting huge amounts of light and being as tiny as it is, you have to pretty much be made of glass, mirror, ice (ice being most likely) in order to reflect as much light as Europa's able to reflect given its size.
Fraser: And as better instruments came along, and as missions were sent there, yeah... absolutely... it's ice.
Pamela: And what's cool is even though its surface is pure ice, unlike several other... particularly of Saturn's moons that are pretty much all ice, Europa appears to probably have an iron core, to be made mostly of silicates... the type of stuff that terrestrial planets—our own Earth—are made of. It's only the outer maybe 100-ish kilometers or so that are this liquid ice and solid ice that does all the shininess.
Fraser: Right. Liquid ice... I believe we call that water.
Pamela: That's true... yes, that would be true. Ok, we're just going to leave that fubar into the show... you can all enjoy it.
Fraser: Ok.. alright. Let's talk a bit about the orbital mechanics because Europa, I know, has a relationship with the other Galilean moons.
Pamela: Right. So, there are these orbital resonances which cause the planets to go around and keep repeatedly lining up with one another. So for every one time that Ganymede goes around, Europa goes around twice, and Io goes around four times. And this beating of the moons against one another causes, first of all, their orbits never completely straighten out to being 100% circular. That's just not going to happen with this repeated lining up. The other thing that it does is it causes... the combination of Jupiter's gravity and this constant tug-of-war gravitationally with the other moons flexes each of these moons in their own horrible way. Io suffers the greatest where we have this rocky world turned molten. But Europa, with its slightly, slightly eccentric orbit goes from when it's closest to Jupiter getting squished a little bit, and then when it's furthest from Jupiter getting to relax. This squishing and relaxing and squishing and relaxing actually builds up heat inside this little icy moon. That heat is just enough to probably keep a good thick layer of water on top of the silica and metallic core of the moon.
Fraser: Right. If we had a whole pile of water on top of Io, we would have a similar situation. But I guess it's like Io is so hot that it just turned all of the water into steam, and the water is long gone. But with Europa, it's just the right temperature.
Pamela: Right. And its hard to know what the history of each of these objects was. What we do know with Europa is we have several different models for what are the different possibilities. All of them include a layer of liquid water. Now this liquid is probably at a very small layer, just to be factually correct, also heated through radioactive decay, just like within our own Earth soil we have radioactive decay helping to keep our own planet

nice and happily molten. There's also this neat theory out there that the inside... the core of Europa... the inside is 100% tidally locked to Jupiter. It always, always has the same part of the core facing Jupiter. But for the surface, that may not be true. So the surface, this icy sphere floating on top of liquid, might be rotating at a slightly faster speed so that every 12,000... every 13,000... we're not entirely sure—more than 12,000 years, we know... years, this shell rotates all the way around. And along with this there could be basically a tidal wave type physics built up in that liquid that's dissipating energy in the form of heat.
Fraser: Hmmm. And that's contributing to the melting of the ice as well. Well let's talk a bit about the discovery, before we get too far into this ocean because, I mean, that's the sweet prize. But first, let's talk about the discovery because this is not brand new, but it's definitely discovered in our lifetimes.
Pamela: Right. So we always knew there was this shiny world out there... figured it was probably ice. As we started pointing really large telescopes at it, it was realized that wow this thing somehow has a slightly existing atmosphere of oxygen. So back in the mid-90s we were detecting this atmosphere and a combination of first the Voyager missions getting images of this icy, weird, smooth world that had features that were defined by color, not by how high or low they were, and has almost no craters. The combination of all of these different features began to paint a really interesting physical picture for us.
Fraser: Right. If you look at other moons of that size or even some of the other outer Galilean moons, they have craters. So they have a rocky surface. But as you get closer into the middle, they get more and more smooth. Europa looks like it's covered in sheets of ice, and Io is just completely resurfaced by its volcanoes.
Pamela: As near as we can tell from trying to count the almost non-existent craters, there are some... from counting these craters on Europa, it appears that the surface could be as young as 20 million years old... 80 million years old... depends on what models that you use. But this is a young surface. That means that everywhere on that surface, something has come and filled in the asteroid holes, filled in the places where rocks hit it, Kuiper Belt objects hit it. That resurfacing.... that says that somehow liquid is oozing out in some form or another.
Fraser: I wonder how that thought process went when the scientists originally saw those first photos that came back. I know that Voyager I passed Jupiter first, and it sent back less-detailed photographs. Then Voyager II got closer, got better pictures, the modern pictures that we're all quite familiar with now, with what looks like these cracks in the surface... what did they think they were dealing with when they first saw this?
Pamela: Well, I have to admit I was a small child being forced to take naps when this was going on, but looking through the literature, there's this leap to "oh my... insert expletive of choice..." that isn't in the literature... but you can tell from the excitement that this idea of now we have to model ice was something that was cool and new and exciting and everyone was re-energized to look at this. Yes it was cool and shiny but otherwise just another blob of ice in the outer solar system. Trying to figure out what dynamical processes can lead to this combination of... there are places where you look at the images of the cracks and you can see where one set of cracks got shifted part-way by an intersecting crack. So imagine you have basically four cracks running parallel to one another. You bisect them with a crack, like a tic-tac-toe mark but you don't finish drawing your tic-tac-toe field. Then you shift half of the tic-tac-toe grid but not the other,

so you have this disconnect in where those four original parallel lines hit. They were seeing these crazy lines that didn't completely line up which indicated shifting in the surface. There's also these weird areas of ice that just basically look like chaos ensued. That's what they call them... chaotic terrain. Just all of this mixed up mess of linear features, chaotic features, cracks, spiral features, trying to model that... that's a mathematical nightmare to someone who hates math, but is a computer modeler's dream project in a lot of ways.

Fraser: If you could go to Europa and land down on the surface and stand on the surface of Europa, what would this look like? Are we looking at an ice rink smooth surface? Are we looking at like a glacier field? Are we looking at dirty snow with cracks in it? What would it look like?

Pamela: It's much more of a glacier field. It's not perfectly smooth like a lake. There are features that are hundreds of meters high and low, up and down, where you have fissures colliding and splitting and swirliness. What's interesting is where the cracks are, you end up with these orange-y yellow discolorations and what we think that is some sort of saline solution, magnesium sulfur... there's some sort of a chemistry that is getting revealed in these discolorations. So if you're standing on the surface, it's not pure white ice in all directions, it's not this perfect surface. It has upheavals, it has discolorations, it has all sorts of crazy patterns that do vary in scale from place to place. There are areas that are much smoother and much whiter. There are areas that are much more chaotic and bumpy, lumpy grooved. It's not what we're used to when we think of large plains of ice.

Fraser: Right, right. What is underneath this? You've got this crack on the surface... we've talked a bit about this ocean but let's kind of paint a bigger picture. What do we think is going on here?

Pamela: Well the generally accepted models say that the surface ice is probably order of tens of kilometers thick. And there are models that say that it's much thinner, that maybe it's only 1- 2 kilometers thick... maybe even thinner than that, but the reason that we tend not to believe those thin-ice models is that where we do see craters, they dig their way in but don't break all the way through. So that gives us a sense of the depth when you start modeling how much heat would be imparted in the ice and yadda, yadda, yadda... when you work through those calculations of the energy of the impact, and you don't break the ice, it starts to give you hints of how thick the ice is. When we take into consideration the thickness of the ice, it looks like underneath it we're probably looking at then maybe as much as 100 kilometer-thick water. We're not entirely sure of the composition, clearly, you have to dig down and take samples. But in all likelihood it's some form of salt water.

Fraser: Now would this be... this underwater ocean... be completely covering the rocky part of the moon and then it's just that it's got ice on top of it? Is there any place where the surface would be poking up? I guess you would see mountains, right, if it was coming through someplace...

Pamela: Well, we know that the moon isn't 100% spherical. The universe doesn't make planets, worlds, moons that way. But, all modeling that we have done indicates that it is mostly symmetric, and that you do have rocky core, silicate layer, roughly 100 kilometer thick water, and then on top of that a couple kilometers of ice... ten-ish kilometers of ice.

Fraser: So that's a lot of water. Liquid water... up at the top it's going to be cold, at the bottom it's going to be warm... that's pretty amazing.

Pamela: We don't fully know what will the temperature gradients be... We don't fully know what the currents will be. The idea that the surface ice and the core of the planet aren't completely coupled, but the difference in rotation is order of tens of thousands of years between the two tells us that whatever currents you have aren't planet-wide, sweeping around, carrying the surface with them. There are some sorts of currents underneath. We don't know what sorts of convective cells might be built up in the water. So there's all sorts of neat things that could be going on... mixing the temperatures. Yeah, it will be colder towards the surface just because you do have a layer of ice there, but we don't know how big the differences are. That's one of the intriguing things is for all we know there's some form of volcanism at the bottom of all this that's driving some sort of rift valleys like the ones we have at the bottom of our own oceans where you have underwater volcanic vents leading to amazing clusters of life. We don't know what's going to be underneath all of this.
Fraser: Well, let's talk life, then. I mean, this is one of the great discoveries here on Earth is the discovery of these volcanic vents and clustered around these vents are all kinds of exotic life that derive their energy from the center of the earth, from the chemicals and the heat that's coming out of earth. They don't rely on the sun at all. I think before, if you cover off the light of the sun, people would say oh, there's no life. But now we know oh no life is perfectly happy to live in a place that never sees the sun. This changes everything for Europa.
Pamela: What's more, not only do we have this chemical, thermal conditions that we know from here on Earth are conducive to life... you have the temperature gradient, you have liquid water, you have the type of stuff that the bacteria that form the base of the food chain here on Earth's ocean vents could similarly have found a place to evolve perhaps if there's volcanism on Europa. But the other thing is... so if you're hanging out on the surface of Europa... yeah, there's a little bit of a magnetic field, but there's still so much radiation that you die. Ice and water are great protectors of radiation. So by getting beneath this layer of ice, you're blocking significant amounts of radiation. So you're also creating a place that's conducive for life due to you're not killing it with cosmic rays, just like our own atmosphere protects us here at the surface of the earth. So there's all of these different things that are in favor of life being able to exist. There's a ton of scientists just dying to go drop something hot on the surface of the ice that will just melt its way through so that we can see what's beneath all this ice.
Fraser: I mean you could, if these conditions are that, you could take life from Earth... from these deep-sea vents... some of these bacteria... and it sounds like it would do just fine in Europa.
Pamela: Well, it depends on what the chemical composition is.
Fraser: Right. Of course, you know, and it depends on the temperatures involved and whether there is energy coming out of the core of Europa into this water, but it doesn't seem as much of a stretch as trying to make life that maybe could survive on Mars, with very low air pressure, with horrible radiation, with really cold temperatures, with no liquid water. It's like with Europa, everything's pretty close. It's really tantalizing. Is there any evidence right now that there is life?
Pamela: No, we have no evidence whatsoever, just a whole lot of scientists saying yes, Mars might have in the past had life, but Europa could have it today! Stop looking on Mars! Let's go to Europa. No evidence; just hope.

Fraser: Just hope. What would be a mission that might be able to find it? Is there any way to find evidence of life from orbit?
Pamela: Of life? Not so much.
Fraser: Like any way that organic materials with a certain signature being pushed out of the ice... leaking in vents somewhere....
Pamela: Not enough that's believable to say... unless you find a dead frozen fish staring at you through the surface of one of these cracks.... organic molecules on their own, that's just a possibility, but it could also be well, maybe it's just some sort of chemical process we don't know about yet. To get the yes, 100% we know there's life... you have to see critters moving around or be able to sample DNA or many other extremely robust tests.
Fraser: So what would be a mission that would be able to answer that question?
Pamela: There are many different very expensive proposed missions to go drop something on the surface of Europa. Admittedly, the first few missions are probably going to simply drop something on the surface of Europa. But then after that, drop something very, very sterile... sterilized more than any surgical room here on Earth... a very sterile object, drop it, melt through the surface trailing some sort of a guide wire behind you that sends up communications to a surface part of the craft. After you drop through the ice, look around and take samples. That's what we want to do... we want to drop stuff through the surface and give it all a good look.
Fraser: But to melt down through 100 kilometers of ice sounds like an insurmountable engineering challenge.
Pamela: It's actually fairly easy when you start looking at all of the insanity that we go through trying to dig for oil where you have to half-way down turn right, go down another ways and turn left. Here we can just drop straight through, and it's a matter of just melting and having enough wire. And it could be that it's only ten kilometers thick. The water itself is a hundred kilometers thick but then the ice on top of that is probably a few to a few tens of kilometers. And that we know how to do.
Fraser: But through melting or through drilling?
Pamela: I've seen plans for both. It becomes a matter of how do you build something that takes the least energy. With a good radioactive pile, you just sit there and you slowly melt your way through by just letting the radiation do what it will. Drilling, that's an energetic process where you have to be putting in energy into spinning things to get the drill, but you may be able to get something larger down by drilling.
Fraser: Oh, I see, so you would take some kind of nuclear reactor, put it on the surface, let it vent its heat and just watch it melt its way through gravity down through the ice.
Pamela: It's a slow process, but it works. Really that's all you care about... does it work...
Fraser: Now are there any missions even in the plans right now officially to be sent back to Europa?
Pamela: To go look at it?
Fraser: Anything! To visit it... to wave... anything.
Pamela: Yes, so we have the Europa-Jupiter System mission. This is primarily international US-ESA joint collaboration mission. It's proposed for launch in 2016. That's likely to slip, but it's proposed for 2016. We're all waiting to see what the planetary decadal survey says. If it does say let's do this, because we do have the launch

opportunity in 2016, maybe we'll make the deadline. That's the proposed plan right now. We'll just have to see if it gets its funding.
Fraser: And what will its objective be? I mean, this is just an orbiter, right?
Pamela: I've actually hear talk of dropping stuff onto the surface of Europa. Basically they have little spacecraft that kind of reminded me of lawn darts in the talk I was in. Where you drop something down, it stabs itself into the ice, and sits there and collects data and sends signals back up to the orbiter that's then going around Jupiter and exploring the system. So, kind of a Huygens probe for Europa.
Fraser: Right, right. And then maybe with this they can try to get a sense of the thickness of the ice... maybe if there's an ocean the depth of the ocean... what's underneath the ocean... I mean, it's kind of hard to...
Pamela: Yeah, it's mostly a seismic mission. You should be able to some sense of how thick the ice is, but beyond that they're not going to get a whole lot of information.
Fraser: No, but I can think about the ways that they have uncovered the layers of the earth here. They use earthquakes, and they're able to sense how earthquakes change and move through the interior of the planet. Maybe if they could, as you say, put some kind of a lawn dart, a seismograph onto the surface of Europa, maybe they can listen how moonquakes go through Europa and then try to map out the shape of the interior... which would be pretty exciting.
Pamela: And we do suspect that there should be some sort of seismic activity. So it's just a matter of sitting there and listening and hoping you get the right type of data.
Fraser: There sure is some over on Io, so...
Pamela: Yeah, that's for sure.
Fraser: Cool. Well, then that's it, and we've talked about on our Titan show just about how Europa is an even more exciting place to search for life, and I think talking to you today... this has made me even more excited about the prospects of life on Europa. It's just an enormous engineering challenge... way tougher than sending a probe to Titan.
Pamela: In some ways, though, it's the type of thing that Halliburton has been training us for for a long time.
Fraser: We'll put them to good use. We'll get their help. We'll find a crack team of miners and oil drillers and send them into space to find life on Europa. That would be a movie, I think. See if Bruce Willis can do it.
Pamela: Yes, yes... definitely.
Fraser: Well, thanks, Pamela.
Pamela: It's been my pleasure. Bye-bye.