Astronomy Cast Episode 274 for Monday, October 1, 2012: Asteroid Vesta

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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 doing?

Fraser: Doing great! Now, you actually sort of jumped into our virtual star party last night…

Pamela: I did.

Fraser: …and you recommended that people go out and search for auroras, there's going to be a big aurora warning. How do people do that? If they want to know when they should step outside and look up and spot the sky lit on fire, how should they do that? With green glow…

Pamela: Well, there's a variety of different Twitter feeds that you can follow and the spaceweather.com website – add it to your list of places that you go check out when you're bored. They show the latest photography coming in from different aurora watchers, and they also allow you to see forecasts for solar storms that tell you both when it's interesting to go look at the Sun during the day, and when it's interesting to go look at Aurora Borealis at night.

Fraser: Awesome, and then the other thing that…I guess we wanted to announce this, which is that we've got the asteroid mappers going on cosmoquest and so people can actually go map asteroids from Vesta, although I guess we're going to talk about Vesta, so we'll probably get into that quite a bit as well, but where can people go if they want to map some asteroid craters?

Pamela: You can go to cosmoquest.org and right off of the homepage, we have a list -- a link to asteroid mappers, and if you feel like just typing the whole darn thing in it's cosmoquest.org/mappers/vesta, and this is apparently going to be a very tongue-tied day. I have no clue what's going on other than jetlag, so I apologize for that.

Fraser: Say that ten times quickly.

Pamela: No.

Fraser: Alright. Well, let's get rolling then.

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Fraser: So there's some topics on Astronomy Cast where we wait until we're good and ready, until the science is all in. Well, the Dawn mission has completed its mapping operations at asteroid Vesta and is moving on to Ceres, so this gives us a great opportunity to take a detailed look at this amazing asteroid, report on the science findings, and give you a preview of what's coming next. Well, so this is good. I can't think of a lot of times when we've had a chance to actually report in detail on an object that from when we began Astronomy Cast, a mission has been launched, the mission has arrived at its destination, it has completely studied its target and has moved on, wrapping up all its observations. I think we've been doing Astronomy Cast for too long maybe. We're getting to the point now that we're outliving missions.

Pamela: Phoenix did do this as well, except Phoenix sort of went to an object that we've been to a bunch of times before, so it wasn't quite as exciting, so this is the first time a bran new object has been reached.

Fraser: So then let's go back into the history of Vesta first before we actually talk about some of the recent stuff. What is asteroid Vesta?

Pamela: Well, it's one of the dwarf planets some would call it. We're still debating about whether or not it counts as round once you take into account the giant basins that are at its south polar region, but whether or not you decide to call it a dwarf planet or not, it's a very large, what we call differentiated object. It's one that has a core, a mantle a crust – just like a planet does, and it's considered to be one of the proto-planets in the asteroid belt that just didn't quite make it into accreting enough material to actually grow up to be a real planet. It's actually a full 9% the mass of the asteroid belt in just this one object.

Fraser: And the rest is Ceres, right?

Pamela: Well, yeah, pretty much. Asteroid Vesta is about 23 per cent the size of Ceres, so yeah, there's a whole lot of mass tied up in that giant asteroid that actually was once considered to be a planet.

Fraser: Well, how does it compare with some of the other objects that we're familiar with, like the Moon?

Pamela: It's much, much, much smaller. If you try and hold them up side by side, well, the surface area of all of Vesta is only about the same surface area as the country of Pakistan, so you basically have very large moon with small potato-shaped Vesta next to it. It's pretty round, but there's still lumpiness to it, it's more of an ellipse than a circle when you look at it, and most of all, when you look at it you notice that the sucker's just been really, really beat up. It's had a hard-knock life out in the asteroid belt.

Fraser: And so formation -- where do they think Vesta, and I guess the rest of the asteroid belt, came from? Is it a destroyed planet?

Pamela: That's what was thought early on. First Ceres was found, then slowly, over time they began to find more and more of these giant rocks that had very similar orbits, and it was thought that they were a destroyed planet, but what we've realized as we've studied them over time is, well, if they were a destroyed planet, they'd all have a lot more compositional similarities than we're finding, so it's believed that what these actually are is fragments that formed in the proto-planetary disk in the early solar system, but they never quite jelled enough to form a complete planet. So Vesta is an object that formed, Ceres is an object that formed, Juno (which is an other asteroid) is an object that formed -- and each of these are discretely formed objects for the most part. There are exceptions. There are chunks of Vesta out there floating around that are kilometer-sized objects, and there's other chunks that have been knocked off of this asteroid or that asteroid, but for the most part, the asteroids are each individual objects that formed out of the proto-planetary disk.

Fraser: And so then, what was there…was there any reasonable science that was done on Vesta before Dawn? I mean, watching it from Earth, they didn't get a lot done, did they?

Pamela: Well, we tried as best we could. There's certain studies that we can do of the asteroids, looking at their reflectivity, looking at, well, how much light in this color do they reflect vs. how much light do they reflect in this color, and that gives us a sense of what their mineralogy is, or at least at the level of: these two things give off the exact same types of reflected light; therefore, they're compositionally probably the same at the surface. And we figured out that there's a whole bunch of bodies that have very similar reflective properties, so they're probably related to one another, and it's now believed that, well, Vesta's the parent body of a whole series of both meteors that have hit the Earth, and other very similar compositioned baby asteroids that are out there. And it's actually thought that, well, there's this giant crater that we were able to make out with the Hubble space telescope, although with Hubble we weren't able to tell if it was a discolored region, or an actual crater. Well, now thanks to Dawn, we know it's a giant crater or basin. Basin is basically a big version of a crater, and when this crater was formed about a billion years ago, Vesta lost about one per cent of its mass during this impact, and it's formed these other objects that we're seeing.

Fraser: And so then before the Dawn mission was actually sent to Vesta, what were some of the big mysteries, the big unknowns that scientist were looking to answer?

Pamela: Well, we were still trying to figure out: are these objects that are differentiated like planets when they get to be this size? The fact that when we look at Vesta, we're able to tell that it has a crust, it's had…not so much volcanoes, we don't see evidence of volcanoes on its surface, but it has had…you have shield volcanoes, and then you also have molten rock seeping through the surface, that has happened at some point on Vesta. So we see it had a molten core at one point. It's differentiated just like a planet, but small. And then there's other weird things that we've been figuring out since then like, it's ringed with giant troughs. We're still trying to figure out how those got there. It has regolith, much like the Moon does, and we're trying to figure out how do you end up with regolith on asteroids without that material getting ejected into space has been a tricky business, and then there's just all these color variations across the surface that are very mysterious, and we're still trying to figure those out as well.

Fraser: So let's talk about Dawn then, and Dawn's arrival. So when was Dawn sent to Vesta?

Pamela: Well, it entered orbit in July of 2011, and it had taken off well before that. This is a spacecraft that has an ion engine, so it's…it kind of plugs along at its own rate, accelerating very, very slowly as it ejects just atoms at a time. So it got there in 2011, it was launched in 2007… it didn't go very far when you think about it. The asteroid belt is just a little ways beyond Mars, so this was a very slow, slow journey to get there. Once it got there, basically, the Dawn mission matched the orbit of Vesta, and then very carefully transitioned from being orbiting the Sun parallel to Vesta on its journey to putting itself into orbit around Vesta, and over time, it slowly lowered its orbit so that it could get high-resolution images, and then expanded its orbit back out, and now it's on its way out to Ceres, so it was a very slow process.

Fraser: And so we had that checklist of things that we wanted to look at that you mentioned. So how well was Dawn able to work through some of that science?

Pamela: Well, it…basically the only thing that Dawn didn't get to do as well as some scientists might like was study the north polar regions of Vesta, and that's simply a problem with during the time the mission was at Vesta, that north pole was never very well illuminated by the Sun, so that was a problem with the seasonal variations and sunlight, not with the spacecraft. The spacecraft itself performed marvelously well, and the southern hemisphere was very well illuminated. And one thing to point out is when we say northern and southern hemisphere, that's defined by the rotation of Vesta, and Vesta is actually flipped over on its head, and so it's rotating in a prograde manner compared to the planet Earth, and many other planets in our solar system. So at its northern hemisphere defined by rotation -- that wasn't well illuminated and studied, and the southern hemisphere, with its one giant, and then second also-giant-but-not-as-giant basin -- that got to be studied very well. And then we discovered these mysterious troughs that we didn't know about, and now it's the modelers that are trying to figure out: well, how do you model these things?

Fraser: What's the best part of these kinds of missions? It's not just the stuff that you were expecting to find, it's all the stuff that you weren't expecting to find, and you had no idea that such a thing could even happen. And as you said, it forces the modelers back to the drawing board to try and figure out what it is that they're looking at. I mean, look at what happened with Enceladus with these crazy cryovolcanism, and these geysers of ice spewing out of the moon! No one ever anticipated that. Or you look at Iapetus and its huge ridge, and the sort of dual colors -- the bright and dark sides to it -- again, not expected. So I mean, I know there were a few of those kinds of things with Vesta, so what are some of these features on Vesta that Dawn turned up that astronomers just weren't expecting?

Pamela: Well, I think the most scientifically interesting are the Rheasilvia, and (I'm going to mispronounce this, and I apologize) the Venenia craters. These are the two giant overlapping basins in the south polar region, and when I say giant basin, it's very hard for us here on the surface of the Earth, which is a big gravitationally flattened sphere, to just understand how big these craters are. One bigger basin of these, the Rheasilvia, it's 90% the diameter of Vesta, so imagine taking the south pole of the Earth and smashing it in such that when you looked at it 90% of the diameter got basically tucked back in. This is a crater that's over 300 miles in diameter, so that's a good six-hour drive. That's pretty much the length of the state of Illinois where I'm living. And then there's also amazing surface relief, and we're not really used to thinking of this degree of surface relief here on Earth. It goes down 13 km, and then it also rises up as much as 12 km on the rim. So if you take the equivalent of sea level for Vesta, the average surface diameter of Vesta, it goes down 13 km, and then up 12 km, so you're looking at something that's significantly bigger than any mountain we have here on the planet Earth, even when you go down to the bottom of the ocean and rise back up to the peaks of volcanoes.

Fraser: I think it's important to say, again, that there is a mountain on Vesta that is significantly larger than any mountain we have here on Earth.

Pamela: Yes, it's just awesome.

Fraser: It's no Olympus Mons, but it's actually pretty close, isn't it?

Pamela: Yeah, and what's awesome is, well, Olympus Mons was just a volcano that built and built and built, this mountain was formed like the splash of the central part of a crater, so you have rock comes in about a billion years ago, the impact energy is transferred into melting the material that made up what is now the south pole of Vesta. That material splashed up in the center, and it froze out into a mountain, and that's just kind of awesome.

Fraser: Yeah! I'm just trying to imagine. I mean, so this is probably one of those situations where, before this discovery, if you'd ask planetary geologists how big an object could you whack into another object and have it still survive…I don't think they would have anticipated this big of an impact.

Pamela: I think it's more of a matter…

Fraser: I mean, look what happened when it created the Moon, right? Earth was hit by something the size of Mars, and it created the Moon.

Pamela: Yeah, we knew that giant impacts like this happened. What startled us was all the varieties of different features that were generated. When you look at Vesta, there aren't any geological elements that aren't affected by this impact. Everywhere you look on the surface there's wrinkles, there's troughs, there's all manner of different impact-related deformations all over the surface.

Fraser: Do you have that situation where, you know, it hits on one side and then the antipode, you know, you get the splat like the shock waves travel right through and collect on the other side?

Pamela: That we've seen. There's nothing like that. We do see that on Mercury.

Fraser: Yeah.

Pamela: With this, it actually appears … and they're still trying to figure exactly how the troughs formed, but when you look at Vesta, there's equatorial bands, troughs, fossae -- pick your geographic term. Basically, there's belts of ridges and dips going around the equator. Now it's important to realize that when we say the south pole crater, that doesn't mean this was the south pole when this impact occurred. In fact, this impact sped up the rotation of this little world. It now has just over a five-and-a-half-hour orbital period. It may have changed; it most likely changed its rotational axis causing it to be flipped over on its head. This was a dramatic event, and whether it was the spin up that caused some of these troughs due to it's spinning so rapidly that material got flung out, or whether these are strictly crumple zones essentially. If you imagine what happens to a car, it has crumple zones. Well, perhaps this is how the mantle crumpled, and the crust crumpled, rather, as the entire planet tried to absorb this impact force. It's just something that modelers are still struggling with, and we don't know if that's a one-answer, or a two-answer, or a more-answer way of trying to understand all the physics that happened here.

Fraser: And I know one of the other questions, as well, was what does the asteroid itself…what's its composition? Is it a solid rock, a metally-rocky ball, or is it like a loose amalgamation of stuff? Where does it fall in that [missing audio]?

Pamela: Well, here it's very much like a planet. It actually has the silica-rich soil materials that we're used to. What I found interesting is this is another world that has a mineral called olivine on its surface, and this is a mineral that requires different waters to be present. There are indications that at some point there were volatiles on the surface of Vesta. So this means that something like comets delivered water, oxygen, other things that sort of evaporate into gas when exposed to the vacuum of space, and over time, these materials, in sometimes volatile ways, and in sometimes…just they evaporated, or sublimated is the correct term, these volatiles were lost from the surface of Vesta, but it did affect the composition to have had those volatiles there at some point in the past.

Fraser: Now I know one of the big questions with Vesta, and with Ceres is one formed inside the frost line of the Solar System, and the other one formed outside the frost line. So Vesta was the one inside, right?

Pamela: Yes, so this is where it had volatiles delivered to it, and then lost them. So far we haven't explored any permanently shadowed regions on Vesta. As I said, beautifully, everything got shadowed nicely on the northern hemisphere, while the southern hemisphere was well illuminated.

Fraser: And, I mean, are there any situations where you've got…like on the Moon, where places are kept in permanent shadow?

Pamela: I just don't know on this one. There could quite possibly be.

Fraser: But then, so far, I mean, they didn't see any patches of snow on the surface. They didn't see any…right, so in theory, as predicted, you've got Vesta, which all of its volatiles were either delivered after the fact, or they all, as you said, sublimated away, but in theory at Ceres we might see ice?

Pamela: It's quite possible that the minerals there will be much richer in… again, we use the word volatiles here. It's stuff that gets mixed into the composition, so when it formed it's not quite right to think of it as having ice the way Mars has poles that are big ice caps, but rather, the materials that make up the minerals might have waters mixed into the minerals, might have oxygens mixed into the minerals that didn't get blasted out by solar heating when Ceres was in the process of forming.

Fraser: Now, I know the way this works, right, is the spacecraft arrives at Vesta, does its mapping mission…you know, in this case it took about a year to kind of gather all the imagery, and I'm sure it took hundreds of thousands of pictures, and tons of data, and all kinds of wavelengths and spectrometers and all kinds of things. So now these scientists are going to be crunching this data. We saw a lot of the big, pretty pictures, but what are some of the other kinds of mysteries and information that the scientists are going to be looking for now?

Pamela: Well, right now, what they're doing is going through all the high resolution images, and they're trying to map out what is all of this crazy stuff that they're finding all across the surface, and this is where asteroid mappers comes in is we're asking everyday people to go in to the asteroid mappers project and help us map out where are there boulders, what are the shapes of the different craters scattered across the surface. And we're also looking to find what are the different color variations across the surface. Are there bright patches? Are there dark patches like we see on the moon? And some of the interesting things that are being sorted out is, for instance, on the Moon we see lots of this gritty, gravelly material: regolith. And this is created by the constant bombardment if micro meteorites, and sometimes not-so-micro meteorites onto the surface of the Moon. Well, with the Moon, it's fairly big, it has fairly good gravity, and so when a rock comes down, hits the Moon and material splatters up, the splattered material often falls back down to the surface of the Moon, but with something tiny, like Vesta, you wouldn't expect that to consistently happen. You'd expect boulders to actually get flung off the surface. You'd expect the dust grains and gravel that gets formed to get flung off the surface, so when we do see these boulders, those are events that apparently didn't have huge amounts of energy, and when we see regolith, it's actually confusing. How do you get dust and gravel that doesn't get flung into outer space? And it's now being thought, due to basically some really neat lab research where they're basically baking and freezing rocks, that you can generate regolith simply by the constant day-to-night temperature fluctuations that the surface of Vesta experiences. This causes fracturing, and over time, the material actually just falls apart from constant temperature fluctuations.

Fraser: So it's almost like weathering on the surface of the object, not necessarily from the impacts because I know, as you said, on the Moon that's what they thought it was going to be is just this constant, steady rain of material that was just chewing up the surface of the Moon. Perhaps the same thing could be true of the Moon that this sort of heating and cooling could also be contributing to the regolith as well?

Pamela: On the Moon it's probably not going to be nearly as much of a dominant factor, and the Moon's rotation is slower, so you're not going to get the sudden temperature fluctuations. With Vesta, you have, again, this over five-and-a-half-hour rotation period, and huge temperature variations, and it's basically…think of frost heaves that form on bridges during the winter. This is the equivalent of constantly forming and unforming frost heaves, and over time, just like that cracks pavement, it's going to crack, well, crack asteroids.

Fraser: Is that the stuff that when you like step on it and it all goes crunch when you're walking down, and the dirt all kind of lifts up, and frost is baked into it? Do you know what I mean?

Pamela: No, I don't.

Fraser: You don't have that there, maybe? Maybe it's just a West Coast thing. Anyway, so Dawn has left Vesta now, so no more of the up-close photography and science. Now it's on its way to Ceres, so when will we get that next big update then?

Pamela: That's going to be 2015, so we're going to have to wait awhile.

Fraser: I can't wait!

Pamela: This is a very slow-moving spacecraft, but 2015 is going to be kind of an awesome year for planetary science.

Fraser: New Horizons?

Pamela: We have New Horizons going past Pluto, we have Dawn at Ceres, lots of different things going on, so we just need to stay tuned, but it's going to take us a while to get through all of the data that was obtained at Vesta, so I wouldn't be too upset about the long wait. There's going to be a steady stream of science coming out from these images.

Fraser: So, we'll just have to keep doing Astronomy Cast for at least three more years, then.

Pamela: I don't see a problem with that.

Fraser: Alright, cool. Alright. Well, that was wonderful! Thank you very much, Pamela.

Pamela: My pleasure.