AstronomyCast Episode 245
For Monday, December 26, 2011:

Calendars

Fraser: Welcome to AstronomyCast, 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: Good. I see you're rested from your exotic cruise.

Pamela: I'm not sure I'd say rested. The thing about vacations is there's so much to do that you just come back a different form of tired.

Fraser: I think your body is so used to travel that it can't tell the difference between holidays and going to some astronomy conference.

Pamela: No, that's entirely true.

Fraser: So for anyone who wonders, we've taken our Google plus experiment to the next level, and we're now recording this episode as a Google plus "hang-out on air," which means that it's just Pamela…me and Pamela in this recording, but we've got anyone who wants can actually watch us record the episode on Google plus, and then when we're done, we'll open it up and let people join us, and we'll ask questions, and we're going to record the whole thing, and we're going to put it on YouTube or something, and so, you know, hopefully, try and make the whole thing a little more interactive because one of the coolest things about doing these hang-outs on air, or the "hang-outs" is that we get to answer questions and meet with the fans. We're trying to sort of take that to the next level. So in the future, if you miss this one, we're going to try to move to a regular

schedule now where you can know that at a certain time you'll be able to join and watch us record AstronomyCast, or you can just wait until it pops up in your audio player just like normal. Nothing's going to change, just more – more better.

Pamela: But this means people can subscribe to our YouTube channel as well as our itunes feed.

Fraser: Yeah, right. It's going to be very confusing.

[advertisement]

Fraser: OK, well let's get cracking. So our lives are ruled by calendars and the calendars are ruled by astronomy, so as we near the end of 2011 and get ready to ring in the New Year, let's discover the astronomy underlying the days, weeks, months, and years that segment our lives. So… I was really worried when I was doing that intro because I was thinking you know this almost starts to sound like astronomy, like, our lives are ruled by the motions of the stars. You know, it's very "astrology sounding," so not astrology, but astronomy runs everything.

Pamela: Right, so I mean, if you think about it, there are so many different things -- mostly related to agriculture, admittedly -- that without knowing exactly what dates the Sun is where, you're going to end up freezing your vegetables, or not harvesting your wheat on time. So at the end of the day, our nearest star, our sun, rules how we should set up our calendar if we want our calendar to make sense for agricultural purposes, and if you get agriculture wrong, everyone dies of starvation.

Fraser: Right so getting some kind of calendar set up and in place is critical. Some of the things that happened, such as the day and night cycle, are just hardwired right into our evolution, but other things clearly are human constructions. So when did calendars first start to happen?

Pamela: As near as we can tell, there's always been some sort of a calendar system, but there haven't always been sensible calendar systems, and the problem that we run into is the Moon doesn't politely orbit the Earth in an integer number of times every year, and so the easiest way to set up a calendar is to set it up based on the lunar cycles, based on full moon to full moon, or new moon to new moon, but if you do that, your year ends up

being about ten days too short and so there's this problem of "Oh, (insert expletive of choice)! How do we keep our year cycled with the planting season?" So then you have to start inserting leap months, but even if you just come up with some mathematical equation to try and tie it strictly to the Sun, even the planet's rotation about its own axis isn't an integer number of days per year, so you still end up with this leap-cycle problem, so basically we've always had calendars and they've never worked.

Fraser: Always had calendars, and they've never worked [missing audio]. So then what are some of the calendars? I mea, what are some of the early ones that people started to use? Because I guess the point being that because they never worked, people have needed to come up with some invention or some solution to solve the problem that Mother Nature doesn't…you know, didn't nicely match up the lunar cycles to the solar cycle.

Pamela: So pretty much looking across all the different calendars, you want to look at…we find over and over and over that early calendars tended to be built on the 19-year cycle because the number of lunar cycles it takes to line back up so that you have a full moon with the Sun in place "X," and you have a full moon *again* with the Sun in place "X" is about (within a few hours) nineteen years. So culture after culture after culture built a 19-year calendar that was based on mostly having 12 lunar months, but then every few years sticking in some sort of a leap month, so this is just one of those things that everyone seemed to settle down upon in some point in their calendar.

Fraser: And so can you give me some examples? I mean, were there some cultures that used that?

Pamela: Well, we see it, for instance, in the Chinese calendar. This is one of the cultures that continues to use this type of calendar today, where they look at the lunar cycle, but it's not built purely off the lunar cycle. The Islamic calendar is built purely off the lunar calendar. The Hebrew calendar is sort of-mostly-kind of built off the lunar calendar. And they look at where the Sun is, they look at where the Moon is, and really they're all kind of complicated -- and crazy math.

Fraser: [missing audio]

Pamela: Well, I mean, really they just sort of have to do things along the lines of, "OK, so the Sun made it most of the way across this particular constellation, we have a new Moon, so since it didn't actually make it out of the constellation, we're going to make this a leap month." Or with the Arabic or Islamic calendar – it's based on the first sighting of the crescent Moon each month. And it has to be a physical sighting of it on the 29th, or they assume it's there on the 30th, and so whether a given month in a given country is 29 or 30 days depends on whether or not somebody saw the moon on the 29th day of the month, and so you end up with all of these things built in that are…it's kind of head-scratching to try and put it all together.

Fraser: So if you were going to try and develop a calendar, what are the problems, as you say, you know, the problems that needed to be solved? Let's sort of iterate through them.

Pamela: The primary problem that needed to be solved is each of the different cultures -- and this really is a cultural problem -- wanted to find a way to have their religious holidays fall at roughly the same time in the solar cycle from year to year. So in the Christian church, it was a problem of trying to figure out how to get Easter consistently about the same time every spring. With the Jewish calendar it's the problem of trying to get Rosh Hashanah at roughly the same time in the fall. The Arabic calendar…they gave up. They simply cycle through so that every year Ramadan falls in a completely different month compared than the calendar used by the Western world. But many of these other calendars were trying to solve the problem of, "how do we have key celebrations fall during the same seasons that often somehow relate to the holidays being celebrated?" Even our own transition in the Western world, going from the Julian calendar, which dates back from the early 300s -- that calendar wasn't perfect, and Easter was drifting and this was a problem, so they came up with the Gregorian calendar to try and solve the problem of Easter.

Fraser: And so you've got this disconnect, right? Between the Sun takes – it doesn't even take 365 days – it takes somewhere between 365 and 366, the Moon takes 29-ish days to go around, right? So each one of these is some kind of mathematical problem, right?

Pamela: Right, and so with the Moon being 29-ish days, the problem was solved by having months that alternated in lunar-based calendars from 29 to 30 days, and a lunar calendar loses about ten days on the solar calendar

every year, so if you throw in an extra month every three years, you can sort of stay on cycle, but that still means that you have that month-long swoosh back and forth for holidays like Easter, so when they tried to come up with a calendar that didn't have as much movement in it, that was when they took the, "OK, for religious reasons we have a seven day week. OK, so we have a 365-day year, mostly, but it's actually 365.256363. How do we make up for that?" Well, .25 means, well, the first good mathematical calendar, it meant that every four years you have a leap year, so we developed, initially, the first really good calendar was a 365-day year with a leap year every fourth year, and that made the average year 365.25 days, and so now you're just missing that .006363 part of the year. Now, while that doesn't sound like a lot, over a couple thousand years, it caused the calendar to drift enough that Easter was misplaced by about 10 days, or at least the part of the year that was a valid part of the year to put Easter in started to drift, and so they decided in the late 1500s, "Crud! We need to figure out how to fix the leap days so that the year is an even more accurate representation of that 365.256363."

Fraser: And they had to do some pretty radical surgery to their calendar at that point, didn't they?

Pamela: Well, it wasn't that radical except in terms of they had to figure out how to get the two calendars aligned. So the change to the calculation went from being 365-day year with one leap day every four years to a 365-day year with a leap year every four years, unless the year was a multiple of 100 in which case it was a leap year only if it was a multiple of 400. So for instance 1900 wasn't a leap year, but 2000 was a leap year, so mathematically it didn't change that month, but the problem was they were off by those 10 days. And so they had a couple of options: they could either have a leap day every year for several years, or they could just suck it up and move the entire calendar, and that's actually what they decided to do.

Fraser: And that's what I meant, was they just said, "OK fine, you know, let's just shift the whole thing ten days. Everybody agree? OK, let's do it." You can just imagine the coordination that was involved.

Pamela: The thing was not everyone agreed. This was something that came out of the Catholic church, and when they were sorting all of this out in the late 1500s, it wasn't a Catholic world, and so when they made the jump, initially only the Catholic European countries made the jump. It took until,

well, very recently, actually, before all the nations of the world had finally, mostly, kinda, sorta given in to using the Gregorian calendar.

Fraser: Are there still people that don't use the Gregorian calendar?

Pamela: Well, so you have to look at, well, what are they using the calendar for? So you still have…the Chinese have the Chinese calendar, the Arabic world still has the Arabic calendar, and all of those different nations are slightly off from one another as well, but for the most part, we finally do have all of the major countries have, at least for financial purposes, adopted it. Turkey was one of the last countries to adopt it, as was China; China adopted it in 1929, and Turkey adopted it in 1926.

Fraser: Are there other motions of the…like of the Earth, like, I know the Earth's axis kind of wobbles a little bit; it precesses. Would that over long terms as well have an impact on our calendars?

Pamela: Well, the precession isn't so much of a problem as the fact that the length of the day is actually changing, so as our Moon slowly moves further and further away from the Earth, we're getting longer and longer days, so we can look back in the historical record, and within the fossil record start getting down to days that were many hours shorter than the current day. So this is where we keep having to add in leap seconds now and then because, well, our rotation rate is changing.

Fraser: And it's at a level that…I mean, I guess the modern scientific timekeeping devices are so accurate that they actually can do that. And so do they actually do that? Do they actually modify the length of the day every year?

Pamela: Well, they don't modify the length of the day, but they have been working to try and keep the calendar tied to the Sun, but they forfeited that in 2012, and there's actually recently an announcement saying that there would be no more leap seconds starting in 2012. The problem that we run into is: modern-day timepieces are accurate enough to notice, "Crud! The Sun didn't line up with the stars on the exact moment it was supposed to relative to my perfectly precise Atomic clock. Let's fix this." But every time they add a leap second in -- that wreaks havoc with operating systems the globe over, so trying to push that out to all the cell phones, all the laptops, all of the…every electronic device out there, they gave up. And this

is actually starting many different people to try and say, "Well, maybe it's time to reconsider our calendars yet again." In fact, there was recently a call put out at an international meeting to change our calendar yet again. Keep the seven day week because people realize there's just some things that aren't going to change, and the seven-day week is one of them. But what if we redo the calendar in such a way that every year Christmas is on a Sunday, every year your birthday is on the same day of the week, and we simply re-jigger the year, and where the leap years fall so that we can have this perfectly lined-up perpetual calendar? And the justification that they do for this is, if you think about it, if you work in academics, or if you work in a business that has lots of holidays, just trying to figure out, "Oh, crud! This year Fourth of July falls on day "X." What day do you give people off? Oh, crud! This year Christmas falls on a Sunday, so we have a different number of vacation days compared to last year." Lots and lots of time goes into figuring out how to schedule work holidays, how to schedule a lot of different things, so maybe if we re-jigger our calendar so that holidays are always the same day of the month, so that the year always starts on the same day of the week, we can save time on having to re-jigger our work schedule every year.

Fraser: Well, of course, though, I mean, our Thanksgiving here in Canada falls in a completely different month than yours does in the States, so you can imagine it's a whole other level of coordination and cooperation. Have there been other… I mean, more radical ideas for your calendars? Things that…I mean, do we need to have seven-day weeks, do we need to have…?

Pamela: Well, we don't need to have seven-day weeks, although it seems to be the right length of period that people are actually willing to work it. If you think…would you want to really work more than five days at a time without getting time off?

Fraser: I've been known to.

Pamela: Yeah well, we've both been known to, but imagine if that was the expectation.

Fraser: Yeah, exactly. Yeah.

Pamela: But there have been people who've moved to say, "perhaps its time we moved to a decimal system, perhaps it's time to get rid of this whole 12-

month thing altogether," and then the Mayans they took the approach of "we're just going to number every day." They have months and all of that stuff as well, but their "Long Count" calendar… they just simply number the days; that's how they handle it.

Fraser: We can't talk about calendars in 2012 without talking about the Mayan calendar. How did the Mayan calendar work, then?

Pamela: The thing that's hard to wrap your head around is their way of looking at numbers wasn't a base-10 system like we're used to. Instead they did things in base-18 and in base-20, so their "long calendar" is actually made of looking at all of these different, crazy cycles that take thousands of years to get through, and they just count the days from the beginning of all of it until today, and so the beginning of all of it, we think – it's always hard looking at archeological records…we think the beginning of everything was 3114 B.C., August 11, 3114 BC if you want to be specific, and it's simply been counting forward ever since then. And it's built on a system where they have days, so there's a one day, and then they have a month-like period which is 20 days, they have a full circle which is 360 days, they have a (I'm going to mispronounce this)…they have a "k'atun," which is the cycle of all of these days, which is then 7200 days, and all of these cycles come together into the "b'ak'tun" (which I know I mispronounced), which is the culmination of all of these days cycling through, and that longest cycle is 144,000 days long, so there's 20 days in the first cycle, then there's 18 cycles of 20 in the second cycle, there's 20 cycles of the previous one and so it's…the entire thing is 1 x 20 x 18 x 20 x 20 to get to their calendar.

Fraser: Right. And 144,000 days from when the calendar started happens to sync up, probably, with December 21, 2012.

Pamela: It's actually 14 times that.

Fraser: 14 times a hundred and…OK

Pamela: Right, and so this is where their myth starts to come in because their myth is: on the 14th of these cycles starting is the day when it goes to the next "b'ak'tun" and so that's…

Fraser: …the end of the cycle.

Pamela: Yeah.

Fraser: Yeah. Right. And, in our equivalent, that's because they numbered every day right from the beginning right until now…you know, this would be day 123,692, or something like that, right? That would be the way they would describe a day. That would get very…that would take up a lot of paper, a lot of stone.

Pamela: Well, they actually…because they're using an almost base-20 math system, it actually ends up being number-number-dot, number-number-dot, number-number-dot, number-number-dot, number-number, which is still a pain, but it starts to…it's the equivalent of saying the 5^{th} day of the 13^{th} month in the 24^{th} year of the 15^{th} cycle of the 30^{th} cycle of cycles.

Fraser: And so then when this calendar…and so this calendar theoretically runs to an end. Would they…I guess the point is they never planned to be around that long; they never really thought about it, like, it was just…would they just…the whole system would just start again the next day?

Pamela: This is one of those things that we just don't have the records to tell us. I mean, it's a cycle, so yes, it does just start over, but I don't think they'd ever really plan for it to start over, but we don't really know, and that's the crazy thing is they don't have any "world ending" lore tied to this; they don't have any "everyone's going to die" lore tied to this -- it's just the calendar, and so it's…

Fraser: You think about the fact that how, like, computer scientists didn't really think through the implications of the year 2000, and they only wrote their code 20 years before the end of the century. They never expected that their software would get used for 20 years, or 25 years, "Oh yeah, no, we'll just put in, you know, '87, '89" -- that never really occurred to them. As you can imagine, again going back to the Mayans building this calendar, "Well, are we going to need this in 5000 years? Nah," you know? It just never came up, so…

Pamela: It's the millennium bug.

Fraser: It's the millennium bug, yeah, exactly…so now we're having to deal with the millennium bug. Thanks, Mayans.

Pamela: It's just kind of funny that the software programmers and the Mayans only have a 12-year difference in their failure to think through their calendars.

Fraser: To think through the long duration of that…yeah, that's good. So then, what things would change our calendars? Would there be events? Would there be things that will happen in the far future, maybe, that would change our calendar dramatically?

Pamela: So, we do have slight changes in the equinox positions that do occur, not due to the precession of the pole, but because our entire orbit – it's not circular, and so as our orbit slowly rotates in combination with the precession of the pole, we end up with changes in equinox, we end up with slight changes in the solstice dates and the spacings of those, and so the slight things add up over time to, again, leap seconds here and there which will eventually, given enough millennia, turn into leap days. So it's just a matter of our planet isn't fixed in space; its axis is turning, its date of perihelion is changing, its date of date of aphelion is changing, and as all these things slowly change, they affect our calendar.

Fraser: But that is something that's going to happen over the course of…

Pamela: Millennium...

Fraser: But that's still going to be a cycle, but it would be a, yeah, but it would be a bigger cycle. You just end up with the movement of our orbit sort of slowly rotating around the Sun. What about the fact that our rotation is slowing thanks to the Moon? Will we get to the point where days last a very long time?

Pamela: Well, the rate at which things are slowing is such that, yes, it will happen. Our Sun will probably destroy the Earth before we have to worry about it too much. So you can imagine over the remaining course of humanity we might see a five-hour change, but I think that's the type of thing…there's already human beings that quite happily run on 30-hour cycles as they work on shift work, so that's the type of thing we can deal with over time.

Fraser: Evolution can deal with that. And then would there be something that would perhaps, you know, when the Sun turns into a red giant, and…?

Pamela: Yeah, we're going to have to be on a different planet by then.

Fraser: …the planet's center of gravity changes, we'll spiral outward, that'll make the years longer, right?

Pamela: Yes. Again, we're likely to be on a different planet, or dead by then, so I'm not particularly worried about the calendar.

Fraser: Right. OK. Alright, alright…just checking. OK, cool! Well, thanks a lot for the calendar info, Pamela. And thanks to everybody who watched us as we did the recording.