Astronomy Cast Episode 259 for Monday, April 2, 2012: The Exploration of Venus

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?

Fraser: I am doing really well…weather's changing, getting a little warmer outside, tearing up my lawn.

Pamela: The weather's tearing up your lawn, or the critters?

Fraser: The weather, yeah…that's what we call good weather in Canada when it only nearly tears up your lawn. No, the weather's nice, so I'm tearing up my lawn.

Pamela: That works.

Fraser: Yeah. Are you getting a chance to get the horse out?

Pamela: I am. I have to admit as soon as this hang-out is over, I'm going to finish off some more email, and then tonight girls' night out with our ponies. And our ponies happen to be giant thoroughbreds.

Fraser: OK, well let's get rolling.

[advertisement]

Fraser: So Mars gets all the attention, but you might be surprised to know how much Venus has been explored – from the initial telescope observations and the early fly-by missions to the landers – yes, landers and orbiters. We know quite a lot of about Venus, but the planet sure didn't give up its secrets easily. So let's kind of go back in history. So Venus…even fairly recently science fiction writers had this idea that Venus was this warm, wet world. I can remember actually as a kid reading…you're going to have to help me with this. I think it was like a Isaac Asimov or Ray Bradbury story about these kids who were, like, in school living on Venus, and it always rained and was always cloudy, and then for one brief second it sort of cleared up – once every 20 years.

Pamela: I know exactly the story you're talking about that. They made a movie out of it, and I remember seeing it in fourth grade, and I was just like "Oh, that's so sad," because like one kid got left inside…

Fraser: …left inside when it cleared up on Venus for the first time in like every 20 years, but of course, really that kid was a lucky kid as the other kids went outside to die a sulfuric acid rain death, so I think that was the lucky kid. So let's go back and talk about the exploration of Venus because I find Mars because I find…we know Mars eats spacecraft, but you can see Mars, and we can see things and say, "Let's go over and explore there." Venus…really scientists had no idea what was going on on Venus.

Pamela: No, so we've made attempts to study it from the planet Earth.

Fraser: Well, Galileo first helped figure out that it was a...

Pamela: Right, so we were able to see from studying it on Earth that it had phases, it had an atmosphere when it passed in front of the Sun during the Venus transits. We were able to see as it went in that there's clear signatures of an atmosphere, and it was that signature of an atmosphere that made us think this must be another Earth-like world that we can go just walk around on and be happy in the atmosphere. The first studies that really started to look at its surface used radar in 1961, the Goldstone Radar Facilities, and Deep Space Network were able to bounce radio signals off the surface, start to get ideas of the fact that this is a nice, rocky planet, but then that whole nice, rocky planet sort of became hellish, rocky planet when the very first spacecraft to get there successfully got there actually 50 years ago this month in 1962.

Fraser: So was there like up until those spacecraft got there, they still didn't know that it was a hellscape.

Pamela: No! We had no way of measuring the planet's temperature from here, and without knowing that it's a planet with sulfuric acid clouds and temperatures of many 100s of degrees, you just can't figure that out. So it was actually the American mission Mariner II that did a fly-by in 1962…and it had two purposes: it was measuring the magnetic field (which really wasn't there), and it was measuring the temperature. And the temperature that it measured was 490-590 degrees kelvin, which is sort of like let's-just-vaporize-everything temperatures.

Fraser: Yeah, hottest planet in the Solar System…

Pamela: Yeah, it shocked everyone.

Fraser: Hotter than Mercury…

Pamela: Yes, although we didn't know that at the time. We just knew that it was hellishly hot. So that was problematic, and from that first U. S. mission to make it there successfully, many different nations have tried to explore Venus: the planet that likes to eat spacecraft, and one of the things that I find kind of interesting is, whereas Soviet missions to Mars liked to crash with verve, it was the Soviet's missions to Venus that were over and over and over successful.

Fraser: But you say over and over successful, but those Venera missions (Is that how you say it -- Venere? Vernera?)… Yeah, I love the iterative process about how they accomplished that just astounding feat. I mean, they went from…

Pamela: Ten soft landings! Ten soft landings! That's just awesome!

Fraser: Yeah, people have no idea. I mean, they went from just smashing probes into the atmosphere, and just seeing what happened, and then learning from their mistakes, and improving their techniques all the way to the point -- and I don't want to ruin the ending, so yeah…

Pamela: It's kind of amazing. They had some problems with their initial missions. Venera I – it was the first mission successfully launched to another planet, but it didn't survive. It had issues, so…

Fraser: Like, didn't even make it to the…

Pamela: Well, it made it, but it didn't really return anything useful, so… It was awesome! It had all of the pieces it needed, but then it had an orientation sensor malfunction, but it got into a parking orbit, it left the parking orbit, headed toward Venus, life was going fine until that one sensor failed. Then in '64 they launched Zond I, but it didn't successfully make it either, so they had all these issues initially, and America just kept doing well in those early days, where in '67, Mariner 5 was able to go measure the magnetic field some more; in 74, Mariner 10 flew by on its way to Mercury. It took ultraviolet images of the clouds, and they were able to tell with the ultraviolet images that the clouds had various different structures to them, and these amazing high winds, so there was early science and the Soviets they just kept plugging away until they got it to work, and so it was Venera 3 in '66 that actually became the first spacecraft from any nation to make it to the surface of another world. Now, it crashed into that surface, but…

Fraser: That's a landing. I mean, you know…

Pamela: It's a form of landing.

Fraser: It's a landing in my book.

Pamela: But to think that they were doing this in '66 when your pocket calculator had more "everything" ability than that spacecraft had. It made it all the way from Earth to another planet, through that other planet's atmosphere, and simply failed to stop in time -- and that's pretty astounding.

Fraser: Yeah, any landing that doesn't completely vaporize your spacecraft is a good landing.

Pamela: Yes. So it was Venera 4 in '67 that was finally able to start returning good science results. This was a mission that directly measured the atmosphere of Venus, and this was where we started to move from "Wow, it's hot!" to "Oh, oh, wow! There's something screwed up here," because we were able to discover that the atmosphere is 95% carbon dioxide, which was completely different from what we had expected, and we were able to finally start getting back information on the temperature, the pressure, and the density of the atmosphere, and this is an atmosphere that is so thick it has a tendency to crush spacecraft, and when the air pressure on another planet causes machinery to go “whump!” to just smush down into small pieces – that’s a thick atmosphere. But that’s Venus.

Fraser: We need to give people context. When we call it atmosphere, that’s only because it’s formed of carbon dioxide and surrounds the planet, but the reality is that this stuff is so thick – what’s the equivalent? It’s like 1 km…

Pamela: It’s 75-100 atmospheres.

Fraser: Yeah, and that’s the equivalent of you being 1 km below the ocean.

Pamela: Yeah.

Fraser: So you know when you, like, dive down, and you’re 10 feet, and your ears are, “Oh, I’m feeling a little pressures in my ears,” and you dive any further and you’re like “Oh, I’m getting a headache,” and you dive down a little…or think about those WWII shows about the submarines where they go down to “300 meters!” and they can hear the bulkheads buckling…yeah. That kilometer down below would take any…almost any submarine ever built and go [cracking noise], and this is the kind of engineering challenge they were dealing with, and they had no idea this is what they were facing. It was like “Let’s send in a probe and see what happens to it, and we’ll use that as our criteria for the next probe.”

Pamela: And one way to think about this is right now the pressure inside your body is precisely matched to the air pressure pushing on your body, and it’s one atmospheric pressure on your skin. It’s 75–100 times that amount of pressure, so if you imagined all the sudden you go from this nice, happy equilibrium to 100 times the amount of pressure on your skin, you’d sort of die, and spacecraft don’t like it either. So that was figured out in the late ‘60s, basically making everyone in the various space agencies rethink how they designed landers going to Venus, and also making all the science fiction writers a little bit sad because, well, colonies in Venus just aren’t in our future.

Fraser: But this was…I mean the Americans I don’t think ever [missing audio]. Did they have a lander planned?

Pamela: Well, we did actually work to land things, and the Venus Pioneer probes in the late ‘70s sent a series of atmospheric probes through the atmosphere. These were balloon-born; they were floaters. So they sent the probes down, and when you have a…100 atmospheres, it's easy to float things through the atmosphere. This was actually a problem with some of the Venera spacecrafts. They didn't make it down to the surface before the batteries ran out because you're buoyant in that type of an atmosphere. So with the Pioneer program in the late '70s, we sent a series of four different probes through the atmosphere, and they descended on December 9, 1978. And they traveled about a third of the way around the planet, taking data as they passed through the atmosphere, and it was from these and other spacecraft that we realized the atmosphere isn't just high-pressure, but it's also winds that are extremely turbulent. So as the variety of different spacecraft that have passed through this atmosphere did their job, basically, they were experiencing lovely things like suddenly getting plunged 1-3 km down in the various downdrafts. So if you've ever been on an airplane that experienced turbulence, you might have suddenly experienced the airplane dropping a few meters -- well, this is a few kilometers. This…

Fraser: Can you imagine if they ever do try to land humans there? It's going to be just the worst turbulence.

Pamela: Right, and it was really the Vega probes that…these were balloon-born. They had helium balloons, they embedded them in the atmosphere, they flew them around in the atmosphere for hours and hours taking data, trying to understand the atmosphere, and they're experiencing these huge plunging downdrafts as they don't so much orbit as they float like any old weather balloons do. And I don't think we're ever going to try to put humans within our lifetimes. I won't beg off…

Fraser: Near the surface…

Pamela: Yeah, there's just some things you send the robots to do.

Fraser: I think we're going to talk about this later on, but one of the really interesting things about Venus is that at a certain altitude above the cloud layer, or within the cloud layer, you get a point where the air pressure and the temperature are the same as Earth, right? And so you could actually go…you wouldn't be able to breathe the atmosphere, but you could go out and sit out on the deck of your balloon, or your…

Pamela: So Cloud City?

Fraser: Cloud City on Venus! Your re-fueling station on Venus, and in your shorts and t-shirt (well, OK, so there's sulfuric acid)…in your environmental suit… But the atmosphere would feel the same pressure as Earth and the temperature would be the exact warmth of Earth. It would just be, like I said, it would just be this driving sulfuric acid rain, so you wouldn't be able to see more than a few meters, but my point being, it's not completely inhospitable to life. But we've done articles on this in the past, and every time, I go, "Oh, we should totally build a Cloud City."

Pamela: Well, so that becomes a problem of trying to support it because you're not exactly going to be able to re-fuel your helium balloons. Hot air balloons don't exactly work in that type of atmosphere, so you start to run into problems of how do you maintain your Cloud City, so…

Fraser: Again, these are details that do not concern me. I just want my Cloud City.

Pamela: [laughing] Yeah.

Fraser: So, let's go back to some real, actual missions. The Venera missions -- you've got these ongoing challenges -- the Pioneers, the balloons to reach the surface of Venus and not die. You've got, you know, engineers going back to the drawing boards, and then having to go back to the drawing boards to re-design their drawing boards so that they can figure out what kind of capabilities would actually make a mission. So let's continue that story.

Pamela: Yeah, it was really kind of amazing in the early '70s, (we're jumping around the decades, and I apologize for this) when they were trying to figure out how to handle this, they had…the first successful landing on Venus was in 1970, and this was Venera 7, and it was able to send back information for 23 minutes, and it sent back surface temperature readings of 455-475 degrees Celsius. This is 855-885 degrees Fahrenheit, so this is a very bad day, and so it was successful. They again had success with Venera 8, and it made additional pressure measurements, but while they were doing all this, what they found was the atmosphere of Venus -- it's 22 miles thick, and they had to sacrifice a lot of spacecraft to get to those things. Earlier missions just plain died. I mean, poor Venera 5 and 6 (these are two missions from '69), they actually died 18 km above that surface because that cloud layer that starts 22 km up gets thicker and thicker and thicker and thicker, and when those missions hit 18 km, they just got crushed into oblivion. So the Soviets had to figure out: OK, we need to build stronger, more capable, basically, exoskeletons to put onto their spacecraft to get them to succeed, and it's really amazing how quickly they were able to overcome the problems they had with Venera 5 and 6 to get 7 and 8 to successfully work.

Fraser: Right. And I mean, at a certain point, you have to think about what the mission's going to look like. You're essentially trying to take a ball of metal, and then trying to carve out a little space in the middle that maybe can do some sensing, but you've got to have these instruments that have got to be able to be outside and be…actually make some detections, and sense their environment, and that's really hard when you're also trying to protect the poor thing from this hellscape that you've dropped this thing into. Total kudos to them, I mean, they really had some engineering "chops" to be able to figure out this happy balance to do some science, even take pictures [missing audio] while you're in this pressure.

Pamela: Right, so it was really amazing, and the more they studied, the more nastiness they found. It was with Venera XI and XII, where they started to include cloud droplet analyzers that allowed them to start to understand the chemical composition of the atmosphere, and what they found was that the atmosphere was filled with chlorine and sulfur and it was alive with lightning, so you have to now worry about your spacecraft getting "zotted," you have worry about the hydrochloric acid, you have to worry about chlorine, you have to worry about sulfur, all of these different things are trying to destroy your electronics while you're reaching out with your little sensor and saying, "OK, I just need a little bit of this cloud to figure out what's going on around me," and it was really amazing! And the Soviets just kept innovating and innovating, and in '81 with Venera 13, OK, they'd made it through the atmosphere, they'd made it through all the chemistry, all the pressure through all the temperatures… they made it to the surface, and they got a probe that lasted for over two hours on the planet's surface, and...

Fraser: Was the first one that landed the one that lasted for two hours?

Pamela: This wasn't the first one that landed, but it was the longest one that landed, and it was the first one to send back color pictures, and it just was this hellscape of clouds and yellowy-red soil, and it worked to excavate and send back soil samples. And once they got there with Venera 13, they got there again with Venera 14, and this was a mission that then found: this is a planet while it doesn't have plate tectonics like Earth, it does have seismic activity. There were earthquakes detected, so now we have shaking, rattling and rolling, high pressure, sulfuric acid atmosphere… They found other acids in the atmosphere as well. It just couldn't get any worse really. It was just gross.

Fraser: And again, once again, to go over this point again and again, they had to engineer the spacecraft so it could communicate these terrible mysteries back to orbit, and get it back to Earth. So again, but you need an antenna, and you need an antenna outside your spacecraft, and you need to have an antenna that can communicate through 22 miles of sulfuric Hell, so I think that was again, just a phenomenal… so how long do these spacecraft last? You said the first one lasted like two hours?

Pamela: They lasted a few hours each, and the balloon-born experiments were the ones that lasted the longest. Vega 1 and Vega 2 lasted for 46 and 60 hours, and those kept themselves up at a more reasonable pressure. They still survived those amazing downdrafts of 1–3 km drops, getting forced down by the winds, so those were pretty amazing.

Fraser: So what was the end, then, of the Venera mission? How did they finally wrap it up?

Pamela: Well, so they kept going, and in fact, they 're still going today with new plans. In the '80s, with Venera 15 and 16 -- these were missions that had fairly high-resolution imaging capabilities. They mapped the atmospheres of the planets; they basically tried to understand what is this amazing weather patterns that we're looking at. They also started to send radar dishes to the planets so that we could get better resolution than we can get from here on the planet Earth. Let's face it -- if you're trying to radar something at the distance from Earth to Venus, you're not really going to be able to pick up that much detail. Put the radar dish in orbit around the planet, you can start to be able to make out features. It was those Venera missions that were the first to realize this is a planet that also has amazingly large shield volcanoes. So now we have a planet with giant shield volcanoes, hydrochloric, pyloric acid, sulfuric acid…all these things in the atmosphere, huge phosphoric acid – all these things. It just kept getting more like your childhood understanding of Hell, or Dante's inferno as we looked more and more.

Fraser: So now fast forward, though. Then we had the Magellan, which was a very successful NASA mission.

Pamela: So it was really kind of amazing. The Soviets managed to take advantage of every single launch window to get to Venus from the early '60s all the way out to the mid '80s, and then there was a gap, and the gap admittedly had something to do with political upheavals all over the planet. That happens, and…

Fraser: Walls coming down, that kind of thing…

Pamela: Right. Right, so the Magellan mission by the United States was the next big mission. It launched in '89, it got there on August 10, 1990, and this was a mission that had a high-resolution -- compared to everything earlier -- radar on it, and it was able to start to radar image the surface of the planet down to 100-meter resolution. So you're looking at: every pixel in these images is slightly larger than a square version of a football field, but that's still pretty good resolution, and it was allowing us to make out that there were canyons and volcanoes and all these amazing features on the surface, but it continued to show us that there's no evidence of plate tectonics, and hinting at the fact that maybe Venus has this weird crust that every once in a while just completely upheaves itself in some sort of mass volcanism all across the planet. There weren't a lot of craters found, and when you don't have plate tectonics, you have to wonder, "Where did all the craters go?" And so this is something …we're still trying to understand this today.

Fraser: Yeah, and when you see those yellow, kind of gold pictures of Venus, not the ones where it's this gray or like [missing audio] yellow – those are from some of the old Mariner stuff, even some of the newer stuff from Venus Express, but when you think about where you could see the surface geology – that was all done by Magellan. And there were some wonderful fly-bys that they did. I don't know if you remember this – you can still get these videos on the internet, we'll link to them in shownotes, but I remember watching them on television, like, back in the '80s, and it was, again -- blew my mind. It was beautiful pictures of...

Pamela: ‘90s – didn’t get there until 1990.

Fraser: ‘90s, that’s right, 90s, sorry, yeah…these beautiful fly-bys where they’d computer graphic rendered fly-bys of going into Venus, and going down some of this surface geology.

Pamela: Flying through canyons, zooming…

Fraser: Seeing what it might look like flying past shield volcanoes and things like that, yeah, yeah…it was really great, and it made a real difference, made a real impact. So then, I guess, fast forward again to the most recent attempt to explore Venus, which is still happening right now.

Pamela: Right, so there’s started to be a series of gaps in our exploration of Venus, and they dovetail in with where we did promote our exploration of Mars. So Venus Express was a mission that arrived in 2006, and it’s a mission of the European Space Agency, and it’s an atmospheric mission that is working to try and understand how the weather on Venus changes orbit after orbit, trying to understand the amazing vortexes we see in the polar regions of Venus’ atmosphere, and what’s kind of awesome is it’s finding evidence of past oceans that were probably destroyed by the runaway greenhouse effect on Venus. And its most amazing discovery, I really think, is the fact that there are these huge vortexes in the South Pole and you can actually look at it, and we think that perhaps we’re seeing almost all the way through that 22-km-deep atmosphere, looking through, basically, the eye of a planetary-wide storm. Another interesting thing is the more we look at the chemistry of the atmosphere, the worse it looks. They were also able to identify hydroxyls in the atmosphere of Venus, and that’s just another we’ll-kill-you type of chemistry.

Fraser: So what does the future hold for the exploration of Venus? Are there any more missions on the books?

Pamela: So, the Soviets (now the Russians), the Russian Roscosmos Space Agency is looking to launch the Venera D spacecraft. It’s nominally going to be launched around 2016, and it’s going to work to map Venus’ surface with an even more powerful radar dish than the one that Magellan had. I heard that there’s also going to be, potentially, a series of what look like lawn darts attached to the mission that will send little probes that have a spiky bit on one end and a radio antenna on the other end, drop them all over the planet to do weather measurements on the surface. And they're also planning a very large, rigorous, or vigorous (I don't know how you want to look at it) lander capable of roving around on the surface of Venus, and I don't even want to think about something that can rove Venus.

Fraser: Well, I think the harder problem with that is it's all about the heat. Heat just builds up and builds up and just cooks all of your instruments and you get to the point where the heat is so hot that it boils that it will boil that it will melt lead, and you need to protect your lander against that heating, and you might start out and the inside of your lander is going to be cooled from space, but over time it's going to get hotter and hotter and hotter, and in fact, we did an article on *Universe Today* a few years ago about this (you can do a …we'll link to it in the shownotes). And you can do a search for like Sterling engines, this kind of engine that you can use, and so they thought if you took a powerful enough power source like obviously like some kind of reactor that you could run a Sterling engine that's purely designed to transfer heat around, and you could actually keep the interior of your rover cool enough long enough that it would be able to survive on the surface, and you could actually get some science done. You might not be able to do what the Mars rovers have done, but you might be able to get by with like weeks, or maybe even days or weeks, and try to make some progress, and try to explore a few rocks, and do some science instead of just fall on the surface of Venus and fry up to the point that all of your interior electronics melts away.

Pamela: And while trying to deal with the heat is definitely the primary problem you have to solve. Once you solve that problem…think about how much harder it is to move when you're at 100 atmospheres. If you've ever driven your car full speed down the highway with the roof off (I advise only doing this in a convertible), if you stick your hand out and feel the air pressure, that starts to give you a sense of the pressure you might experience, but only on one side. Now, you try curling your fingers and stuff like that, it's harder to do with that extra pressure. Now, imagine that extra pressure is bearing down on you from all sides, and you're trying to move forward, to roll forward, to get yourself going with this huge pressure against you. It's going to make everything more energy-intense, although you do have at least all of this heat energy that hopefully you can convert into something useful.

Fraser: Hopefully, the Russians with these steel-reinforced drawing boards that they've been going back to -- they'll be able to figure this one out.

Pamela: It's really been amazing.

Fraser: Absolutely, and like I said, I can say, for me, one of the highlights of the whole journey of space exploration so far, when you see the pictures of the surface of Venus, it's just so…well, cool! Well, thanks a lot, Pamela, and we'll talk to you next week.

Pamela: Sounds good, Fraser. We'll talk to you later.