Astronomy Cast Episode 232 for Monday, September 26, 2011
Galileo Spacecraft

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?

Fraser: Good. Well, this is our first show after we got back from Dragon*Con and after our summer hiatus, and so all of you are going to notice a great big gap from May 'til September, and that's because we uh… took the summer off, and took a break -- but that's not actually true. I'm actually sort of "retcon-ing" our history and the reality is that we actually fell behind over the course of the entire year because of both of our busy schedules, and because of Pamela's crazy travel schedule, so we would sort of catch up and try and get some episodes done after the fact, and backdate them so nobody missed an episode, and at some point, we kind of surrendered and gave up, and cut it off and then brought it back now, and so the…we've actually got a bunch of things we're going to put into the feed. There's this show, which is the official Astronomy Cast show, and then we've also got several episodes that we did at Dragon*Con: we did a live show, we did a kids' show, and we did a sort of "ad hoc" show that we…sort of became an impromptu Astronomy Cast episode about weird things in the Universe, mostly in the Solar System, so you'll see those in the feed when you see them.

Pamela: And we learned I'm not as smart as a second-grader. It was very, very…I don't know what Snowball Earth is …I have no clue what Snowball Earth is.

Fraser: You got stumped. Yay! Do a little more research on Snowball Earth -- that would be great. But that was the whole…so the other thing that's really interesting is that we have been recording episodes of Astronomy Cast as Google hang-outs, so if you're interested in joining us and watching us record Astronomy Cast live, we will post announcements that we're about to record, and then eight lucky/unlucky listeners can join our hang-out and watch as we do the recording, so if you're interested in doing this, it's super-fun. You just need to circle either me or Pamela (probably me because I think I'm a little more active on Google Plus than Pamela is, but um…), and then you'll sort of see the announcements and then you'll see the invite to do the hang-out, and then you can just join us if you can get in. And there's only ten people allowed in the hang-out right now, but we're trying to get into the Hangouts On Air, which is this new service that Google's going to be allowing where you can have more people actually watching it than joining it so… and if there's any Google listeners right now, please, please, please -- we would love to have access to the Hangouts On Air, so… whew! So let's get on with…over-announcing, right…let's get on with this week's show. In last season's thrilling cliff-hanger, we talked about astronomer super-hero, Galileo Galilei. Would a mission be named after him? The answer was "yes." NASA's Galileo spacecraft visited Jupiter in 1995 and spent almost eight years orbiting, changing our understanding of the giant planet and its moons. OK, Pamela, so Galileo -- this is another one of those missions that has this long and tortured history of its initial inception in the hey-day of NASA's, you know, conquering of the Solar System to the point where it actually launched and actually arrived at Jupiter, so let's hear the…when did the idea for the Galileo spacecraft first come up?

Pamela: Well, the idea dates back to the ending of the Apollo era, as we started to look out and say, "OK, what's left? What else do we need to go and explore?" We had the Voyager probes on their way to the outer Solar System, but they were just fly-by missions that would go in get their data and go out, but not really linger anywhere and scientists knew that as soon as we got all of that data back, we'd want to have those dedicated missions that went out and spent time studying Jupiter, spent time studying Saturn, and Jupiter was our first big target of, "this is what we want to go look at." And so the Galileo mission really started to be conceived in the early '70s as we were preparing for the space shuttle. It was designed to launch on the space shuttle, which is part of where its fate became particularly tortured…

Fraser: But not just a fly-by, I mean, we're talking: go into orbit and study the planet, its moons for as long as possible.

Pamela: Yeah, carry a whole bunch of different instruments, be prepared to image it in different parts of the electromagnetic spectrum, be prepared to measure all of the radiation levels, be prepared to -- through a variety of different things -- look at the magnetospheres, the plasma, the dust…a whole variety of science from a whole lot of different instruments was planned.

Fraser: Right. OK, so the plan was you know, build this spacecraft, launch it on the space shuttle, and straight to Jupiter, and "boom!" you're done, you should be there, you know…

Pamela: In a few years...

Fraser: Yeah, a few years! So what really happened?

Pamela: So the idea originally was to launch it on the STS-23 back in 1982, but the shuttle launched '81 successfully, but it took them a while to get everything they needed done, to figure out a lot of the issues, and get to the point that they were completely ready to launch the spacecraft, and so this allowed for more development of the probe, no one was particularly upset, they added four years to the timeline, which for a spacecraft is really nothing.

Fraser: Yeah, it's pretty normal.

Pamela: Yeah, so Plan B was launch in 1986 aboard the space shuttle Atlantis…

Fraser: Uh-oh.

Pamela: Yeah, so unfortunately 1986 was the year of the Challenger disaster, and that changed how we fly the space shuttle. It changed what orbits we go to, it changed what we carry in the cargo bay, and it's that second part that really affected Galileo because to get a mission all the way out to Jupiter, you can't just carry it to low Earth orbit and give it a nice shove. You have to put a rocket booster on it, and the plan was to mount it on a (Atlas) Centaur G, which is a liquid hydrogen-fueled booster…

Fraser: Right.

Pamela: And you can imagine that they weren't exactly excited to be launching a cargo bay filled with explosives.

Fraser: Right.

Pamela: Yeah.

Fraser: So these safety concerns about launching a bomb into space overrode the being able to send that mission directly.

Pamela: Exactly, so in the end, it's ended up finally launching in 1989 and they had to completely rethink how they were going to end up launching it. They still ended up launching it on a space shuttle, but they couldn't launch it with the rocket attached, so they had to change how it gets to Jupiter. Instead of firing away and going "full-tilt boogie" and getting there fairly quickly, they decided to instead use a couple of gravitational boost exercises where they did fly-bys of Earth and Venus, went through the asteroid belt a couple of times, and used the gravity of our planet and Venus to assist it in adding more and more velocity.

Fraser: Yeah, if you see the path that Galileo actually took -- it's amazing. It went out and then back and then out again, and then back until finally, making its way out to Jupiter, getting the velocity it needed to reach Jupiter. I mean -- it's brilliant! I mean, it really is one of those situations where I can just…I don't know… all of these little moments, like you have it in the Apollo 13, right? Where someone dumps out all this junk on the table and says, "This is what the astronauts have. Build them a carbon dioxide filter!" [laughing] or all of the missions, I mean it's amazing…in almost every mission there are these situations where you find out what kinds of constraints the scientists are dealing with, I mean you can't just go and open up the spacecraft and replace the part that you need, and put it back together again. It's so far away and you've only got what you've got, you've got to re-program it on the fly…it's amazing, and I think Galileo was one of those missions where the space scientists working on it just never gave up. I mean, they just…they really had constraint after constraint, problem after problem, and they never gave up. And I don't know if you want to talk about the antenna…

Pamela: [laughing] Oh, Geez…so this poor mission -- it gets shelved for awhile while they figure out exactly how they're going to get it to Jupiter, and when you shelve a spacecraft, it can have bad side effects, and one of the side effects here was, well, one of the things they tried to do fairly early on, they launched in October of 1989, and a year and a half later, in April of 1991, they tried to open up it's high-gain antenna, which looks a lot like an umbrella, except the problem was, some of its spokes seemed to have gotten bent, or jammed, or something, and when they tried to open it, it said "no." And it's theorized that maybe some of the lubricant evaporated, or something got bent – we'll never know exactly what happened to the antenna. What we will know is that NASA tried everything it could to get it open: they cycled the power, they basically hit the on, open close open close open close a bazillion times trying to get the thing to shake loose, and nothing worked, so they had to, on the fly, change how the mission compresses its data, so instead of sending things back on the hundreds of kilobytes high-gain antenna, they're sending things back on the tens of bits per second antenna -- and that wasn't fun. That really limited what we were able to do scientifically, but they still did such amazing science.

Fraser: Yeah, it's great, you can actually see this in the pictures, so if you ever look at some of the pictures of the Galileo mission, and I'm sure we'll link some from the show notes, you have this situation where you've got…you can actually see this spacecraft and it's got this crumpled umbrella high-gain antenna, and so it's really funny because whoever was doing the artwork for the mission, they went back and redid the artwork to accurately match what the antenna must look like with the spacecraft currently going in, you know, when it actually reached Jupiter. That was a nice touch [laughing].

Pamela: [laughing] Well, I'm sure there were members of the public keeping them honest, but yeah, this was a real challenge, and the other thing about this mission is it's so old -- it's technology – they were recording all of the data to magnetic tape. Think like old-style cassette.

Fraser: That's…just a flash-drive – that would have been nice.

Pamela: Yeah, I'm sure they would have given anything for one of those 32-gigobyte, size-of-your-thumbnail flash-drives that's out there today. So they're recording everything to, basically, an audio or videocassette, and at one point the sucker got stuck in reverse, and they had to figure out, "OK, how do we get it out of reverse?" They did that, and then there's this concern that…

Fraser: "What if it reaches the end of the tape?!"

Pamela: [laughing] Well, hitting the end of the tape definitely happened and they were very concerned that this had done damage to the end of the tape, so they had to permanently not use that section of tape, and never fully unwind the tape for fear that it would come off the spindle, so not only were they limited by the fact that they're writing to a tape which doesn't hold that much, but then they can't even use the entire tape, and the only way they can empty the tape is to use their low-gain antenna, and so it was just problem after problem, but they solved them -- and that's the awesome thing.

Fraser: Yeah, but, I mean, for a lot of that mission, they were really just nursing its various components, and its data systems, and its communications systems, and it was constantly having to give and take and say, "Well, I can't receive information because I need that," and "You've got to wait," and I can just imagine the negotiations and the meetings and the conversations, and you know, at one part, it's quite exciting because the problems are where people really shine, but at the other end, I can just imagine how awful it was to like have to wait for your data and having to prioritize and, you know, all these terrible choices that the mission directors would have to make on who gets what, and so on and on…so it's just amazing. So after this big, long, convoluted trajectory, Galileo with its bad high-gain antenna makes it to Jupiter – bring on the science. So, what happened?

Pamela: So, it finally made it there in December of 1995, but what's kind of awesome is some of its best science actually did get to come before that, which is a good thing, so these poor, innocent scientist who started planning this mission in the '70s, and they had to wait and wait over a decade to start getting data, and they started getting data first during the two passes through the asteroid belt. So we had the first encounter with asteroid Gaspera, which was in October of 1991. It flew within in 1600 km; it was the first time we actually got good images of an asteroid, and then I think this is the image all of us have seen and no one really remembers this is from Galileo. In August of 93, Galileo took images of the asteroid Ida, and found its little moon, Dactyl, and that was amazing science realizing, "Yes, asteroids really do have their own moons," and as Galileo came up on Jupiter from behind, it was the only thing in the Solar System able to watch the chunks of comet P/Shoemaker-Levy 9 impact into Jupiter. From where we were here on the planet Earth, the impacts were happening on the far side of the planet where we just couldn't see them. We had to wait for Jupiter to rotate to see the splash points.

Fraser: That's amazing! When you think about it, I mean, to see a comet break up, and all of the various pieces collide with Jupiter, and scientists didn't really know what was going to happen. I mean, were they just going to disappear into Jupiter? Were they going to cause fairly large explosions on the surface? Would it dig up material from underneath the top cloud layer? This is one of those pretty deep questions that scientists, if they had known that P/Shoemaker-Levy 9 was going to colliding into Jupiter, they would have like made a mission, and sent it just to study this event, so the fact that Galileo happened to catch this just as a happy accident is pretty amazing, like "Oh yeah, by the way, here's a bonus, you know -- comet colliding with Jupiter!"

Pamela: And that was one of those times where we really didn't know what was going to happen. I was working at Kitt Peak that summer and we were all told, well something might happen, but really expect absolutely nothing, and that's what we told the public, and then the images started coming in and this was the first time I remember really using the worldwide web. This was back in the days where we were all using Mosaic, and it was amazing.

Fraser: Gopher, yeah…

Pamela: Gopher…and we were downloading the pictures from Antarctica and praying for all the clouds to go away, and just to see the images coming in from everywhere in the Solar System was kind of awesome.

Fraser: Yeah, yeah, that was quite a time, so I mean, this is all the bonus science, but the real science, I mean, the stuff that Galileo was actually tasked to do…what was its, you know, what did it discover once it finally…where did it go and what did it do once it was in the Jovian system?

Pamela: So once it finally got there in December of '95, it did 34 orbits. This is one of those things…I personally always have to rescale my brain because, I don't know about you, but I'm used to thinking of orbits as being things like 90 minutes – yeah! Orbits are short.

Fraser: Yeah, once a month for the moon, right?

Pamela: Right, and here it was on a basically two-month orbit, and as it went round and round, it brought us back images of the Jovian rings, it allowed us to realize that it's the constant impact of small asteroids, meteorites, chunks of other ice and rock hitting Jupiter and her moons that are constantly feeding those small gossamer rings. There was the realization that Jupiter's radiation field is a whole lot worse than anything we ever thought, it was the realization that Jupiter has these amazing lightening storms. And then, of course, there's all the science that came out of studying the moons. Io -- we realized had lava that could fill areas the size of Arizona, and…[laughing] in a year or so, no big deal…

Fraser: The huge geysers of lava that go hundreds of km into space and rain back down around on the moon -- crazy!

Pamela: Yeah, it was somewhere beyond crazy, and into the land of "Oh my God, that's insane!" We found that the moon Ganymede has its own substantial magnetic field, so I mean, we always talk about on the show how radiation is the big thing humans need to worry about when we travel into space…well, going to Ganymede -- not as big a deal. It has its own magnetic field to keep you safe.

Fraser: Yeah, then you just have to worry about the space madness.

Pamela: Yeah, yeah, and the cold -- things like that. Then we found that Europa, Ganymede and Callisto all have salt water beneath their visible surface, and with Europa, there's the potential for life beneath its icy surface, and just the idea that somewhere between the icy oceans of Europa and the lava-covered surface of Io, we found everything in between. It was just this fabulous look at the diversity of what our solar system has to offer.

Fraser: Yeah, yeah, just amazing! And I know that as the mission was going on, they got more and more risky. I mean, this is amazing because I mean the mission itself was falling apart right from the beginning, but they just kept taking bigger and bigger risks – getting closer to Jupiter and finding out what they could do with the spacecraft before they killed it.

Pamela: [laughing] Yes. Well, they had their initial mission where they had basic science goals to study the atmosphere, plot the radiation belts, but they didn't want to get too close to the moons because there's always the risk that you're going to accidentally end up *on* the moon, instead of flying *past* the moon, and so during the extended mission, this was where they started doing things like probing the radiation environment around Io and getting very close to Io to take these amazing images of the lava fields. This was where they started getting particularly close to the surface of Jupiter and probing its magnetic…magnetosphere, and in the process, they kept running into problems due to radiation, and in the end, it was problems with radiation that caused them to basically call an end to the mission. As they got particularly close to the moon Amalthea, they took a huge dose of radiation to the point that the LEDs they get used to work with the tape drive basically stopped lighting up, and they had to figure out how to re….. the LEDs remotely by changing the voltage through them and providing constant power and all sorts of crazy remote electronic repairs that I'm just in awe of what they were able to figure out how to do, but if they hadn't been able to do that, they wouldn't have been able to get the final data off of the tape.

Fraser: Yeah, yeah…right and as the spacecraft was starting to get more and more damaged by the radiation, it was a bit of a clock winding down. They had to figure out a way to end this mission gracefully, and not have the spacecraft crash into one of the moons.

Pamela: Right. So, the concern is that there wasn't particular care taken to make sure that bacteria and viruses didn't end up on Galileo – this was not a sterile spacecraft, and as we realized that there was potentially liquid oceans, in particular beneath Europa's surface, but also potentially beneath some of the other surfaces…well, you don't want to end up basically carrying small pox-covered blankets to these alien worlds, and that's essentially what Galileo might have been. Imagine it goes and it crashes onto Europa, and human viruses and bacteria escape, and we go on experiment 20 years later and find out we've killed Europa's oceans. We didn't want to do that, and so they "suicided" the mission into Jupiter's atmosphere. The polite way of saying it is that they "de-orbited" it into Jupiter's atmosphere, but no, they killed it.

Fraser: It's almost as if Galileo was orbiting around the Jovian system for hundreds and possibly even thousands of years, it would be almost inevitable that it would collide with one of the moons.

Pamela: Right.

Fraser: You just can't calculate all of orbital perturbations?

Pamela: Perturbations.

Fraser: Yeah, so they decided to de-orbit it, and so they crashed it into Jupiter, and when did they do that?

Pamela: 2003…so it was April of 2003, it got to hit its greatest distance away from Jupiter, capture some stunning images, and then they plunged the sucker to its death.

Fraser: And do you remember when they were talking about how they were going to do this, people were threatening or worrying that Galileo was going to somehow turn Jupiter into another star because of the plutonium onboard or something like that?

Pamela: Oh, that was just crazy talk. So, in April it gets to its greatest distance, takes these stunning images…this is the same time that we're starting to talk more and more about brown dwarf stars, and people somehow make the crazy connection that, "Oh no! Jupiter's really a failed star, and we can ignite it!" and so as Galileo is starting its final journey to its death in September, you get these crazies who were calling, "You can't do that! You shouldn't do that!" because somehow the amount of mass on this little, tiny spacecraft that would fit in a big room is capable of igniting Jupiter into being a star, and the thing is that, while there's brown dwarfs that are roughly the same diameter as Jupiter, that's just because of the way gas dynamics works. You have to add 15 times Jupiter's mass to get to a star, and the issue is you have to have the inside of the object, the planet star *thing* hot enough and dense enough that nuclear reactions can happen.

Fraser: Yeah.

Pamela: Jupiter's just not that hot or dense.

Fraser: Right, so unless Galileo had like, whatever, 70 times the mass of Jupiter packed into it somehow, nothing is going to happen, and nothing did happen, but I'm sure that if they have to do the same thing with Cassini, people will freak out again, and…yeah, it's ridiculous.

Pamela: And Cassini will have to be de-orbited as well because there's, well, we have Titan, and we don't want to go and pollute Titan.

Fraser: And so Galileo fell into Jupiter's gravity through the top cloud layer and got squished.

Pamela: It got squished, and it sent back data along the way. So between it and the Galileo probe that had dropped through the atmosphere when Galileo first got to Jupiter, we got to actually learn things about Galileo's atmosphere…we got to learn…not Galileo…we got to learn things about Jupiter's atmosphere, we got to learn that it just doesn't have quite as much water vapor as we thought, we got to learn that there's high-speed winds, and so we got to study meteorology for the first time, really, in detail around another planet.

Fraser: It was a noble sacrifice.

Pamela: Death can be good.

Fraser: Alright, well, thank you very much, Pamela.

Pamela: It's been my pleasure. I'll talk to you later.

Fraser: Bye.

Pamela: Bye-bye.