Astronomy Cast Episode 223 for Monday, March 7, 2011: The Transit 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 at Edwardsville. Hi Pamela, how are you doing?

Pamela: I'm doing well, Fraser. How are you doing?

Fraser: I'm doing really well. So since the planet Venus is closer in to the Sun than Earth, there are rare opportunities to see it pass directly in front of our parent star. This is known as a planetary transit, and thanks to the geometry of the Earth and Venus, they only happen a couple of times a century. The transits of Venus have been used by astronomers to unlock the scale of the solar system, and there's one just around the corner. Alright, Pamela, so today we're going to talk about the transits of Venus. So first I think, when we think about the geometry of the Solar System, it almost seems obvious, right? The Earth is farther away from the Sun than Venus, and so as Venus orbits more quickly than Earth, you would kind of imagine Venus passing right in front of the Sun like several times a year, or once a year anyway, so why doesn't that happen?

Pamela: Well, the reality is that the orbit of Venus is shifted 3.4 degrees relative to the Earth, so this means that if you had two hula hoops, one smaller than the other, and you lined them up just like Earth and Venus, the one on the inside would be tilted over 3.4 degrees, and the distance between Venus and the Sun is so great that that small shift means that most of the time, we see Venus as appearing above or below the Sun in the sky, and this difference prevents transits from happening on a regular basis.

Fraser: Right, so when we are able to see Venus, it's not lost in the glare of the Sun, then we're sort of making a direct line from us to Venus to some point on the background sky, you know, it's not passing in front of the Sun, but even when Venus is lost in the glare of the Sun, it's actually a little above or a little below the Sun, right?

Pamela: That's exactly the problem we're dealing with and the only time we ever see a Venus transit is that magical moment when it just happens to be that the Earth, Venus and Sun are lined up just as Venus is at that mid-way point in its orbit, at the node in its orbit, where it crosses from above the Sun to below the Sun, and that doesn't happen very often.

Fraser: Right, I can imagine it, right? It's almost like it's…sometimes it's above the Sun, sometimes it's below the Sun…it's just when everything lines up. So how often does this happen?

Pamela: Well, it happens in a pattern of…you'll get a 105.5-year gap, an 8-year gap, a 121.5-year gap, and an 8-year gap, and this keeps basically repeating over and over and over due to the patterns of how the Earth and Venus orbit against one another. There's a basic resonance in the system, and so it's nice we happen to live when we can see a pair of these 8 conveniently for our adult lives, but there's a whole lot of people that are going to live and die in those 100+ year gaps that will never have the opportunity to see this, but right now there are some people that got to see the 2004 transit, and there will be others who will get to see the one in 2012.

Fraser: But that's kind of strange. I mean, you get an 8-year gap, so that's like what we're about to experience. We had one in 2004, and then we're going to see one in 2012, and then you get…what was it? A one-hundred…

Pamela: You have 105.5 and 121.5-year gaps

Fraser: 105 and 121, so why do you get a short gap and then a long gap?

Pamela: It's just the way things happen to line up where you'll get two hits, so you can sort of imagine if you're watching windshields beat up against each other where you'll get two back and forth strokes if they aren't quite perfectly in alignment, where it looks like they're aligned and then they'll go out of cycle for a long time, and then you'll come back and you'll see two that appear to be in line together, and it's just this partnering of those two sets, you end up with it just briefly allows these two alignments to come together perfectly.

Fraser: We often get solar and lunar eclipses paired up in kind of the same way.

Pamela: This is the exact same sort of process.

Fraser: Right, it's because the planet and the Moon and the Sun are all nicely lined up on the one side of the Moon's orbit – you get the solar eclipse, and then 15 days later or less, you get the lunar eclipse. It's just because they're all still kind of lined up. I guess that's what Venus…it's like you're getting one side of it being lined up, but it's still kind of aligned, but the next time it goes past the Sun from our point of view and so you get that alignment, and then it's completely out of whack for the next 100 years.

Pamela: Right. So this is a rare event and it's kind of fascinating to look back over history and think that in the amount of time that we've actually understood orbits, this has only happened really on seven times, and it's only been observed five times, or at least observed well.

Fraser: Mmhmm, and one in our recent history… So then let's kind of go back then -- when was this concept even understood? Right? I mean, did astronomers know that these transits were happening, and they just couldn't observe them, or when did somebody say, "Hey I'll bet Venus is passing in front of the Sun?"

Pamela: As near as we can tell, in ancient and medieval history no one noticed this. Now they didn't exactly have pinhole cameras for projecting the Sun up on walls; they didn't have lenses, so there's no real way to observe this happening, and in fact, it wasn't until Pythagoras came along that people recognized that Venus in the morning and Venus in the evening were even the exact same object. So it really took until Kepler came along in 1627 and started running numbers that we're able to make this sort of prediction. And unfortunately, while Kepler was working, while he was working with the most precise numbers at the time, we still have a lot to learn. And so when he predicted the 1631 transit, he wasn't able to predict where on the planet it would be viewable from, so it wasn't viewable in Europe, and no one actually made arrangements to go see it where it would be visible because, well, we were still sort of figuring that sort of thing out.

Fraser: Hold on, so it actually depends on where you are on Earth on what you're going to see?

Pamela: Well, it's the old problem of half the planet's looking toward the Sun and half the planet's looking away from the Sun, and you have to be on the part of the planet that's looking toward the Sun and be able to see Venus and the Sun in the sky at the same time, which is anyone who could see the Sun, in order to see the transit.

Fraser: So the transit has to occur during your "day?"

Pamela: Right, and if it's nighttime during the transit, you get to sit on your thumbs and be bored.

Fraser: Right, or get traveling, and I guess back in the day, that was a pretty serious commitment. I mean, if you're in Europe and you're not going to see it unless you're in North America or in Asia, that's a big trip.

Pamela: Those are major endeavors and this actually led to a few people having a lot of life difficulties, I guess is the best way to put it.

Fraser: I know, there's some amazing adventures in trying to see this transit.

Pamela: There was this poor fellow by the name of Guillaume Le Gentil (and this is where I say I can't say anything in French correctly), and this poor fellow took off to try, try to view the 1761 transit, except it…pretty much the planet was against him. There was French and British wars to contend with, Spanish uprisings in various places…this was during the Colonial Period, and the poor fellow was basically trying to get originally to a French colony in India and finally arrives after all sorts of trials and tribulations, bouncing all over the planet in some regards -- and he gets clouded out.

Fraser: [laughing] That was like you seeing the solar eclipse and you got clouded out.

Pamela: Except for me I had the option to just hop on a plane and fly home and I was home two days later. So this poor man, he's gone all the way around the planet, and he decides that he'll just stick around for eight years, and -- I mean, can you imagine? This is a married man, who in the name of science, decided to just spend an extra eight years.

Fraser: Yeah, that would really fly in my house.

Pamela: Yeah, I think I'd be a dead woman. There are no number of spousal permission units for that one. So he decided to spend eight years mapping the eastern coast of Madagascar, which was a good use of his time, and he continued doing various astronomical observations, but then come June 4, 1769, according to what I've been able to read, he'd been dealing with beautiful glorious awesome weather, day after day after day after day -- until the day of the transit, and he pretty much went insane at this point, and it took him a while before he reached the point of being able to pull himself together and consider journeying back to France. By the time he finally got home in 1771, his wife is remarried, his family plundered his estate (they'd assumed him dead), he'd lost his academic posting, and the King of France had to intercede to get this poor man's life back together.

Fraser: Well, sometimes you gotta take those big risks for science.

Pamela: You know, I'm willing to pull the all-nighter occasionally, but 11 years facing things like dysentery and civil war is not something I'm willing to do in the name of astronomy.

Fraser: You just don't want it bad enough then.

Pamela: No, I don't. I don't.

Fraser: OK, so that's just one – I know there's a whole pile of stories, but I think even further back astronomers started to get a sense that the transit of Venus was something that they needed to observe.

Pamela: Exactly.

Fraser: But why?

Pamela: It's a simple reason: we didn't know where the Sun was. We knew it was in the sky. We knew that it was a standard distance away from us because it didn't appear to change in angular size all that much. We knew there was some variation, but since we didn't know the exact size of the Sun, we couldn't say how far away it was precisely, and the hope was that if you got two different people observing when Venus appeared to cut in front of the Sun, and when it appeared to come back out again, that by timing these transits, and being on different north-south lines, we'd be able to calculate via parallax the distance to the Sun -- and it worked!

Fraser: Right. So just to understand this: I've got it's not about making one observation; it's not like me going to India setting up the telescope and having good, clear skies and being able to make my observation. It's about me being on one spot on the earth, and you being on another spot on the earth at the same moment, and us both doing our observations, and then the difference between our observations is what then gives us the triangles that we use to calculate everything.

Pamela: Right, and you can get a long way simply by doing one observation and carefully measuring "when does Venus start to pass in front of the Sun?" and we break this up into four different contact points: so there's the moment at which the leading edge of Venus touches the Sun, there's the moment at which the trailing edge touches the Sun (so now you have the full disk of Venus in front of the Sun), there's the moment of which the leading edge of Venus touches the other side of the Sun, and the moment that the trailing edge of Venus touches the other end of the Sun as Venus completely leaves being in front of the Sun. And we know how fast Venus is orbiting, and that gets us part way there, so you do want multiple measurements; you do want multiple measurements from multiple places, but it's a matter of: you need all four timings as well to get you there.

Fraser: Right. And so the more measurements you get, the more people who measure all those different timings, then you can build that accurate thing. So you've got all these measurements, the astronomers come back together, they do some math and then what does that tell them?

Pamela: Well, for the 1761 and 1769 pair of transits, Jerome Lalande was able to calculate that he thought that the Astronomical Unit -- the distance to the Sun -- was a 153 million km. This was only good within a million kilometers, and it turns out that it actually wasn't good within a million kilometers, but this was the most accurate number we had up until that point of how far away the Sun was, so that was an excellent start. And then the next set of transits in 1874 and 1882 allowed us to get to the point that it was within a million km accuracy, so they came up with 149.59 million km, and the real number is 149.598 and then we can add more digits. We actually know the distance within meters, but that number changes depending on where we are in our orbit.

Fraser: But before that, literally, astronomers had no idea. Like it's probably not 20 km away, but it might be 10,000, you know? We're not really sure, so you know, it might be 100 km away, in fact, as you said, it's 150 million-ish km.

Pamela: We knew it was beyond the moon…

Fraser: Yeah, I know, and they just had no sense of scale at all, and suddenly they now were within degree bars that were quite comfortable to wrap your head around.

Pamela: And from Kepler's laws, by knowing the distance from the Sun to the earth, we could then scale the entire solar system because we knew how the ratios of the planets worked. We knew that if the Earth orbits at this period of time, and Venus orbits in this period of time, what the ratios of their distances from the Sun had to be, and so this one simple, but hard-to-get-physically-to measurement allowed us to not just measure the distance from the Earth to the Sun, but effectively measure the distance from the Earth to everything else that we'd observed orbiting the Sun.

Fraser: Yeah, it unlocked our place in the universe, as we understood it then, you know, and then later on you get the other sort of deeper understanding about the rest of the scale the distance to the stars the other galaxies, but for a while there just knowing the size of the solar system -- I'm sure was pretty amazing.

Pamela: It was a step in ever growing our solar system.

Fraser: Now, I know there are more hilarious, hijink anecdotes for people trying to see these transits. Are there any more great stories?

Pamela: That's really the one that is so amazingly over the top that everyone repeats it over and over and over. There is, of course, Captain Cook made observations at a point that is still called Venus Point, Catherine the Great invited people to observe the Transit in St. Petersburg…so I mean, can you imagine a royal party just to watch and astronomical event? That's just a fabulous idea. We need more kings, queens, presidents and prime ministers inviting people to make astronomical observations, but those were the main ones. The big issue is for a long time you pretty much had to get to awkward locations like random archipelagos to make good observations, and in days where ships were powered by the wind, that wasn't a good thing to have to experience.

Fraser: Yeah, yeah, I mean, I guess if you knew the next transit was going to come in eight years, you started to go pretty soon, you know, give yourself a year to get over there, right? So then the next one -- now there was the one that was in 2004 I didn't get a chance to see it. Who got to enjoy that one?

Pamela: Europe's had a very good view and bits and pieces of North America got to see it during sunrise. I and some other colleagues made a foray up to Nova Scotia because that put us an extra hour to the east and we had some very nice telescopes set up overlooking the Bay of Fundy, which is absolutely a fabulous location to be, and we got rained on so we used our telescopes to view baby eagles plunging themselves happily into the Bay of Fundy, but folks in Boston, where I could have stayed home, were able to see it as the Sun came up, [laughing] and there was an excellent view in lots of parts of Europe.

Fraser: But you didn't stay eight years, though.

Pamela: No, no.

Fraser: You're not still there right now…so let's talk about the next one, then. When is it? Set your calendars everybody.

Pamela: Set your calendars. And now is the time to make your reservations because hotels will book up, and tour groups will book up. So the next one is scheduled by the

Sun and gravity for June 6, 2012 and it will be visible at sunset for all of continental North America, Mexico and northern South America. Unfortunately for southern and central South America, no transit is going to be visible – it's nighttime. And the same is true for South Africa and much of the west coast of Africa, but then if you want to see it during sunrise, just travel to the eastern coast of Africa and to anywhere in Europe except for Spain and Portugal. Spain's kind of "iffy" depending on where you are, but everything to the east of Spain and northward…it's going to be visible during sunrise all the way to about the midpoint across Russia and China, and then for the rest of the parts of the world that I haven't mentioned that much about, it's just going to be visible the entire time, so much of Australia, all of Japan, Indonesia, Alaska…it's going to be visible in its entirety. And in fact the best place in the world to be is going to be off the coast of Japan – a ways off the coast of Japan, but in the no-man's-land where nothing really exists.

Fraser: Come on, western Canada? Will we be able to see it in western Canada?

[laughing] You are able to see it if you go north, if you go way north, it will be visible during daylight and the rest of the time it's going to be…you'll be able to see it during sunset.

Fraser: Perfect. Barbecue! I'll have a barbecue.

Pamela: That sounds excellent…perfect summer weather.

Fraser: Perfect summer weather, transit of Venus in the middle of it, sounds good. You're all invited. People are going to take me up on this…[laughing]. So now don't just stare at it with your eyeballs -- standard, "you're looking at the Sun" precautions apply here.

Pamela: Yes, in fact the best way to enjoy this is to make yourselves a pinpoint projector. Take a piece of foamboard, poke a hole in it and you can fuss with it, actually I've seen a lot of people take these things and attach them to camera tripods, and things like that where you can use the part where you normally stick your camera on the tripod, use that as the flat surface to attach the foamboard to and then move this around until the Sun is shining flat against the board, and then use a second board or a wall or something else to project an image of the Sun onto. Now, if you're feeling a little bit more industrious, one thing I've found is a great way to view these things is Edmund Scientific sells these tomato-shaped telescopes. There's really no other way to describe them. They are these little, red -- maybe you'll see them looking as like some sort of a crazy beaker -- they're strange-shaped bright red, cherry tomato telescopes.

Fraser: Like a gourd…

Pamela: Yeah, basically, and they're not that expensive, and they're very hard to destroy. And what you can do is just pull the eyepiece out, point the telescope at the Sun, and project the light that is coming out through the eyepiece onto a wall, and this is a really good way to get a nice, crisp magnified view of them.

Fraser: See now, I think that's cool, you know, but taking something that people are only going to see, for many people never in their lifetime, and using a piece of cardboard to watch it…like what would be the greatest experience? You know…

Pamela: OK, so the absolute best way to observe this, if you're willing to invest some money, is to get a nice set of neutral density solar filters. These are filters that allow you to continue to see sunspots. They don't let you see the corona and they don't let you see the granulation on the surface of the Sun, but those things can really confuse you if you're trying to watch Venus transit. So just a nice Baader Sun filter for a good 4-inch telescope is really all you need.

Fraser: What about binoculars?

Pamela: You know, I actually bought solar filters for my binoculars, so I just have a pair of everyday Nikons. Now, the problem that I've run into (and this may be one of I'm not a coordinated individual) is when you're trying to point binoculars at the Sun, you either see absolutely nothing, or the Sun. So, it's not like you can go "OK, the Sun is straight up from that lamppost. Find the lamppost; scroll up on the sky." No, you just have to sort of dead reckon your way to the Sun.

Fraser: I think people can work their way through that problem.

Pamela: [laughing] OK.

Fraser: Yeah, so again though, it's almost like the kind of binoculars you'd want for doing some really nice stargazing, or even planetary observing are total overkill for this kind of a job.

Pamela: Actually, it depends on how active the Sun is. The thing about the 2012 one is there is some potential for there to be good sunspots, so having reasonably good binoculars where the Sun nicely fills your field view and allows you to see sunspots, I think, is completely reasonable. The real trick is just getting a good fit on your solar filters because they come in a lot of different sizes, they're not necessarily brand-specific, and the trick I actually learned…I bought a nice pair of filters from Oceanside Photo and Telescope that found filters that, in theory, matched my binoculars, but I didn't trust the filters to actually stay on is I got foamy tape, that type of tape that you might put on the bottom of a television or something to make sure it doesn't scuff shelves, and I just put foamy tape all around the inside of the filter cap, and that made a much snugger fit.

Fraser: And so how long does the whole transit take?

Pamela: Hours.

Fraser: Oh, really. OK.

Pamela: Yeah, this is an all-day…you're idea for a barbecue is actually pretty much right. You can start heating up the charcoal at first contact, and be finishing off your ice cream and thoroughly exhausted and children melting in the corner about the time that it's ending.

Fraser: Right. Right. OK.

Pamela: With time for a game of volleyball in the middle…

Fraser: And one thing that's kind of neat to add on top of that is that if you're going to test out a pair of binoculars or your telescope to see if you've got the right kind of magnification, you can always use the moon as a stand-in because it's the same size.

Pamela: Right, so before you even buy one filter, just go out and look at the moon.

Fraser: Yeah, and that will make sure that you're happy with the size. And then how big will Venus appear?

Pamela: [laughing] You know, the last transit there are a few pictures…I'm actually thinking of the last Mercury transit, not the last Venus transit…there are pictures where some of the sunspots were bigger than Mercury was and bigger than Venus would have been. So if you think of a nice, really large sunspot cluster, that's about how big Venus will appear, except Venus is a nice, perfectly crisp, round object as it passes in front.

Fraser: Right. But we won't see like a shadow?

Pamela: No, no, no…

Fraser: Since the Sun is the thing that's putting out the light…OK. Well that's great, Pamela. I'm really looking forward to watching the transit. This time I get to see it, so that's fantastic! Well, we'll talk to you next week. Thanks!

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