Astronomy Cast Episode 234 for Monday, October 10, 2011:

# Lunar Phases

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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: Good. So once again, we're recording this episode of Astronomy Cast as a Google hang-out, and so all of the…our eight closest friends who are listening to this episode -- you can all wave, but keep your microphones silent. So…if you want to participate with us, probably the best thing to do is to go onto Google plus, add me and/or Pamela to your circle, and then you get the notifications on when we do them. Right now, they're completely random, and I apologize for that, but that's just sort of our schedule, so it's sort of like if you happen to notice that we do the recording, and it fills up fast, and I apologize for that, and so if anyone from Google's listening, let us get on to the Google hang-outs on-air -- that would be awesome, and then we can broadcast it to a larger audience. So now, did you have any more…anything else to update this week?

Pamela: Um, no. I have absolutely nothing. It's boring.

Fraser: You're plugless?! What?! You?

Pamela: I…well, we need donations -- we always need donations, but we have to restock our store, so go in there. You can buy lanyards, but you know, by the time people listen to this, we are going to be selling "Surlys," so there may be "Surly Amys" available if you go in and check out Astrogear.org.

Fraser: These are cool little ceramic necklaces that have our logo on them among other things. OK, well let's get rockin' then. So the moon is a stark reminder that we actually live in a universe filled with stars and planets and moons. The changing phases of the moon show us the relative positions of the Earth, the Sun and the Moon as they interact with one another. Let's learn about the different phases, the geometry of the whole system, and some of the interesting science wrapped up with our fascination of our only natural satellite. Did you like that? Was that a nice intro?

Pamela: You're getting good!

Fraser: So I think that, you know, but I mean, when I look out and I see the Moon, and I see the phases, it's…for me that's the reminder that we live in the Universe and that we have this ball of rock orbiting around the Earth. So how did the early astronomers and philosophers and stuff try to come to grips with what they were seeing in orbiting the planet, or not even orbiting the planet, just in the sky?

Pamela: Yeah, it was a god. It was not actually attributed as the source of the tides until remarkably recently. That's something that continues to confuse me is how did Galileo not realize, among everything else he realized, that the Moon is responsible for the tides? But it was seen as a god for a while… They realized that it was part of the Solar System and along with the planets and the Sun was originally put on an orbit going around and around the Earth, and it was a holy object and a celestial object, but they didn't realize it was a rock until Galileo came along and that was actually kind of a complete change in paradigm. Before that Aristotilian philosophy had said that the Moon was a perfect sphere – it wasn't a perfect color, but it was a perfect sphere, and when Galileo looked at it through a telescope, he realized there's mountains. They didn't have the concept of crater, but there were mountains, there were differences in coloration, he could see shadows, and that was when they finally realized 400 years ago: it's a rock. And since then we've been trying to understand it from a geologic point of view, trying to understand it as another object a lot like the Earth in many ways.

Fraser: Right. So when we see the moon, when we see the phases, when we describe it as "phases," what are we really seeing?

Pamela: We're just seeing differences in geometry, basically, between us, the Sun and the Moon. As the Moon goes around and around the Earth, you can imagine there's this line connecting the center of the Earth and the center of the Sun, and when the Moon is on that line between us and the Sun, all of the Sun's light hits a side of the Moon we can't see. Now, most of the time, the Moon isn't actually on that line in particular. It's above or below the line, such that it doesn't come between us and the Sun. The Moon's orbit is tilted relative to the Earth, and this a good thing, otherwise we'd get monthly lunar eclipses, and that would get really un-exciting after a while.

Fraser: Right, and I think the way to do this right, of course, is to go into a really dark room with like a tennis ball, and hold…and then turn a really bright light on or a flashlight on from one source, and then hold the tennis ball at arm's length. Your head is the Earth, and that's what we see, and then if you put the tennis ball right in between us and the…you know, you and the flashlight. You can't see the illuminated side of the Moon, and that's the new moon. Now, you could still have the tennis ball a little above or below the flashlight itself, so you could still actually see the flashlight, but you're not going to be able to see the lit side of the tennis ball -- and that's the new moon.

Pamela: And the way it works is it's actually a couple days' orbit to either side of the new moon before we can start to clearly make out the crescent moon, and exactly how long depends on how good your eyes are. And holidays like Ramadan are actually tied to: when is it that you first see that crescent moon reappearing as the Moon comes out and starts to show its illuminated side again? And I know for me, in particular, my favorite views of the moon are these amazingly thin crescents that you can sometimes see in the twilight.

Fraser: And there's some really neat astrophotos that I've seen as well, where photographers will catch the moon -- you know, they're trying to break the record for the newest moon that they've been able to image. They'll try to image the moon hours or even minutes after it's passed the new moon phase, and try to get the littlest sliver of sunlight.

Pamela: Right, and yeah, it's really amazing, particularly when you can start to get it close to planets and things like that. There's been a few cases where you've had the Moon right next to Venus, the Moon right next to Mercury in the sky, and one of the things I love is watching how often people get the crescent moon completely wrong in artwork because you need to think of the illuminated side of the Moon as chasing the Sun across the sky, so as the Moon gets closer and closer to the Sun, you end up with a thinner crescent and it's curved so that the illuminated part is toward the Sun, and the nonilluminated part is away from the Sun. And as the Moon goes past the Sun, it switches to keep the illuminated side always closer. Now, this has the effect that as the crescent moon gets low on the horizon following a sunset…so you have the sunset first and then the Moon setting later, you should have basically horns poking up where the Moon is doing an imitation of a longhorn for all you UT alumni, and occasionally you'll see crescent moons drawn so they're perpendicular to the horizon, and that geometry just does not happen.

Fraser: That doesn't happen. Right. OK, so let's imagine that we're going to sort of take one full circle – again, go to your imaginary dark room with your tennis ball held at arm's length, and so you're seeing this thin sliver of light on the edge of the tennis ball, and as you turn, you're seeing that grow and grow and grow. Now, which way are you turning?

Pamela: So, the way I always remember it is you take your right hand, put it over your heart, and the direction of your fingertips -- that's the direction the Moon orbits, so it's going from the right toward the left around your head if the North Pole is at the top of your head and the Sun is in front of you.

Fraser: So I'm turning left…is that right?

Pamela: Yes.

Fraser: In the room…OK, so I'm arm out, tennis ball, and I'm turning left, and so I'm seeing more and more light on the tennis ball; I'm seeing this wrap around and I guess that's the indication…and that should have been the indication that the Moon is a sphere is that you're seeing this crescent shape wrap around, this light on the Moon, that should have just been like, "Duh, everything's a sphere, even the Earth. And they're all orbiting one another, and the Sun's probably a ball…" and you know, like, it's funny that that didn't sink in.

Pamela: Well, the Greeks were pretty good about understanding that the Moon is a sphere. It was the everyday people of Europe in the times of Columbus that weren't so keen on the "round planet" thing going on. So it's interesting how knowledge doesn't always filter through and, um, yeah, yeah…so smart people did figure it out: it is a sphere based on the pattern of the shadows moving.

Fraser: And so now I've turned 90 degrees, and so you can imagine now that before my arm was stretched out pointing towards that flashlight. Now, I've turned left so that my, sort of, right shoulder is facing the light and I'm holding this tennis ball out, and now I guess I'm going to see half the ball illuminated?

Pamela: You have a first quarter moon, and the first quarter moon actually can do some really neat tricks. It's a moon that you have a chance to see both during the day and during the night. It's one that rises at noon, it's high in the sky at six p.m., setting around midnight. This is a moon that people really like to have around for star parties, so a lot of groups will schedule their star parties specifically for first quarters, so they can show people the shadows that Galileo saw.

Fraser: Right, of course. I mean, the best time to look at the Moon with a telescope is this halfway point. You know, at a new moon you can't see anything, at a full moon everything washes out, but when you have this quarter moon you have these nice, long shadows across the surface of the Moon and the craters are just highlighted, and you can really see them, so a lot of the times when you have this full moon, people are like "Oh, can we look at it with a telescope?" but that's actually the worst time. It's much better when it's this quarter moon. Oh, and we actually got this…we did an article recently in *Universe Today* about this. People were wondering, "How can we see the Moon and the Sun at the same time?" -- and this is it. I mean, if you are near the equinox, you've got these, sort of, night and day having roughly the same length of time, so you can absolutely have both the Sun and the Moon in the sky at the same time. So, it's all geometry. Right, so now I'm holding this tennis ball, and I see it sort of half on and so now I'm going to keep turning, and so now my back is to the light, my…I'm holding the tennis ball, but the tennis ball's not in my shadow, so I'm not actually blocking the light from the light to the ball, and so now I can see a full moon, so I can see the whole tennis ball that I can see is completely illuminated by this light.

Pamela: So, you've now watched the moon do what's called "wax." So "wax on, wax off"-- the Moon does that. You've seen the Moon wax toward full, you now have a Moon that if you end up with a full moon precisely at the equinox, some really neat things can happen. So if you traveled to the Equator and it's one of those special equinox days (September, March), you can have the Sun setting at 6 p.m. in the west at the exact same moment that

that full moon is starting to peek itself up above the horizon in the east. This is a kind of magical thing to get to see. Even if you don't live on the Equator, you still get to see the same effect. It's just not quite as dramatic when you're elsewhere on the planet. The full moon is the washed-out, hard-to-see-interesting-features Moon, but it's still pretty impressive when it's down low on the horizon, and this actually leads to "the Moon illusion."

Right. "The Moon illusion" -- this is where people always think the Moon looks way bigger when it's close to the horizon. It's the Moon is just rising, "Look how big the moon is!". It's hilarious if you go onto Twitter, and you do a search for Moon around the time of the full moon, you will see tweet after tweet, post after post, people going, "Why does the moon look so big? Look how big the moon looks!" and I'm often…I'll just jump in and reply to people, I'm like: "It's not actually big, it's just an illusion, it's a trick of your brain," and I'll link them to various articles that are happening, but the…and the way that you can test this out, right, is you hold your arms out at full you know at arm's length, your nail on your pinky finger will cover up the Moon perfectly and then you try it again later when the Moon is really high up in the sky and you'll see the same thing, so you're clearly being tricked.

Pamela: And what's kind of neat if you have a telephoto camera, you can actually magnify this illusion. Get so that there's some dramatic building off distant on the horizon with the Moon rising right beside it. Well, the distance between you and the Moon hasn't really changed, but the distance between you and that building has changed significantly enough that it appears really small. Now use that telephoto lens to zoom in on the building and the Moon will appear as big as the building -- and this is just an effect of making the building the size of a fingernail so that it's the same size as the Moon. It's a great way to make a dramatic photo.

Fraser: And I've seen some great time-lapse photos that people have done where they capture the Moon every two minutes or so, and you get just circle, circle, circle, circle, circle, and you can see the transition of colors. The Moon is coming from the horizon up higher in the sky, and it's getting through the atomospheric haze, and it's changing its color from this deep red to yellow to white, but the size is exactly the same -- it doesn't change, and so you can really see clearly this is not the case. The Moon does not change in size at all, and yet if you go outside and look at the Moon, it will absolutely trick you every time -- and you fall for it, too. Now, we mentioned that back when the Moon was a new moon, and now when the Moon is a full moon that, you know, the Moon is not blocking our view of the Sun, even though the Moon and the Sun are actually roughly the same size in the sky, and yet the shadow of the Earth is not falling on the Moon, so why when you get these…these…this geometry, why is this not happening? Why is the Moon not blocking every time, and why is the Moon not passing into our shadow every time?

Pamela: So we have this double-angle effect. The Earth is inclined relative to the Sun, and then the Moon's orbit is inclined relative to the Earth and this adds up to have the Moon, most of the time, as much as more than 20 degrees above or below the center line that connects between the Earth and the Sun, and this difference in angle is sufficient to keep that little tiny moon from blocking that little, tiny sun in the sky. So the way to do this is to actually take a hula hoop and connect your tennis ball somehow (cut the hula hoop, drill a hole through the tennis ball), and take that hula hoop and tilt it slightly. And the act of tilting it…you can now see what the orbit does, where that tennis ball is most of the time above the line or below the line, but twice each month, it cuts across the line and we only end up with an eclipse at those two magical times, and it's not magical, it's physics, it's geometry -- at those two times of the year when the full moon just happens to occur near the time when the Moon is cutting across that line between the Earth and the Sun.

Fraser: Right, and we've mentioned before in our "Eclipses" episode that they often go in pairs -- that you'll get a solar eclipse and a lunar eclipse in…one after the other because the Moon is spending its time…it's at the point in its orbit, or the point of its inclination where it is actually passing through the shadow, and then blocks the Sun on the, you know, half a month later. OK, so we're at the point now where we've got our maximum brightness, the Moon is washed out, we're not really seeing anything and then we're turning, we're continuing to turn, we're turning left some more before we were waxing, so now the amount of Moon we're seeing is starting to decrease again.

Pamela: So now we're waxing off, or the correct term is "waning," and a lot of people will mispronounce it as "wanning" so you can…

Fraser: "Wanning"…like you!

Pamela: I'm better now, it's "waning." I've learned, and…

Fraser: That's all I'll say. Just to…not to drag you through the mud, but in a previous episode, that is what you said, and I called you on it, and I did a bunch of research, and I was right, and anyway…who's the astronomer now?! Anyway, let's continue… I know, I'm the linguist…

Pamela: Yeah, well, this is what happens when you learn from books. Books don't teach you how to pronounce things.

Fraser: Right. So the moon is waning and it is…we're still turning left, the Moon is waning, the amount of light…so now we're seeing almost like this crescent of darkness starting to appear on the Moon as it's getting less and less, and the funny thing as well is you'll still get, as I've said I've been watching the twitters recently, and people will still for about four days think that the moon looks full.

Pamela: Right, so as the Moon orbits past the position of true full moon, it takes us a while to catch on to the fact that this is now called the gibbous moon. This is any time the moon is less than full, you can have a waxing gibbous, you can have a waning gibbous…and it wanes its way towards what's called third quarter.

Fraser: Right, so I'm continuing to turn left holding this tennis ball on the hula hoop at arm's length with its slight tilt, and now, again, I'm seeing the Moon half-lit. The front part is lit from the light, the back part of it is in shadow because I'm seeing it from the side, I'm seeing it half lit, half in darkness, and it is a waning quarter moon now. It's a last quarter moon? Is that right?

Pamela: Last quarter, third quarter -- this is when you see the Moon in the morning. And I know one of the things that stumped me is you're seeing half the Moon, and we call it a quarter moon, and that was profoundly disturbing! Well, it's because it's a 3-dimensional object, and so we're seeing one quarter of a 3-dimensional sphere illuminated, so a full moon is a half moon.

Fraser: Right, we're seeing one quarter illuminated; we're not seeing the quarter that's also illuminated, we're seeing one quarter of it that's dark, and we're not seeing the other quarter of it that's dark.

Pamela: Right.

Fraser: OK.

Pamela: So, it's that silly geometry. Once again, if you want to learn geometry, the Moon offers you everything you ever didn't know you needed to know.

Fraser: And even more… Right, so you've got… and then the Moon continues on in its orbit, day after day, and you get to the point where we approach it being a new moon again.

Pamela: Exactly, and the thing that is interesting about all of this is because the Moon's orbit isn't completely circular – it's slightly elliptical, its speed actually varies as it goes around, sometimes it's moving a little bit faster, sometimes it's moving a little bit slower and this causes, since it's rotating about its axis at a constant rate, this causes, sometimes its rotation gets a little ahead of its movement around the planet, sometimes it gets a little behind its movement around the planet, and this allows us to see a little bit more of the planet than we would get to see otherwise. And since its orbit is inclined up and down relative to the central line, we also get to see a little bit more in the north-south direction as well. So along the way, even though in general the Moon looks the same, if you take photo after photo after photo what you realize through the passing nights, is we're actually getting to see a little bit extra of the Moon as we get to look over the top look under the bottom, look around to the east, look around to the west, and all these different motions together get referred to as the lunar librations.

Fraser: And there's an astonishing video that we…we actually posted on *Universe Today*, so Nancy's going to be doing our show notes, and she's going to know exactly the video that she did where you see the Moon move through all of these phases and it just looks…it just looks amazing. You can see the Moon almost -- I can't even describe it, I'm using my hands here, but it looks like it's sort of oscillating back and forth, it's like it's wobbling back and forth over this period. It's one of the coolest videos you will ever see, so I highly recommend…look for…check our show notes, or do a Google search for lunar libration video, and its just astonishing! The other thing that's really interesting to see is the fact that the Moon, as you said, it's on an elliptical orbit, so the times that it's very close and the times that it's very far, actually will get out of sync with the full moons and the new moons, and so you will have full moons that are super-full, you know, these "super moons," and then other times you're going to have these times when the…even though it's a full moon, it's at the furthest point, you know, the apogee of its orbit, and so it looks a lot smaller, and it can be significant. So the Moon when it's at the perogee and at full moon at the same time, it's actually quite bright.

Pamela: And this is where we end up with annular vs. full solar eclipses is when you have the Moon, in the case of an eclipse, at new moon when it's closest to the Earth, it's much bigger and it's able to block the Sun for longer; whereas, when you have the Moon at its greatest distance when it's new moon, and you have a solar eclipse, this is when the Moon can't even fully block the Sun, and you end up with what is called an annular eclipse. So there's lots of different things to take into consideration, and one thing, though, that is a myth -- there are people who are actually concerned when there's a full moon with the Moon at its closest to the Earth that this can actually have major geological effects on the planet Earth, and there are people out there who tried to blame the earthquake and tsunami in Japan on a "super moon" that occurred a few days later. That's just not something you actually have to worry about. The difference between these two things in terms of percent change, is sort of like if you're in California and you jump east -- how much closer are you to New York City at that point? It's just not a lot to have to worry about.

Fraser: Yeah, again, you feel more gravity from, you know, I don't know, a table in front of you than the Moon, so and the changes are not going to wrench the Earth's surface apart, and it doesn't matter! What does it have to do with the phase of the Moon? The Moon gets that close every month, and so whether it's illuminated or not illuminated has no difference on the geologic impact on the Earth -- so get that out of your heads.

Pamela: Right.

Fraser: So before we wrap this up there's this one thing that's kind of neat. So what we see playing out with the Moon going around the Earth, we also see with Venus going around the Sun; Venus goes through phases, too.

Pamela: Right, and so does Mercury; it's just a lot harder to find Mercury, at least with a pair of binoculars -- it tends to get lost in the twilight Sun. So one of the ways we're able to figure out that Mercury and Venus go around the Sun and not around the Earth is from the phases that we're able to see. If Mercury and Venus weren't located where they are, we wouldn't be able to see them go through essentially a full set of phases. So what happens is as Venus gets ready to pass behind the Sun, we can see it as almost full, or if you can ignore the glare of the Sun somehow, a full Venus. Now, as it comes back around towards us, it gets to a crescent phase as it passes above or below the Sun. We essentially have a new Venus phase if you could find it in the glare of the Sun. It works best if you're in space and can block the Sun without having the atmosphere get illuminated in the process. And it was Galileo that was able to see Venus go through this full set of phases, and there's something actually really awesome about seeing a crescent Venus. And you can really see the angular size -- how much of your field of view and your eyepiece Venus takes up as it's closest to you for the crescent phase, and then furthest away from you for the full phase, so you get to see this tall, skinny crescent Venus, and the much smaller full Venus in the greater distance.

Fraser: Yeah, yeah, and it's actually brighter when it's in the crescent phase than it is when it's further away, right?

Pamela: Right.

Cool! Well, thanks a lot, Pamela. Well, so I hope you can all do this experiment in the room, show your kids, really let it sink in, and then never be confused by the phases of the moon again. That was awesome – thanks!

Sounds great! I'll talk to you later.