

Astronomy Cast Episode 231 for Monday, May 2, 2011: Galileo Galilei

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. I'm jetlagged in Austria. How are you doing?

Fraser: Well, I was going to ask you, "Hi, Pamela -- *where* are you doing?" but you are in Austria.

Pamela: I am. I am actually in the town of Graz, which is where Kepler had his very first position, and I found that out looking up things for this show, and so tomorrow I'm going to have to find out where he had his first position and walk there.

Fraser: Is there any chance to do some kind of "astro-vacationing?" Do a tour or something?

Pamela: I have no idea, and the thing is everyone I've been talking to who knows Graz, is like, "Oh my God! You're in the most boring place on the planet Earth." I find it quite awesome. It's a medieval village that has a bunch of really cool architecture.

Fraser: Yeah, I liked Austria.

Pamela: Yeah, and there was a random castle that I saw from the window of the train on the way from Vienna. Like you just happen to look out the window and there's like *giant castle* on a cliff with cliff faces, just like if you've been reading too much J. R. R. Martin like I have lately, or G. R. R. Martin. Yeah, I suddenly had a castle. It was awesome. Anyway, we should record it.

Fraser: You are recording!

Pamela: That's true. That's true.

Fraser: This is in the show -- there's no getting away from this. Alright, well yeah, that's true. Well, let's get on with it then. So it's hard to imagine a more famous astronomer than Galileo Galilei. He's widely recognized as the very first person to point a telescope at the skies and study what he saw. Galileo discovered the moons of Jupiter, the phases of Venus, and much more. It was his controversial stance on the nature of the Solar System that brought him into conflict with the Church. I cannot believe we haven't done a Galileo show yet.

Pamela: I think we must have answered questions about Galileo, related...

Fraser: We did...yeah, and I was like looking back and thinking about who to do a show on, and I was like, "Have we done Galileo?" and we haven't. Again we're going to do a two-parter: Galileo today, and then for the next episode we'll do the Galileo spacecraft, which is going to be really cool. So, let's go right back to...who was Galileo, then?

Pamela: Galileo was...he started out pretty much as just a regular guy. He thought he was going to become a priest; he was urged by his dad to, instead of going into the priesthood, go to medical school. He enrolled at the University of Pisa, and may be one of the very few people ever to get distracted from something like medicine to go into instead mathematics. Here I'm showing a small bit of a bias, a large bit of a bias, but it was from that foundation of math that everything else he did derived from, and what's interesting is, along the way, he also studied fine arts. He's an amazing writer who told a lot of his science stories as parables by different characters that were acting things out, debating among one another. It was just a fascinating way to try and communicate, and he revolutionized everything he did throughout his very long lifetime.

Fraser: And I think we'll get back to that, but that got him in a lot of trouble by the end. I mean, he essentially openly insulted the Church through one of these stories that got him into really hot water with... Right, so he went to University, was going to become a doctor, segued into mathematics...I guess astronomy wasn't quite the formal science that it is today. So then what happened?

Pamela: So he went into mathematics, and got sidetracked by art along the way, and he was appointed the Chair of Mathematics at the University he attended in Pisa, and he, unfortunately, was someone whose life was never easy. He ended up...he was the oldest of six children...he ended up having to take care of one of his younger brothers. Money was always an issue for him. After just a couple of years as Chair in Pisa, he ended up moving to the University of Padua, where he spent many years of his life. He was teaching geometry, mechanics, and astronomy until 1610, and one of the things that kind of startled me is the contradictions in his life. He was someone who's always trying to take care of his family; he is someone who thought a lot about joining the seminary, and then he had three kids out of wedlock all with the same woman, and all of his...he ended up sending his two daughters to both become nuns, and he actually maintained correspondence with one of them. He just had this very complicated life, and I think you can't really give a chronological tale of his life that's succinct. There's a fabulous book that does it, Galileo's Daughter, and it goes through and it uses the letters that he wrote with one of his daughters in the convent as a way of going through the story, but I think the best way to really look at his life is to just look one item at a time at all these major contributions he made one after another to the sciences and math.

Fraser: So, then, which one...I mean, should we talk about the astronomy contributions first? I mean there's the big one, right, which is pointing the telescope up?

Pamela: Right, so, telescopes weren't invented by Galileo. This is one of the strange misconceptions that kind of everybody has, but the reality was he was simply the first one to take a telescope that was being used to look across land, to look for boats coming over the horizon, and to look up at the stars instead. The telescopes that he had the first several years -- they weren't that great. He went from 3x to 30x to...he could just sort of barely make out Saturn's rings, but that simple act...

Fraser: Saturn's ears...

Pamela: Yeah, he saw them as ears, as handles, but that simple act in 1609, which we celebrated in 2009 with the International Year of Astronomy -- that simple act changed the Earth's place in the Solar System because he was able to prove for the first time that the Earth goes around the Sun and not

vice versa. He was able to prove for the very first time that moons and planets aren't perfect spheres, as had been predicted by Aristotle using thought. He just did so many things one after another, and his studies of Jupiter and finding its moons really laid the groundwork for showing that we live in a physically describable universe.

Fraser: Right -- and this is really important, right? That he...when he saw the moons going around Jupiter, this shattered the preconceived notion to that point that the Earth was the center of the Universe, and that the Moon and the Sun and the planets and the stars all rotated around the Earth, and that when he saw the moons going around Jupiter, and then looked again a few days later, they had moved in their position and it was quite obvious that they were orbiting around Jupiter. So up until that point, the rule was everything orbits the Earth, and Galileo was able to say, "Uh, no, something's orbiting around Jupiter," right? And then, as you said, you know, everything in the Heavens were perfect spheres. He looked at the Moon and saw the pockmarked craters and could see that the Moon was not a perfect sphere.

Pamela: And I think, for me, my favorite -- simply for the simplicity of it -- piece of evidence he used to show that everything goes around the Sun was the phases of Venus because if Venus is going around the Earth, then the Sun would be able to illuminate it in radically different ways, and in fact, we'd never be able to see a mostly-illuminated Venus because Venus would always be between us and the Sun pretty much, and what he found was, "Oh, dear! You see Venus go through most of its phases as it goes from crescent to pretty much full, you lose it in the glare of the Sun as it passes behind the Sun relative to our position..." It's just such a simple and elegant piece of proof.

Fraser: Yeah, yeah, and so, in the end, I mean, what did he get a chance to see? He saw the Moon, he saw Jupiter, he saw Saturn and saw what he thought were the "handles," you know, the "ears," but he couldn't quite make out exactly what was going on there. It took Cassini...

Pamela: Right.

Fraser: ...and Huygens later on to get a much better sense of the rings right? And he was able to see those phases of Venus, and again, these are all things

which you take a regular telescope or a Galileo-scope, and you can see the exact same stuff that he saw.

Pamela: And the Galileo-scope is something that it's really worth if you want a low-cost, lightweight telescope to give a kid that they can just beat the tar out of -- Galileo-scopes are still available. You can find them at Galileo-scope...I think it's .org. And these are telescopes that were designed to have absolutely amazing optics. They're made out of plastic, you can drop them down the stairs, and they're designed to pop apart, you scoop the pieces up, you put it back together and it just goes. But the really neat thing they did, is they included a lens that mimics that really horrible view that Galileo had.

Fraser: Right. Those are better...yeah.

Pamela: Yeah. And so you can look through and go, "Whoa! How did Galileo even point anything and find anything in the sky?" And it's an eye-opener! So if you're looking to get a really low-cost (under \$50) that's for a kid that may use it as a sword now and then, Galileo-scopes are the way to go.

Fraser: Sounds like my kids. So, I mean, he made these observations and I think what's really important was he knew what he was looking at, he understood the implications of what he was looking at, that the observations he was making that anybody could make if they had a telescope, could repeat his observations, these observations were calling into question whole beliefs about astronomy and about our place in the Universe, so he didn't keep that quiet, you know, he used that to sort of make the next logical leap.

Pamela: And this is where Galileo got himself in trouble...and his life spanned more than one pope, and when he was first getting started, he got along well with the Pope and the Pope supported his work, helped make sure that his life was good. He was smart -- Galileo was smart about who he dedicated his books to most of the time, but Galileo was kind of cocky. He knew when he was right and he wasn't going to let anyone tell him he was wrong, and when he got ticked off, he was an amazing writer and he wrote things that mocked people, so as he started to get basically annoyed that people weren't believing some of the things he was saying, he wrote different documents that were scolding, were petulant, where they included far more emotion than you expect in a modern-day science journal.

Fraser: Right, and he was supporting the Copernican model, right? Once he heard the model from Copernicus, his observations matched that up and he supported Copernicus' view, which was... Copernicus didn't even publish his work until after his death; he was afraid to even tell anyone. Galileo took it up.

Pamela: And so not only did he take it up, but he printed things when he was told he wasn't supposed to, he talked when he was told he wasn't supposed to, and he just kept doing things in a politically stupid manner. And eventually it wasn't so much that the Church was all upset that anyone was supporting the Copernicus model, they were upset that Galileo wasn't playing nicely, and they beat him up for it, and that was what finally got him in trouble. He was even forgiven a couple of times, that's the crazy part, is that they kept trying to forgive the guy, and then he kept like publishing books when no one was looking, or sneaking things out into Protestant Europe and... yeah.

Fraser: And what we sort of alluded to earlier in the show, right? He wrote his book...

Pamela: Discourses Concerning the Two Chief World Systems was the one where he basically argued the two ways of looking at it.

Fraser: Right, and he, you know, and as you said, he took this kind of clever way of approaching this, where he would have one person speak one philosophy and another person speak another philosophy and have them have a debate with one clearly besting the other in the debate, and this was done in a way to kind of humiliate the Church -- and they didn't take it well.

Pamela: No, no, and you can sort of see why they wouldn't take it well [laughing], and...

Fraser: And they had all the power, right? So...

Pamela: Yeah, and at least they did allow him to live out his life in his own home and his daughters never suffered because one of the things about back when he was alive in the 1600s is you sent your daughter to the convent, and in his case, he sent both his daughters to the convent because he didn't think that as bastards in the traditional sense of the word that they were marriage

material, and so he did the only thing he knew how to do with a daughter back then, but when you sent your daughters to the convent, you kind of had to pay their rent for the entirety of their lives and he was able to keep supporting his daughters, so they never really suffered too badly while being in the convent.

Fraser: Yeah, you know, it's weird to say, I mean, I kind of oscillate back and forth, right? On the one hand it's like, it's outrageous that the Church even got annoyed to the point of jailing him for questioning their beliefs, I mean, that's ridiculous! But at the same time, they were the ones with the swords, and you behave that way toward the Church, telling the truth, then you were going to kind of get yourself in a lot of trouble. In a way, he should have just kept his mouth shut, but at the same time, it's like how could it even be a crime to question the nature of the Universe? So, it's a fascinating, fascinating story and I think it's really complicated and very interesting to dig into it and see all of the letters that went back and forth, and the, you know, I'm holding air-quotes here, they gave him a bunch of chances, right? Chances...you know, that's ridiculous that they were giving him chances, you know? He was just calling nature as he saw it, right?

Pamela: I think that the impression that I got, reading Galileo's Daughter, was that had he just stopped mucking with the Pope...the science they were kind of OK with -- just go over there with it.

Fraser: And even if he had taken a little bit longer to release it, or had thanked the Church more in helping come to the bottom of it... They were kind of on board, it's true, it's a really interesting, complicated political piece of history to look into and it's, you know, it's like every story that we've heard so far is really simplistic about what actually happened on both sides.

Pamela: And at a certain level, there were just points in his life where Galileo was a spoiled academic brat, and if he had just been more of the stereotyped quiet, shy, afraid-to-talk-to-people scientist, it might have gone better for him.

Fraser: Right, but then...and that's where you oscillate. It's not about it going better for *him*, it's about him telling the truth to power. Like I said, I think it's an absolutely fascinating story, but, I mean, that part of it we talked

about, I mean, like when in his life did he start to make those observations? I mean, it was quite later in his life, wasn't it?

Pamela: Well, he started making observations in 1609, and he was born in 1564 (it's 1:20 in the morning and I'm doing math in my head), so it made him about...he was in his late 30s.

Fraser: Yeah, yeah.

Pamela: Going into his 40s...

Fraser: So, old.

Pamela: So, it was later in his life that he started making these observations, and he'd already been playing the system for a long time. He'd already been a prominent scientist for a long time, and that's the thing that you have to keep in your head is he'd had time to make friends and he'd had time to make enemies before any of this ever started, and it wasn't just with the Copernican theory where he was poking at people, he actually poked at Kepler, saying that he didn't think that Kepler's elliptical orbits were right because a circle was the perfect shape, so even Galileo, who was showing that planets orbited the Sun, not the Earth, fell prey to the conceit that orbits must be circles. Even the man who showed that there were mountains on the Moon and the Moon isn't a perfect sphere couldn't let go of that one conceit, and then he got himself into trouble with comets, where he was arguing left and right with someone about comets, and he was trying desperately to prove tides, and refused to understand that the tides had something to do with the Moon. He thought it was "slushing" back and forth evidence of the Earth's motion because they didn't have gravity -- gravity hadn't been invented yet. So he was just someone who argued with people about things.

Fraser: Right. I think we know people like that.

Pamela: Yeah, we do.

Fraser: But, so I think that, I mean, that and as you said, that was one whole story, right? That the getting his hands on a telescope, being the first person to think about pointing it up in the sky, making these incredible observations, publicizing them, and backing Copernicus' model, getting in trouble with the Church, and then living out a sort of quiet life under house

arrest...but that's not the only story. I know there were some other stories about Galileo that you wanted to tell, right?

Pamela: Right, so my favorite one is when Galileo was doing his physics experiments it was sort of assumed that the natural state for everything was to come to rest, to come to a stop, but if you're trying to imagine a universe where the Earth goes around and around and around and around the Sun, the idea that everything eventually comes to a stop just sort of breaks your logic. And so Galileo started doing experiments on friction and acceleration, and to do accurate experiments -- they didn't have clocks back then -- so you had to develop a method of timekeeping, so he developed a water clock that the number drops that fell out of the water clock was proportional to the amount of time, and through his experiments with inclined planes that we still replicate in a lot of freshman physics labs, he was able to come up with the laws of inertia, and the idea that an object in motion tends to stay in motion unless acted upon by a force, and an object at rest stays at rest unless acted upon by a force, and he did all of this before we knew what forces were!

Fraser: We did that experiment in our physics class, you know, you do the one with ramps, and rolling balls and stuff down ramps, and timing how long they take to reach the bottom.

Pamela: Right, and what was awesome about what Galileo did is he actually figured out, "Oh, shoot! Balls roll -- that might be slightly different," so he was doing things by sliding things in grooves, and he just took everything into consideration, and when he wrote this up, he actually did a thought experiment of...so let's imagine that the friction is actually little devils trying to slow down what's rolling, and the number of little devils is proportional to the amount of friction, and it was just this fabulous little discourse trying to show that it's a something that's stopping the ball and not a nothing that's stopping the ball.

Fraser: Right, and didn't he do the famous experiment on the Leaning Tower of Pisa?

Pamela: You know, no one actually knows if that's real or not. That actually comes...

Fraser: Oh, really?

Pamela: Yeah, that actually comes from one of Galileo's students, Vincenzo Viviani (forgive me if you're Italian). He wrote a biography of Galileo that's one of the primary sources of information other than Galileo's notes. The thing is that while the student wrote this fabulous story... Galileo was an amazing record keeper; he was your quintessential scientist who took notebook after notebook after notebook of records. He wrote everything up in his various publications -- and Galileo never mentioned doing this, and it just seems like one of those things he would do. So it's now generally considered that even Galileo who fought so hard to get people to look at physical reality and do experiments, it's considered this was probably actually a thought experiment, and the thought experiment runs along the lines of, in modern terms, imagine you have a bowling ball and you drop a bowling ball, it all falls at the same speed, now you cut the bowling ball in half and connect the two halves with a thread, well, how is that different than the bowling ball as one piece? And so as you extend this out, it becomes the two halves of the bowling ball falling side by side at the same rate as the original fully-connected, put-in-one-piece bowling ball -- again, different object for Galileo.

Fraser: Right, but you can see that thought experiment. I mean, that's the kind of thing that Einstein was really good at was looking at that in a sort of conceptual way, and coming up with the experiment in his mind that would prove it, so it's too bad it's apocryphal, but it's the same as the Newton apple dropping, right?

Pamela: Exactly, exactly. Everyone needs a few apocryphal stories in their lives.

Fraser: So did he discover, or discovered, sort of, friction, and...

Pamela: He developed the theory, I guess is...

Fraser: Developed the theory of friction and developed the theories that went into inertia. A lot of that was heavily used by Newton later on.

Pamela: Right. He worked on pendulums, didn't get his work exactly right, but he opened the door for other people to start doing research on pendulums. He did work on math throughout his entire life, and he just wrote and wrote and wrote and wrote, and...

Fraser: And in this really accessible style...I mean, you can...anybody can pick up some of his books, and they're entertaining.

Pamela: And he lived at such an amazing time. He, in his lifetime, saw both the birth and death of Kepler, he overlapped with Rene Descartes, he was watching the Protestant rise in the north of Europe, while living in Catholic Italy, and all of these things were going on around him and they were trying to get letters back and forth and build a scientific community, despite the schisms between the Protestant and Catholic parts of the continent, and throughout all of this he just kept trying to spread information while constantly trying to learn more about the Universe. One of the things that keeps cropping up over and over about the various scientists that we've talked about is no matter how friendly or not they are, they were always communicators, and this sort of goes back to...I think it's something that you've said on the show before, that you can be a fabulous scientist, but if you never say what you're doing, no one will ever know.

Fraser: Yeah, and it's interesting to hear Galileo had to invent the tools that he needed as well, right? I mean, you know, he had to develop a better telescope for himself, he had to develop a way of keeping time...

Pamela: Right.

Fraser: It's the same conversation about Huygens, you know, just like, "right now, I need to invent a clock, now I need to figure out a way to..." you know, just necessity of invention, necessity if the mother of all invention...yeah.

Pamela: He was also one of the early developers of the microscope. He was looking at bugs with it and presented one to one of the Cardinals. He was friends with the Cardinals until he poked fun at them too many times. He just...

Fraser: Didn't he also develop a thermometer?

Pamela: He developed a thermometer; he was a man who never got bored. And one of the saddest things about the way he ended his life is he studied the Sun with a telescope (not realizing that that was a bad idea), and so he was the first one to document sunspots, and he went blind in his old age.

Fraser: First one to document going blind looking at the Sun...

Pamela: Yeah, so when they say, "Do not look at the Sun with your telescope," we have an experimental reason why.

Fraser: And so I think we'll wrap this up now, but next week we're going to talk about the Galileo spacecraft – a wonderful spaceship that orbited around Jupiter and helped uncover, you know, a tremendous amount about the "giant planet," so that'll be cool. Alright, well, thanks a lot, Pamela!

Pamela: That sounds great! I will talk to you later. Bye-bye.