Astronomy Cast Episode 50:
Venus

Fraser Cain: Last week, we talked about Mercury, and so this week our planetary parade proceeds (like the alliteration?) to Venus. Hopefully we'll be able to get through all the planets, but this week let's talk about Venus.

Go!

Dr. Pamela Gay: Well, it's the brightest object in the sky, the hottest object in the solar system, and it's probably one of the most deadly places to go and visit.

Fraser: All right, let's talk about the bright part – not as bright as the Moon (or the Sun).

Pamela: The Moon's really close, so we can ignore it. If it were at the same distance as Venus, we wouldn't be seeing it with our eyes. The Sun… it's a star. It's going to be bright. If you look at everything else in the solar system, Venus is the brightest.

This is because it's covered in clouds that are really good at reflecting light. It has what's called a high albedo. It reflects light that comes back to us. It's also very close, compared to the other planets. We get closer to Venus than we get to any other world in the solar system. This combination of really reflective and, on the grand scheme of things, not too far away, allows it to shine big, bright, right on the horizon on a very regular basis.

Fraser: Let's talk a bit about how it gets too far away. I know that the times when Venus is at its brightest, it actually looks like a crescent, doesn't it?

Pamela: That's one of the neat things about it. Because the planet Venus is between us and the Sun, it actually ends up getting phases, the same way the Moon gets phases. In this case what's happening is you'll end up with Venus partway between you and the Sun, such that it's kind of off at a 30 degree angle with the Sun straight in front of you, and we can only see part of the illuminated planet.

The only time we can see a pretty much completely full planet Venus is when it's just about ready to pass behind the Sun. so to see a full Venus, you have to be looking at it right on the edge of the solar disk, and you generally don't want to do that. It's bad for your optics; it's bad for your eyes.

So when we're looking at Venus when it's furthest away from the Sun, we have this crazy geometry going on where it's off to the right, the Sun's straight in front of us, and we're only able to see a sliver of the illuminated disk.

Fraser: So those are the times when Venus is the brightest because we can see the whole disk, but it's at its most distant from us, so in the end it's actually not quite as bright.

Pamela: The times when it's most distant from us, we'll be able to see crescent phases only; it's when it's furthest from the Sun on the sky.

One of the problems with discussing astronomy is you're dealing with two different ways of looking at things. There's the how does it look in the sky perspective, where I can say it's furthest from the Sun… that's just an angular distance (the Sun's below the horizon, Venus is high above the horizon).

Then there's also the question of how far away it is physically (the stepping outside of the solar system and looking down on the planets from above perspective). When Venus is actually at its furthest from the planet Earth, it's on the other side of the Sun, it's a full disk. That's when it's at its furthest.

When it's closest to us, we can't see anything illuminated because it's directly between the Sun and us. As it starts to creep to the right, creep to the left… that's when you start to see the crescent phase, and when its physically closer to the planet Earth.

Fraser: All right. Let's move on to the second thing you talked about, which is that it's the hottest object in the solar system? (Once again we're going to skip the Sun)

Pamela: (laughing) Yes, skipping the Sun is appropriate here.

Venus has a surface temperature of about 462 degrees Celsius.

Fraser: Can you give us some context? That's hotter than my oven, isn't it?

Pamela: That's hotter than my oven goes. That's kiln-hot. That's destroy space probes hot. That is all the oceans evaporated. There's no water left on the surface. Bone dry, baked dry hot planet.

Fraser: All right, now why is it so hot (he says asking a leading question)?

Pamela: (laughing) There's this little thing called the greenhouse effect. The atmosphere of Venus is extremely thick, and it's made primarily of carbon dioxide. It's about 96.5% carbon dioxide. For comparison we only have trace amounts of carbon dioxide in our atmosphere, and we still worry about its affect as a greenhouse gas.

So here you have this planet that's 96.5% carbon dioxide in the atmosphere, and all that carbon dioxide is working to help trap heat inside the atmosphere. Sunlight comes in (the Sunlight that doesn't reflect back to shine prettily back at the Earth and other planets), goes down, hits the planet, and some of it's going to scatter back up. A lot of it that scatters back up, scatters back up as heat. That heat gets trapped by the clouds and bounces back and forth, building up the temperature. Other things added to this are happening.

At one point in history, Venus probably had oceans the same way the planet Earth has oceans, but as the temperature increased, those oceans evaporated and you end up with this extremely humid atmosphere (which also adds to the greenhouse effect).

Fraser: Did they evaporate into space, or just into the atmosphere?

Pamela: Well the oceans originally just evaporated into the atmosphere, but that water vapour in the atmosphere is getting hit by UV light from the Sun. one of the problems with UV light hitting water molecules is UV light can actually break the water molecules apart. Instead of having a nice molecule of H2O, you have a molecule of H2 and this lone O off by itself.

H2 is a really light molecule. As it's floating around in the atmosphere, it will undergo collisions with other atoms, other molecules, and these collisions can end up increasing the speed of the H2 molecule until the H2 just leaves the atmosphere. It builds up escape velocity and heads off for deep space.

So that water that used to be oceans, went into the atmosphere, the water molecules got broken apart by the UV, and then the H2 molecules got beat up until they fled the atmosphere entirely.

Fraser: So there's no going back.

Pamela: There's no going back. It's gone.

Fraser: Right. People think about maybe there's some way you could cool down the planet and get the oceans to re-condense, but those oceans are long gone.

Pamela: Those oceans are long gone, and one of the biggest problems is there's no carbon cycle. Here on the planet Earth, we have all sorts of processes that work to lock the carbon dioxide in our atmosphere into rocks, into plant matter, into all sorts of different things, but locking it into rocks is a kind of important process.

Without the liquid water on Venus, there's no way to get this carbon cycle going, so the carbon's just trapped in the atmosphere and there's no getting it out.

Fraser: What effect does its temperature have on other parts of it? Geologically or its surfaces…

Pamela: One of the really strange things about Venus is when we do radar mapping of it - you can't image the surface, the clouds are too thick, but what we have done is sent space probes, particularly the Magellan probe did an excellent job doing highly detailed radar mapping of the planet. In looking at these radar maps, there are just not a lot of craters. What craters there are indicate that only really big asteroids get through the atmosphere. The smaller ones all get burned up by the really thick atmosphere.

The big ones that do get through, we only see indications they've been getting through for 500 million years. Now, we know Venus didn't have some miraculous past where it wasn't getting hit by asteroids, so when the oldest craters we see are only about 500 million years old, that means something happened that really dramatically resurfaced Venus entirely.

What we think happened is because there's basically no water in the crest of Venus; it can't have plate tectonics like we have on Earth. Our plates are slowly sloshing around. They cause volcanoes, Earthquakes. The recent devastation in Peru was caused by one plate rubbing against another plate and plunging underneath it. All of this is lubricated by water. Without water to lubricate the motion, you just end up with the plates sitting there, jammed up against each other.

The motion of the plates releases heat from the inside of the planet. Without that motion, without that release of the heat, the heat builds up and builds up and builds up. We think every once in a while on Venus, the heat just weakens the entire crust and there's this amazing period of mass volcanism where the entire surface of the planet will pretty much get resurfaced in one fell swoop of escaped heat.

Fraser: Wow, and the last time that happened was 500 million years ago?

Pamela: That was the last time it happened. Unfortunately we have no way of knowing when it will happen again.

Fraser: All right. You said the third thing was that Venus will kill you.

[laughter]

So what are all the ways that Venus would like to kill you?

Pamela: Well… it rains sulphuric acid. That alone is just a bad thing. When we look at the clouds on Venus, they're sulphuric acid, not water. So that's kind of deadly.

The heat: more than kind of deadly.

Then there's this other problem known as its atmosphere is really thick. The Russians had this amazing program to send space probes to Venus. They just flung them one after another, more of them successful than not, year after year after year.

The first probe that they got to Venus that functioned, worked for 93 minutes in the atmosphere. It was on a parachute descending through the atmosphere, and in 93 minutes it didn't make it to the surface because the atmosphere was so thick that the thing just didn't fall.

Fraser: Oh, so it could only last a certain amount of time in the heat and the pressure and the sulphuric acid rain and it was so thick it couldn't even make it to the ground.

Pamela: Yeah. So they tried again. They sent Venera 5 and 6. Each of these spent 50 minutes in the atmosphere trying to make it to the surface - they had smaller parachutes. In this case as they made it toward the surface, eventually what killed them was the atmospheric pressure.

At the surface of the Earth we're at about one atmospheric pressure (depending on where on the planet you are). Atmospheric pressure on the surface of Venus is 90 atmospheres.

Fraser: So every part of your body is experiencing 90 times the amount of pressure than you would be on Earth.

Pamela: Yeah.

Fraser: So you'd have to be under water if you wanted to experience something like that here on Earth.

Pamela: Venus has this amazingly thick atmosphere. It's 90 times the atmosphere of Earth, and to give you a sense of just how much that is… if you go scuba diving, for every 10m of depth you gain 1 atmosphere. So you have to go 900m – almost a kilometre – under the surface of the ocean before you start to get to pressures of 90 atmospheres.

Fraser: I can think of all those submarine movies where they're down a few hundred metres and the pressures starting to make them creak and the rivets are popping out and … yeah.

Pamela: Yeah. So these poor, innocent space probes are getting baked, getting pressured… it took a lot of tries before they finally managed to land things. They landed Venera 7-14 on the surface of Venus. It took a long time before they got to things all the way to the surface that would then return images. And once they got to the surface they didn't last very long before heat and pressure killed them.

Fraser: But there are actually some photos from the surface of Venus.

Pamela: It's a really cool surface. There are rocks, there are things that have clearly been weathered. It's a really funky looking planet – just not someplace you want to visit.

Fraser: Right.

Okay, so now let's talk a bit about what's happening right now. There's a mission at Venus, right?

Pamela: The Messenger mission, which we talked about last week, just departed Venus. And the European Space Agency's Venus Express has arrived. It's there to try and figure out the weird magnetic field associated with Venus, work on studying the atmospheric composition.

Venus is a really mysterious world, and we don't know quite how it got to be the way it is. Its magnetic field is a lot smaller than we expect. The planet is a little smaller than the Earth; it rotates a lot slower than the Earth.

Its year is 224.6 days long, but each one of its days (the amount of time it takes for the same point on the planet to go from facing the Sun to facing the Sun) is 243 days. So, your day is longer than your year.

The thing is rotating in the wrong direction. It's orbiting in the direction the rest of us are orbiting, but it rotates in the opposite direction. We're not sure how these things are tied together, or how they're related.

The first question is trying to figure out the magnetic field. Near as we can tell, the magnetic field isn't arising the same way you get the magnetic field here on Earth. Here on Earth, the liquid molten core is convecting. You have hot stuff in the centre bubbling off, cooling off as it gives its heat to the crust and then its flowing back down. You have this dynamo going on in the centre of the planet, with this motion causing charged particles to move, causing a magnetic field.

With Venus, the core of the planet is just hot. It's not convecting; it's just sitting there being hot. Potentially it's at a constant temperature all the way through the liquid molten core. It's not making a magnetic field we understand. What little magnetic field that Venus has is coming from some other means.

Fraser: Does this magnetic field protect the planet in the same way the Earth's magnetic field does?

Pamela: It's not strong enough. If you went to Venus and survived the sulphuric acid rain, and the 90 atmospheres and the 462C… now you're getting struck by radiation from the Sun as well.

Fraser: You'd probably get to enjoy cosmic rays as well.

Pamela: Oh, yeah. It's all thrown in for free.

Fraser: Is there any prevailing theories about why Venus does have a magnetic field?

Pamela: It's probably some sort of an interaction between the solar wind and the atmosphere of the planet. You can get these interactions between the Sun and planets – Mercury probably has a similar magnetic field, where you're getting interactions between the Sun and the planet that lead to a planetary magnetic field. But we're still trying to map it, and understand it.

One of the things Venus Express is looking at is the magnetic field. It's also looking at the atmosphere of the planet, trying to understand what are the greenhouse gasses, what is the pressure structure, what is the weather. The planet's rotating slowly, but there are parts of its atmosphere that are going all the way around the planet in four days.

As we watch hurricanes on planet Earth, you can see them sort of claw their way through the Gulf of Mexico that a fast motorboat can go at (in fact, slower than a fast motor boat can go at – large ships regularly outrun hurricanes). On Venus, the storms are moving all the way around the planet in four days. We're really glad hurricanes don't do that.

Fraser: Yeah.

What were some of the other mysteries Venus Express is going to try and help solve?

Pamela: Some of the other things it's looking at are the global characteristics of the atmosphere. How are the prevailing winds moving? Does it have a jet stream? How are the clouds flowing? How does it circulate?

How does the composition of the atmosphere change with depth? Do the clouds at the surface and the clouds at the bottom have the same chemical composition, or is there stratification as you go through?

How does the atmosphere affect the surface of the planet? What sort of weathering is taking place?

Since it doesn't have a magnetic field that is working to protect it, how does the end up interacting with the solar wind that's able to directly bombard it?

So we're looking at all the different layering affects. You have between the atmosphere and the surface, the atmosphere and the solar wind, and all the stratifications between. It's basically a meteorologist's most fun dream.

Fraser: Yeah, but it's funny because the photos that are coming back from Venus Express are mostly pretty boring. It's clouds and more clouds. It's not even necessarily the pretty storms like we see on Jupiter. It's a much more even covering of storms. There are some interesting storms and formations in the Polar Regions of the planet – did you want to talk about that?

Pamela: Almost immediately after ESA got their Venus Express into orbit, while they were getting into their final orbit, they swooped under the planet and took a look at the South Pole. What they saw there was this amazing vortex structure in the clouds. What's neat about this is we're starting to find vortexes in poles on a regular basis.

There was an amazing image similarly released by Cassini that was looking at Saturn's poles. In some of these dense atmospheres, the cloud dynamics are such that you end up with vortexes and spiral patterns that we just don't ever get here on the planet Earth.

We're working to try and understand them and the Venus Express engineers couldn't have been happier to, just within the first 24 hours, make this wonderful discovery.

We'd had hints that this might be possible because the North Polar Region does have vortexes. Now we're finding both the northern and southern poles have these amazing vortexes as the planet's atmosphere quickly whips around this slowly rotating world.

Fraser: All right. Let's go back to something you mentioned earlier on. I took a note on this – Venus has this strange backwards rotation. What's the story there? That sounds like a collision to me.

Pamela: This is one of the cool things: we actually have a mystery in our solar system. Mysteries mean that theorists get to have fun with their computer models.

As we look around the solar system, things are consistently rotating the same way. If you were standing in the plane of the solar system with north through your head, and pretended to do the US Pledge of Allegiance, with your right hand over your heart, you'd always be orbiting and rotating in the same direction that your fingers are now pointing. So you end up with your left shoulder going back, right shoulder going forward and stepping forward, doing this crazy, swirling dance.

This is what planets do, with a couple of exceptions. There's Uranus and Venus. Venus appears to have somehow gotten either flipped end-over-end, such that its north pole became its south pole, or it got knocked such that it started rotating backwards, or there's some sort of crazy kinematic and tidal interaction that did something to it.

This is the type of thing that when students are looking at pictures of the solar system with the rotation axes on it, they say the same thing as you. "Oh, there must have been a cool collision." There might have been.

Venus doesn't have a Moon; this is one of those curiosities. Earth has a Moon, Mars has a Moon – Mars captured a couple of asteroids, Earth got smacked with something and kept the debris from the smacking.

There are people that think Venus used to have a Moon, and the Moon somehow spiralled down toward the surface and impacted the planet. The conservation of angular momentum somehow ended up screwing up the rotation of the planet.

There are other people that think something came along and smacked the planet and perhaps just flipped it end over end and set it so it was rotating in the opposite direction.

Now, there are also theorists out there who go "tidal forces!" We talked about tidal forces a couple of episodes back. They look at the rate at which Venus is rotating and the rate at which it's linking up with the planet Earth, and they see this 2:3 resonance, where maybe there's tidal forces that are locking Venus to the Earth and the Sun.

By doing complex models, looking at the tidal forces exerted on the atmosphere of Venus, they have figured out that you can actually take a Venus that starts out spinning in the correct direction at normal speeds, slow it down and eventually get it rotating in the opposite direction. Gravity can yank a planet into rotating in the wrong direction. In models.

It could also just have been smacked. We don't know. Because the planet resurfaces itself entirely every once in a while, we have no way of knowing.

Fraser: I guess if there was a way to get geologists down to the surface to examine rocks and dig around, perhaps they could actually try and solve that mystery.

Pamela: The thing is it's quite possible that Venus entirely erased the evidence. Here on Earth, we can figure out what happened with the Moon because we can go to the Moon, measure rocks, go to the Earth, measure rocks and compare the differences. Venus: no moon. Can't look for debris from a collision.

When Venus resurfaces, it pretty much takes the entire outside of the planet, sucks it inside and takes the inside of the planet and puts it on the surface. Whatever happened to it probably happened 3-4 billion years ago. It's been resurfaced probably several times since then, so the remnants of whatever collision might or might not have happened have been reprocessed through volcanism, through tectonics, through general badness of being on the surface of a planet that rains sulphuric acid.

Fraser: We're starting to run out of time, but I wanted to talk about observing Venus in the sky. Do you have any suggestions? Where should people look if they want to find Venus?

Pamela: It's always going to be near the Sun. Venus switches between being a morning object and an evening object; it can never really be both (it's on one side or the other). So look on a website like www.theskytonight.com and if it's up, it will be (flat out) the brightest thin in the direction of either Sunrise or Sunset. You can see it as being slightly greenish.

At its furthest from the Sun, it will get five fists above the horizon, once the Sun has just begun to set. That's fairly high up in the sky. Once you've figured out where it is, you might be able to even go out the next day during the daylight and find it with binoculars during the day. That's one of the really cool things about Venus. If you know where it is, you can find it pretty much any day of the year (as long as it's not right on the edge of the Sun).

Fraser: What does it take to actually be able to see that crescent Venus?

Pamela: You can do it with a 4" telescope. It doesn't take a lot to be able to see that Venus has phases.

Fraser: That's great. Can you see it in binoculars, or not quite?

Pamela: Not quite – at least, my eyes have never been able to make it out. I've heard students claim they could see phases. I love my students; they claim a lot of things.

Fraser: The great thing about Venus is it's so bright that even terrible telescopes will still give you a really nice image of the crescent.

Pamela: Yes. It's just really cool to see half a planet, or a sliver of a planet.

Fraser: Cool, all right. That covers Venus. I guess we'll be on to the next planet in the solar system next week.

This transcript is not an exact match to the audio file. It has been edited for clarity.