Astronomy Cast Episode 197

Astronomy Cast Live from DragonCon

Fraser: Astronomy Cast Episode 197 for Monday September 6, 2010, Astronomy Cast Live from DragonCon! My name is Fraser Cain, I'm the publisher of Universe Today, and with me, as always, is Dr. Pamela Gay, a professor at Southern Illinois University Edwardsville.
Pamela: How are you doing today, Fraser?
Fraser: I'm good, I'm good. So, we have a special guest today...
Les: Hi! I'm Les Johnson. I work for NASA at the Marshall Space Flight Center at Huntsville, Alabama. I'm the deputy manager of the Advanced Concepts Office there, which means we look at the next generation of space systems.
Fraser: So, the original plan was we were going to be talking about space on television, and we had some guy named Phil who was supposed to be joining us... didn't come. I also know that Kevin Grazier wasn't able to make it as well, so we thought we would mix it up, change the topic... something we're interested in which is what is going on with Constellation... what's the state of the human space exploration program right now. That will be the first half of the show, and the second half is going to be... you know... we're going to try to deal with some of the questions that you guys submitted, sort of show Pamela's gigantic brain... So, this is the fourth... the end of the fourth year anniversary of Astronomy Cast. We started it on Sept. 6, 2006, and actually announced it at DragonCon to a bunch of people over beer. I said, "Yeah, I'm going to be doing a podcast with Dr. Pamela Gay." A couple of people said, "Oh, doesn't she do the Slacker Astronomy?" "Yeah, yeah..." And so we talked about that, and that was the big announcement. We had no idea what was going to happen until then. Then, as Pamela said, this is the first time that we've ever done a live show together. She's done lots of live shows without me, but this is the first time they've been able to get me off my island and come to an event.
Pamela: Yes, but he lives on an island! So it's all good.
Fraser: Great. Ok, so....
Les: Notice how carefully that was deflected...
Fraser: So, what is the state of the human space exploration program?
Les: Well, I'm glad to get an easy question. I do work for NASA, but I have to give the caveat that I'm here at DragonCon as a private citizen. So what I'm going to say is related to my work, but I'm not speaking for NASA. Just so everybody knows that... The human space flight program for NASA is in a state of transition right now—there's a lot of uncertainty. We had a vision for what we were going to do under the former presidential administration. President Bush laid out a plan for a return to the moon, setting the framework for building the rockets, the landers, all the technologies we'd need to go from the moon on to elsewhere. We were underway with building a lot of those systems, when President Obama came in and there was an issue that was discovered with regard to not really having sufficient funding to carry this whole program to its completion. So there was a big review held of what we were doing, and a lot of experts came in to look at where we were going with human exploration, trying to figure out what we could do within our limited budgets. The answer was something very different than the program for a return to the moon. It was a new direction for NASA that was

proposed by the President earlier this year which would cancel the whole plan for returning to the moon, and the rockets, and the technologies that were being developed to do that. It would instead focus on commercial enterprise taking people to low Earth orbit, for resupplying the Space Station, and doing a heavy investment in technology to have some kind of a breakthrough that would enable human exploration to be more affordable and sustainable in the future. And that's kind of where we are, and unfortunately, we don't know yet what's going to happen this year because Congress hasn't decided to go along with the President's budget, and we aren't really continuing on the previous plan, so NASA's kind of in the state of in between two programs and we're not really sure where we're going until the Congress gets finished doing what it does.

Pamela: One of the things that as an outside observer, I do have funding from NASA but I'm a university faculty member, and I'm also not representing NASA here... unless I'm handing you a comic book in which case I am... and please take comic books later... So, with the Constellation mission, this wonderful decision in some ways was made to take existing technologies and tweak them a little bit. Take the SRB's from the Space Shuttle and tweak them a little bit. Take every technology we'd already invested in and been using since I was 5 years old and make it re-purposed. But if any of you have ever completely redesigned your house without tearing it down, you know sometimes it really is easier to gut the house down to the basement and start over. I think a lot of what was determined was sometimes you need to gut your rockets all the way out of, well, your rocket book, and start the book over with a completely new design that is what today's five-year-olds are going to grow up with.

Fraser: But isn't that kind of the same story that's kind of being said again and again, right... Oh, you know what we need to do is go back from scratch, rethink the program, figure out what our new goals are, we need a grand plan... then four years later... another party comes in... they want to rethink the plan. Is this just the future of human space exploration?

Les: Well, I hope not. I think there is some of that, and we can't forget that NASA is an agency of the federal government. So ultimately, when you, the people, make a decision in terms of the leadership of the government, you're making a decision ultimately about what NASA is going to be doing. And the presidential candidates in any election usually somewhere way down in their platform or in some stump speech somewhere will have a statement or two about what they want to do with NASA. It's just inevitable, as a part of our system, that when we have a presidential change, we have a change in potential direction for NASA. We're going to do more science or less science, what are we going to do with human exploration vs. not... Given that it takes us more than a presidential term... more than four years... to build these systems, that can lead to problems. If the vision changes dramatically, a lot of work that you've put into this just goes away.

Fraser: But is it almost... like is it fundamentally... I don't want to say impossible, but it's almost like you've got to have the launchers and you've got to have the landers and you've got to have the launch platforms and you've got to have the infrastructure and you've got to have the people in Huntsville and the people in California and they've all got to have their jobs and it's all got to be put together... At a certain point it takes 10 years... it takes 20 years to see that vision through and there's no way that can withstand the political process. And it's my impression that we're seeing that play out.

Pamela: There's one new hope for longevity that I'll be interested to see where you stand on this... With the current budgets, in both the House and the Senate and the Executive budgets, there's money set aside for the commercial space agencies. Except in Obama's budget, the amount set aside is less than what we use to subsidize Amtrak. So when you start looking at the proportion that way... and it's a whole lot less than we use to subsidize the entry ports for people taking cruises... That's about 8 billion dollars a year... that kind of confused me. By subsidizing the commercial space agents, the commercial space firms, we are creating an environment where people who aren't at the leisure of the Congress to do what they do, are able to dream big. My hope is that we're maybe 10 years away from seeing a Pan-Am TWA style competition for human space flight as we saw for manned airplanes going across the ocean a couple decades ago.
Fraser: So it would be like... Monday September 6, 2020? Should I book my flight?
Pamela: Sure, I'm willing to go with that.
Les: I think it's unfortunate that you picked Pan-Am and TWA because I don't think they fly anymore...
Pamela: No... no...
Fraser: No, but they made the commercials, right?
Les: But, but I'm with you. I saw 2001 and we had Pan-Am going up to the space station in 2001. No I think one of the great things that's happened in the last 10 years is commercial space. As in a previous panel we were talking about this, the notion of someone who's not an official government astronaut or a millionaire—right?—going to space is suddenly a potential reality... not for most of us, but for people who are definitely a larger number of people than there are millionaires. For a few hundred thousand dollars, someone can buy a seat on a suborbital flight and actually go to space. Now, 10 years ago, that would have been science fiction. But, that's going to start happening in just a few years. To me, that is just way cool, and I wish I made more money than I do because I would love to sign up and do that. But that's not the same thing as going to orbit, and that's something we have to be really clear on. It's a lot harder to go to orbit. It's all about energy. To build the rockets to get the speed you need to have to go to orbit, it's a lot tougher job. And there are companies that can do that, but those aren't going to be companies where you'll be able to buy a seat for the money that's in your IRA, or in your house equity. You'll still need more money than that.
Pamela: Yeah, but the stuff Elon Musk is doing really gives me hope that we will have companies building rockets that can meet the needs of AT&T, can meet the needs of all the television networks who need their satellites put up into different orbits, that can take supplies to and fro with the International Space Station. We proved before most of the people who are in this room were born, but not all of you, that you can take a missile and put people on the top of it and get them into space. Well, we're redesigning our missiles to launch the Space Station and it's not a far cry to put people on top of those as well... it's just harder.
Fraser: So, with the Constellation program, the plan was the end of this decade some of the missions would start going back, feet would be on the moon in 2020... kind of... so what would you say is now the timeline?
Les: That's to be decided. I mean that's the big frustration... we don't know.
Fraser: For sure, but I mean... you know...

Les: Because if the President's vision is implemented, then we'll have private industry taking people to the Space Station and resupplying the Space Station. Humans won't go anywhere until after 2020. If we were to get the funding to go implement project Constellation as it was conceived and was insufficiently funded, then we might be able to do that at or before 2020. We seem to be on a third path, now, which is kind of a hybrid between the two. The destination has been given to us as a near-Earth object, but there's no firm date attached to that. It's more like go as far as you can as the money allows you to do it.
Fraser: I'm actually really excited by that as a destination. You talk to a lot of people and they're like... "We should go back to the moon!" But I actually think going to an asteroid is a much more doable target... there's a lot of really good science that can be done... it doesn't require as much infrastructure and is a better bridge to a space-faring civilization, so I actually really like that.
Les: I like the idea of going just about anywhere...
Fraser: So do you feel like... my feeling is that with the government and with the way that they have handled the space exploration and the Shuttle and all that... it kind of sucks the oxygen out a bit of the private firms being able to do their thing... being able to raise funds, being able to... I know that a lot of the private companies have felt like they had a really hard time making headway and it's almost like they're working at cross purposes with the government. Do you think those days are over now? Do you think the private agencies have a better environment now?
Les: Well I guess to make one thing clear here, NASA doesn't... we don't fly the rockets. Most of the stuff that we launch... our science payloads... we buy a commercially-provided rocket from a Boeing or a Lockheed-Martin or private companies who sell these launch services.
Pamela: The Space Shuttle is the exception...
Les: The Space Shuttle is the exception, but even there we pay companies and industry to go do that. It's a lot of NASA people, but it's a lot of industry that is doing that too. I think the difference between the "new space" and what people would call the "old space" is that the new space wants to do it from an entrepreneurial point of view of we're going to go do it independent of your money and make this happen, and then you buy the services from us... is kind of the vision that they have. And I'm not sure about the business case for that without the guaranteed government purchase of products. I'm not an expert on that. But I am excited about it. I think competition is good. I think it would benefit all of us if there were more competition because that would drive down prices and make it a more affordable thing. So, I'm in favor of it.
Pamela: So, one of the things that's been fascinating for me to watch as someone who gets to see a lot of the addresses by Charlie Bolden, by many different representatives from NASA is what you just said about "We don't know when," "We don't know exactly what right now..." is the first honest timeline we've been given from NASA in about ten years.
Fraser: Yeah... we have no idea... thank you.
Pamela: And the delightful thing about it, though, is in the big formal Town Hall Addresses this has been followed by them outlining of a plan where we're going to enjoin these forums, we're going to bring in the experts from academia, the experts from industry, the experts who are currently in NASA... get them talking to one another and

figure out what is realistic, what is needed, what are our goals. They're building this into a long-term framework. In both astronomy on the space mission directorate side of NASA and in planetary sciences, we just finished a process where the entire community sat down under the guidance of the National Academies of Science and came up with ten-year plans... decadal surveys... to guide our long-term vision. So, we're starting with a plan instead of with a presidential proclamation... which is cool and awesome and you can use it to inspire small children... but it's not the way to figure out if you have the economics right.

Fraser: Well, how much overlap is there between the science goals and the human space exploration goals? Because I think...

Pamela: We want big rockets.

Fraser: Yeah... of course....

Pamela: The awesome thing about the Constellation program as it was is you could take the largest heavy lift of the three, stick the Gemini telescope as it is built for on the ground for gravity, and just launch it. Now, we would never, ever, ever do that... that's a waste of fuel. But the idea that we can start putting tractably really large science payloads in space is an awesome thing. So we need that heavy lift capacity.

Les: In our office, we actually did some studies that support the decadal survey in astrophysics for the ATLAST telescope, which is basically taking, inside the launch faring of the vehicle, the big heavy lift which would be for carrying people and putting a telescope designed for being put in space. A huge, huge telescope—6 meters in aperture, which is huge. We also looked at a mission to Titan... to actually go down to Titan and do a sample return mission from Titan using one of these heavy lift vehicles. So, there's lots of things you could do in robotic space and science if you had this capability that you're really developing first and foremost for sending people.

Fraser: Right... and that rocket's been cancelled, right?

Les: Right now the Ares V has been cancelled, but in the Congress... in the Senate side... there is discussion of restoring funding for a heavy-lift rocket, similar to what the Ares V would have been. So we may actually see that vehicle get built.

Pamela: Now in the news I've seen reports that Charlie Bolden has said that some of the NASA centers keep doing what you're doing with keeping Constellation rolling. Is that true or is that misreporting?

Les: Being asked if your administrator said the truth or not is not a good question for a NASA person....

Pamela: No, I'm asking if the journalist said the truth or not... the journalist, the journalist...

Les: Ok...

Pamela: Is the news lying?

Les: Yeah, yeah, yeah... I'm just kidding... See there are... I can't.... the answer is we are really in a period of incredible uncertainty right now because it depends on what the Congress does. The President directs... the Congress funds. You get direction but have no money, you don't get very far, right? So it really is going to depend on how these negotiations between the House and the Senate and the White House come out on what NASA is going to be doing. And the honest answer, from where we sit, is that we are literally at Marshall planning for three possible futures come October 1, which is the beginning of the fiscal year, because we don't know yet what the Presidential direction is

going to be. Now from the point of view of what's funded, the law says that if you go into what's called a continuing resolution, which is where they don't give us a budget... they just basically say we need a little bit more time, keep doing what you're doing... we're going to keep doing Constellation.
Fraser: Right.
Les: Ok, because that's what we're doing, and by law we can't start something new unless Congress appropriates the funds to do it. So, something will happen October 1, and if inaction on the part of the Congress, it will be the continuation of Constellation.
Fraser: Right. And...
Pamela: But...
Fraser: Oh, go ahead...
Pamela: But what's cool to watch, though, is all of the international partnerships going in to this because we live in a global age and I think when a lot of people have the "oh 'expletives'" realization of we have a really awesome space station that will finally be fully operational... The space station will be fully operational... no laughter? Ok... Just as we lose the Space Shuttle, there is the realization that we can partner with others. The Soviet... the former Soviet Union... Russia... I was there when it was the Soviet Union and I still misname it... Russia can continue to partner with us and carry us up. We're working closely with the Indians, we're working very closely with JAXA, the Japanese space agency. Just in the past 10 years I've seen this wonderful thing happen in the planetary sciences. Where pretty much every new mission going up has a suite of instruments, each from a different nation. We're figuring out how to make space international, even if we're not that successful here on Earth. So even if NASA doesn't necessarily have everything we need for a while due to our country basically redefining itself, we have partners and we aren't going to lose manned space and we aren't going to lose access to low-Earth orbit because we have friends in other nations.
Fraser: Now, has the progress of the Chinese human space exploration program had any impact on US efforts at all?
Les: I would say, at the level at which I work...
Fraser: It's just us... you can tell us...
Les: I'm just trying to figure out how to accurately answer your question... at the level at which I work, no.... other than personal interest. Because we don't have any kind of mutual agreement to work, at the level where I am, with the Chinese. From my point of view, I think it's great. I mean, they're pushing ahead... they've sent people into orbit... they have plans for going to the moon. I'm real pleased when any part of the human race is going to be pushing those boundaries. From a nationalistic point of view, I wish it were us with firm plans to do that. But it's not. But I'm glad somebody's doing it. So that's... I don't know... I don't know about levels higher up...
Fraser: Right, but that hasn't affected planning, hasn't affected the policies at all yet?
Les: Not directly. We do have agreements in place to work with the Europeans. We have joint projects with India in science, as well as lots of other countries. Nothing that I'm aware of... and there maybe something I'm not aware of... with the Chinese.
Fraser: So, we're about at the half-way point, so I thought we would switch over and tackle some of the questions... you can pitch in as well, which would be great... so if anybody still wants to write down some questions for us, that would be great.

Pamela: This is Kortney Hogan walking down the aisle. If any of you have sent us any email, she is the wonderful soul who answers all of your emails as best we can. She keeps me sane and keeps Fraser and I both chugging along as best we can. Yay for Kortney!
Fraser: Alright...
Les: That's a lot of cards....
Pamela: There's more here...
Fraser: Oh man... I knew this would be rough... ok, so here's a good one... "For an amateur astronomer, what type of telescope would you recommend with a budget of around $1500?"
Pamela: 1500? Ooooh... that's...
Fraser: That's getting to be a nice telescope.
Pamela: Yeah, so at $1500, you can start to get a really reasonable 6-inch with a killer mount. Now the reason I say "with a killer mount" is you can have the best optical train in the world, the best lenses the best eyepieces, and if you stick it on a cheap, rickety, wooden tripod, that you bought for $80, you're never going to have a good view. So you want to invest a third to half the price of the telescope, unless it's a Dob and then it's all one unit on a lazy-Susan. But for $1500, invest in a solid "you could kill somebody with it," "you could walk into it at night and injure yourself and not your telescope," "solid as a rock" tripod. Then get a 5 or a 6-inch computerized telescope to put on it. Oceanside Photo and Telescope has some great packages at about that price, and the reason I recommend them is I've called them up and said, "I want to get yadda, yadda, yadda," and they've said, "No you don't. You want this other thing that's $500 less." And so they'll be good to you.
Fraser: And definitely the computerized side of it is pretty great... there's some neat systems for that... they can triangulate, looking at different stars, or if you know the GPS coordinate and your time... then it's just great... you just go "Mars." Then your telescope goes over... it's great to learn your constellations the first time around, but after a while you really just want to be able to point it quickly and show people some stuff. So, how large is the entire universe? And not just the visible part...
Pamela: Oh, man... ok, we can't tell you how big the entire universe is... all we can do is put bounding boxes on it. We know that the part of the universe that we're able to see is no more than... last time I looked... the numbers may have revised... last time I looked... about 4% of the total universe. We know that from looking at the cosmic microwave background. There's no two places that look the same. If our universe was finite and closed... which we know it is... this would be the equivalent of standing on the edge of a donut, shooting two laser beams, and having them come back and hit you in the back of the head. The cosmic microwave background can kinda sorta do that if the universe was small enough that the laser beams had time to hit the back of your head. But since they haven't had the time necessary to wrap around and hit us in the back of the head, we know the universe is bigger than that. So this is how we get at the 4% estimate, and I hope I haven't just confused all of you. So once you get to the roughly 4%, I believe our current estimate for the visible universe is that it would be... I want to say 40-something billion light years across. So that would only be 4% of the minimum size of the universe. So, 40-something billion light years... lets call that 10-something billion light years per percent... back of the envelope... you're now looking at over 100 billion light years

minimum, minimum, minimum size. We'll check the numbers and post the checked numbers online.
Fraser: Um... I love this one... so, what thing—this is for both of you—would you try to discover with a reasonably unlimited budget? So, money is no object... what scientific question do you think we could reasonably go after and try to answer?
Les: Well, in my career in NASA... and I've been there about 20 years... the coolest job title I've ever had was Manager of Interstellar Propulsion Research. It was not actually to go to another star, but it was to take those first steps beyond the edge of the solar system so you could get data back before the people who launched it died. Ok... so it was a very simple goal. If I had the budget, I would invest in the technologies that let us go as far as we could go and get the data back in the lifetimes of the people who did it. Explore the outer reaches of the solar system, go through the Kuiper Belt, go look for something called the solar gravity lens point. The sun bends light... it's a lens... you can use it as an optic. There are different people who have proposed putting telescopes out... way, way out... like at 550 Astronomical Units... so I would try to take whatever the biggest engineering challenge is to go these distances and put money into it to make it happen.
Fraser: Right.
Les: That would be what I would do.
Fraser: Pamela?
Pamela: So, the problem is there's some really awesome fundamental questions like what the heck is convection? We can mathematically describe it but the details of how something as simple as convection in stars... how it works... throw an infinite budget at that isn't really going to help us. But, I'd love to be able to fix all the details in stellar evolution so we can go aha! I know that star because it has this mass, this metallicity, this temperature and therefore it's this age and I can figure out everything about this star. We still come up against issues figuring out the life cycles of stars where we go ok, we understand when it's burning hydrogen, we understand this stage... but then there's this crazy stuff called mass loss. Trying to sort all these pieces together so that we stop ending up with theoretical trails that give us stars that are older than our current universe... we're getting better at it, but I'd love to be able to completely understand something as fundamental as a completely run of the mill star from inner core to outer surface without having mysterious things like "and we're going to wave our hands at convection now." Let's get rid of the hand-waving with stars. Better computer models, more people thrown at the problems, more people doing high-density plasma physics, and let's just keep exploding things with laser beams because that's how we start simulating all the reactions going on in supernova reactions... and we're starting to design things like petawatt lasers. Those are lasers that fire as much energy as the U.S. uses. That's kinda cool.
Les: We could use those in advance propulsion, too.
Pamela: The problem is they tend to be kind of big. Don't fit on a rocket so well.
Les: That's why we need more budget.
Fraser: And I think for me, would be to get something like the terrestrial planet finder somehow launched because really it's like within the next couple of decades we could... by we I mean they... we could build a mission that could observe the atmosphere of planets orbiting other stars. Within a couple of decades we could know conclusively if there's life in the universe apart from Earth. And that's like, for me, the most fundamental question that we could even possibly ask, and it's so close that we could

have that answer. After a while, when the kids are looking through their books on science, they'll be a bunch of stars and yeah.. everyone knows that it's methane life over there and it's probably plants on this star. It will still be decades and decades after that before people can get a better view of them, but to just... just to know would blow my mind. Yeah... that would be great. Ok, so what is a virtual particle? Actually, I've had this question asked me a few times, so if I understand correctly, these are these particles that will pop out of nowhere... exist for a second... and then... what are they?
Pamela: So virtual particles are basically... the word virtual—no... they're real... They just don't last very long. Energy and mass are the same thing. $E = mc^2$ you've seen it on Homer Simpson. Any time you have energy, there's the probability that bits of it are going to rematerialize as a bit of matter and a bit of anti-matter. As long as they're close together, they're instantly going to go "whump" and go straight back to being energy again. Now, there's interesting exceptions. On the edges of black holes you might have this happen where one ends up on one side of the event horizon and the other ends up on the other side of the event horizon... and this is how black holes evaporate. Now generally the evaporation doesn't leave them empty like a cup of water set on the counter because there's a constant influx of particles that the amount falling in is greater than the rate of evaporation. So you can imagine putting a cup of water under a dripping faucet in a desert. Yes, the glass of water is trying very hard to evaporate, but it's not succeeding because of the influx of water. Well, that's how most black holes work. Now these virtual particles.. they crop up in lots of different places. I had a moment, not too long ago, of... but if all electromagnetic forces are carried by photons... particles of light... where's all the light when you stick your refrigerator magnet to the refrigerator? It's a fundamental question that I can't believe none of my freshmen physics majors ever asked, but it stopped me cold one day and I went and found a theorist. They're scary-brilliant and you leave them alone with whiteboards and they start drawing Fermi diagrams, and he's like oh yeah... it's all just virtual photons, so when you stick your refrigerator magnet to the refrigerator, there is imaginary... virtual... whatever you want to call it... photons holding it there... communicating the force between the magnet and the refrigerator. At the end of the day, it's just energy. But, you're just energy, too. It's just different faces of energy.
Fraser: Alright, I've got an easy one for you.
Pamela: Oh, no...
Fraser: What is time?
Pamela: Would you like to take this one?
Les: No...
Fraser: I'll give you one minute... of time...
Pamela: Ok, this is actually something that Einstein did a fairly good job for us defining. Time is what you get when you require light to be traveling at a constant velocity. So, if you shine a flashlight from me to the back of the room, and I wait for it to come back, and I time that journey of the light beam, that can be defined as my clock. I can watch how quickly it moves, I can measure distances. At the end of the day, the fascinating thing is, the ticking of my clock changes as I move to keep the velocity of light constant. This is one of those mind-breaking things. No matter what you do, light always travels the same speed. Now this means that if you hop up, you get your jet pack... I want a jet pack... you get your jet pack and you're chugging out towards Pluto because you want to explore the Kuiper Belt and you're going at a reasonable fraction of the speed of light and

you shine your light to light up Pluto in the foreground... it's going to take a long time for the light to get there... well, as you watch that light beam race away, you might be going a significant fraction of the speed of light, but you still see that light beam going the same speed. Now, the only way that is possible is if your watch is slow. So the way to think of this is... you're driving down the highway... you're going 30 miles per hour... this car zips past you and to your eyeballs, which are used to standing on sidewalks, it seems like that car zips past you at 30. Well you know from your speedometer that you're going 30. You see this other car zip by. It appears, relative to you, to be going 30... so you can guess that it's going 60. And cops do this periodically when they ticket you... not so much anymore—they have radar. Now if, standing on the sidewalk, you shine a flashlight and it appears to be going one speed, and when you're in the car going 30, going 60, going 600,000, it always appears to be going the same speed. That means that your watch has to slow down... which is very strange to think about... but the faster you go, the slower time is. If you hit the speed of light, time stops. Now this means that a photon emitted in the first moments of the universe, that gets absorbed by your eye, to that photon, it lived and died in the same moment. But to you, you're experiencing a bit of light that 13.7 plus or minus 0.1 something-new-I-haven't-memorized-yet billion years old. So light experiences no time. That's kinda cool.

Fraser: Done! You saw it right here. Alright... this is good. So, radiation is a pretty significant hazard in outer space. What are the plans to protect astronauts from radiation for long-term space flight?

Les: Well, there are two types of deep-space radiation you have to worry about with space travel and people. One is what comes from the sun which tends to be lower in energy, but pretty intense when it happens. The other is what's called the galactic cosmic rays, which are very high-energy particles coming in from outside... galactic... which are a lot higher in energy, but there are a lot fewer of them. So with regard to the ones that come from the sun, when the sun gets very active and there's a coronal mass ejection, and lots of ionizing particles coming out, those can basically hit an unshielded spacecraft and kill the astronauts. So, the designs that are thought of are to use water... water is a pretty good radiation shield... and have storm shelters so that when there is a storm that's observed coming from the sun, the astronauts can take shelter in a central part of the ship that has lots of mass to protect them from that radiation. And that would work pretty well. One thing I want to mention is that a little mass is a bad thing... a lot of mass is a good thing. Because when the radiation hits, it interacts with some of this mass and can create what's called a particle shower... secondary particles which can do a lot more damage than the initial radiation. So you want to make sure it's not just a little bit of mass... it's the right amount to stop a lot of it. So you could go into a central core, and that's actually been designed into some of the concepts for deep-space missions. There's not a lot we can do for the galactic cosmic rays because they will basically go right through most of the shielding and over the long term it will increase the long-term cancer risk for astronauts and other people who do the deep space exploration. There have been ideas about trying to create an artificial magnetosphere. See, here on Earth we essentially have a deflector screen around us that's caused by the earth's magnetic field and the trapped radiation that's in there. It tends to deflect a lot of this radiation...some of it still gets to the ground but not a lot. The idea is to do that in the spacecraft, but you need really intense magnetic fields to be able to affect these really fast-moving particles. We haven't really found a practical way to do that yet. So the answer is just shielding is the best way to do it, and just accept some of the risk for the longer term. And I haven't met too many astronauts... in fact I can't think of a single one that I've asked the question to... who've said I would not be willing to take the risk given the opportunity to go to Mars. So, we have to accept some risk, I think, is the answer.

Pamela: And one thing that's really cool, and a lot of you know that I'm really into citizen science, our current astronauts do have to worry about getting zotted by coronal mass ejections and there's a citizen science project called Solar Stormwatch that takes images from the STEREO missions, which are two imagers... one leading the earth in orbit, one trailing the earth in orbit... looking at the space between the sun and the earth. When you have two sets of eyes looking, you can actually figure out the trajectories of things that get shot in this direction. We ask everyday people like you, because NASA doesn't have enough people to do this, to look at the images that come down every single hour and help us predict do we need to worry or not? As the sun is starting to get active again, a lot of scientists are excited because hey, we can do cool science. But, it is a much larger health hazard for the astronauts. You can be part of realizing... oh, no... astronauts need to take shelter now by using Solar Stormwatch.

Fraser: So, did anyone have any questions they would like to ask us directly that's occurred to you now, either about science, space, astronomy, or even just the show? About Pamela's brain? Yeah... go ahead...

Questioner 1: Oh, this is just something regarding what you've just mentioned that I've heard before... Is it true that the Apollo astronauts essentially got lucky regarding radiation from the sun?

Pamela: Yes, totally...

Les: Yeah, totally... that's right... It was a time where there was not a lot of activity and within a reasonable window of weeks, I think, on one of the missions there was a solar event that had they been in transit, it would have been what NASA calls a bad day. It could have been very bad for the astronauts. That's exactly right.

Questioner 1: Thank you.

Les: And that's something we're going to have to worry about if we do go back to the moon or we go to a near-Earth object and the astronauts are outside in EVA, you're not going to get a lot of warning when this happens. And the reason it's not a big issue for the space station is you still have a lot of that shielding... even though you're out of the atmosphere, you're still within the magnetosphere of the earth and you get that shielding at the space station. So if something happens, they need to be aware of it but it's not as time-critical as it would be if you were on your way to Mars or on the surface of the moon.

Pamela: And with some of the coronal mass ejections, they come with different velocities. Some of them, given proper warning, they could actually evacuate the International Space Station, evacuating the moon is a bit harder... but this is where looking for things like holes into empty lava tubes becomes extraordinarily important. A project called Moon Zoo is actually... again citizen science... asking people like you to help us look at images from the Lunar Reconnaissance Orbiter to identify places where you have a channel where lava had cut and left a big hollow tunnel and it caved in, in part. And going into these caves... getting dirt, ice, soils, between you and the radiation... that's one way that we can protect our astronauts.

Questioner 2: Hello. This question may be a little too political and theoretical, but NASA's a military agency, so...
Pamela: No...
Les: Government... government...
Questioner 2: I meant to say government... I apologize... When you're talking about high-energy space propulsion systems like petawatt lasers, those make good weapons. If a government is building it, that has all these political implications... You know, if NASA builds a laser that can vaporize stuff on the moon, etc., etc., how big of a problem do you think that's going to be in developing truly high-energy propulsion systems, or just high-energy technology needed for space exploration and such?
Fraser: Well, the governments in the United States and around the world have enough nuclear weapons to kill us all ten times over... so now they're going to kill us all and then shoot us with lasers?
Pamela: Lasers on sharks...
Fraser: No, I mean, that genie is out of the bottle... we need lasers for space research.
Pamela: There's much more subtle things that we have to worry about. For instance, the Chinese have been practicing hitting satellites together... imagine suddenly we lost our entire GPS network... imagine if we suddenly lost our cell phone communications network... our weather satellites... our imaging satellites... That's a much more subtle way to take things out. As we've unfortunately been learning in our current economic situation, it's the really big weapons that don't necessarily matter... because they're really easy to spot... it's the little subtle ones that you can carry in suitcase or cause by... I'm going to move my satellite this way so that it sits in front of another one... isn't that fun... Those are the things that we can't defend against and are much more dangerous. Petawatt lasers you can... in theory DOE is funding them... eventually use them to generate energy. So, there's lots of different ways.
Questioner 3: If you were in orbit around a black hole, a safe orbit... close enough to observe it... just a quiet non-feeding black hole... what would Hawking radiation look like?
Pamela: Oh, crud. I should know this. It has a characteristic radiation pattern... I'm afraid I just don't remember... I'm sorry. What we're really actually hoping for is... or not "we" in general... some of us are really hoping that with CERN, as they run these collisions, that they will at some point create a microscopic black hole.... something that's completely safe and evaporates very quickly in a burst of Hawking radiation because then Hawking can get a Nobel Prize and that would be awesome! That's the problem with being a theorist... you can't get a Nobel until an experimentalist comes up and proves you're right. And we haven't actually observed Hawking radiation yet. It's a wonderful, beautiful theory that most of us believe is true, but it's a belief system with no evidence attached to it. There is a theoretical characteristic radiation pattern... I'm sorry I don't remember the details of it, but hopefully we'll get to see it over in Switzerland and France in the not-too-distant future.
Fraser: Anyone else have a question?
Questioner 4: Yes... pound for pound... I have 2 questions, actually. Pound for pound, is it cheaper to put humans or machinery into space? And with that in mind, is there a higher velocity that you can push machinery than you can push humans because of the g-

forces? And second question just for Pamela... when you said that astronauts get zotted by the sun, is that "zotted" with a "t" or with a "d?"
Pamela: Z-O-O-T-E-D
Questioner 4: Because the thing you hear is important. If it's zotted with a "d" like "Kneel before Zod..."
Pamela: Pass! Anyone who's ever IM'd with me knows I can't spell... I'm going to go with zotted... spell it how you will. What was your other question?
Les: I'll just answer the question about that... it's interesting because on a pound for pound basis I believe that the robotic spacecraft costs more per pound but the amount of pounds you need to support people is far larger. So when you're talking about sending a vehicle that carries people, it's going to be a lot more expensive because you need so much of it. We demand these things like air and water and radiation shielding and all these other things that you don't have to put on robotic spacecraft. So just in terms of launch mass and how much it costs for each kilogram of mass, they're both kind of expensive...
Questioner 4: Is there a fuel cost saving because you can push harder?
Les: Well... force equals mass times acceleration. So the more mass you have, you gotta have more propulsion to get it to the speeds that you want to go to. That's why these big rockets are good for big payloads because you can lift a lot of propellant to push it where you want to go.
Pamela: So what I think you're getting at is... so you're asking about acceleration because human beings... it's bad when you go faster than about six g-forces because we tend to stop having blood in our brain. Fighter pilots will occasionally go faster than that, astronauts will occasionally... it's not faster... it's accelerated more than that... So we can get... like New Horizons is zipping through the solar system but that sucker accelerated really slowly because it's an ion drive. It's the acceleration that causes you to feel the g-forces, not the velocity. So I could very, very slowly... you would die in the process because you don't live that long... accelerate you close to the speed of light. By doing it slowly, you'd never experience any bad g-forces... you'd just not live that long to see you get close to the speed of light. I could also accelerate you very fast to something slow, like 100 miles per hour, and kill you in the process because I accelerated you too fast. So it's a combination of acceleration and velocity, but in all reality, it costs too much energy-wise to have the really fast accelerations. This is why we use energy-conserving orbits that take six-ish months to get to Mars when we could just full-throttle it all the way. Every pound you put into orbit costs more. Every pound you put into interplanetary space costs more, and by using energy-conserving orbits it's slower, but it's cheaper. That's what matters....
Les: Plus the rocket equation limits you with rocket fuel because it's just not energetic enough. So you also get into the problem of can you contain that much energy to get the accelerations to make it a more rapid transfer. That's why you want to do some new technologies that are more efficient. You mentioned ion propulsion... ion propulsion is about ten times more efficient than chemical propulsion for every pound of propellant. But its acceleration is very... it's very small. Fortunately... or unfortunately... space is big. So no matter how low the acceleration is, it's going to take you a long time to get there. You can do it more efficiently and get up to very, very high speeds with a very low acceleration more efficiently with something like an electric propulsion system than you

can with a chemical system. It's a trade-off of where you want to go and how fast you need to get there and how much mass you want to take that really determines how you do it... whether you do it chemically and take a long time, or use one of these other propulsion systems... it just depends on what you want to do. There is no one size fits all. And I wish we had the antimatter drive so it could be, but we don't.

Pamela: Again, takes too much energy.

Questioner 5: The time dilation effect... how does that impact our ability to get reconnaissance from unmanned spacecraft... if we could ever get one to a neighborhood star in our lifetime? Would we be unable to get any data from it?

Pamela: No... that's not so much the time dilation effect as time lag. So, time dilation comes from... you get going really, really fast... you experience time at a different rate than your buddy... this is the twins paradox. One twin stays on Earth, the other one gets on a ship... accelerates really fast... experiences time at a slower rate... reverses direction, comes back, and is young. But if you get to another star, it's not that whoever got there is younger that you're dealing with... it's the fact that it takes 4 to 6 to 12 to 20 years for the information to get from that star back to Earth.

Fraser: Right, but if we were to send a spacecraft close to the speed of light, would we be able to communicate in any kind of rational way?

Pamela: No. We could match the signals so that as the signals hit the spacecraft they would be encoded at a rational rate. Mathematically that's very challenging. We don't have a powerful enough set of dishes to do that currently. But if you think about it, the information... by the time it gets there... is out of date. It's a complicated situation... you can't have realistic conversations.

Fraser: But that would only really be a problem if you were going 99% the speed of light?

Pamela: Well, you start to notice it at any significant percent of the speed of light.

Fraser: 10% the speed of light? 1% the speed of light?

Pamela: Yeah. You have to start encoding your information at different rates.

Fraser: Because from the spacecraft's point of view, hundreds of thousands of years or millions of years are going by on Earth... it's just experiencing a few hours... days... whatever?

Pamela: There's a whole myriad of effects. It's not just the time dilation that you have to worry about. It's also the frequencies. Any of you who've ever tried to tune a radio... as the spacecraft starts accelerating away from the earth, it starts seeing the signals from the Earth as redder and redder, as longer and longer, moving down the radio dial. As you change your velocity, you have to retune your radios. So you have this retuning effect, you have then... now you're starting to worry about relativistic effects, which is change in time, which is again changing your wavelength. So all of this comes out as a shift in color... it's a very complicated shift in color. This is an equation that at one point in grad school did make me cry. I was trying to figure out galaxies that are at cosmological distances and it was awful.

Fraser: But if you're having to worry about how to communicate with your relativistic spacecraft... that's a good problem to have.

Les: Yeah, I'm sitting here thinking "This would be great... let's solve it..."

Pamela: I don't want to solve it. I want some theorist to solve it.

Questioner 6: I have a question about black holes. We've all heard that when matter gets sucked into a black hole, it gets compacted and condensed down into a singularity, and I would assume that there would be a lot of mass with a super high density, and with density being equal to mass over volume, I would assume that the volume could not be equal to zero?
Pamela: So, the reality is, we can't really say anything about what happens within an event horizon. Physics kind of breaks... We're trying to figure out how to unify gravity and relativity and all of the different forces, and we're not there yet. When you actually start running the equations... and Phil Plait has done this more than I have, so I'm going to give you numbers I learned from him... the way it works out is black holes aren't actually single points of mass. Black holes get fluffier the more massive they are. So it's not infinite density in all reality, it's simply a density at which the neutrons are no longer capable of supporting one another. So you take a star, you remove the energy source in the center that's holding it up, because stars are carefully balanced between light pushing out and gravity pushing in. So you remove that light and the star collapses. If it's a star like our sun, it collapses until the protons and neutrons and electrons are all sort of going "ok, stop!" and in reality, it's the electrons pushing on each other with what's called an electron degeneracy pressure that ends up supporting a white dwarf. A white dwarf is take the mass of the sun, make it the size of the moon, and it's held up by electron degeneracy pressure. Now add too much mass on top of that and the electrons give off a collective expletive and give up. Protons and electrons combine into neutrons.... there's a burst of particles given off... and now you have something that's all the neutrons going... ok, I'm pushing against you... we're fine.... Keep throwing more mass on and the neutrons give up... this is where you end up with a black hole. This means that you could also have a five particle black hole, it's just that those particles are so compacted together that neutrons wouldn't fit in that space. So we don't know inside of a black hole, is all the mass condensed into a singularity... we don't think so. But we do know that the physics is radically different and we can describe the state of electrons pushing on each other. We can describe the state of neutrons pushing on each other, once you crush the neutrons into oblivion... physics stops. We're waiting for the next brilliant mind to help us out of this particular corner.
Fraser: But it's possible there's something in there that has physical...? It's possible that it is continuing to collapse at increasing acceleration... forever... getting smaller and smaller and smaller, and it's possible...?
Pamela: If it's not feeding, it's probably not still collapsing. It probably stops that process at some point. This gets into all sorts of weird time dilation issues. I was talking to a theorist because apparently I hate myself and...
Les: I'm noticing a trend here...
Pamela: ...he was explaining that one of the problems you run into is as the stuff starts collapsing down and accelerating faster and reaching higher and higher velocities, time essentially stops such that it may be that no black hole has actually had the time necessary to form because of time dilation effects. But the black holes are actually there because we can see them, but how do you disentangle all these time effects... it's something that people are still struggling to conceptualize. Computers don't have a problem with it... they'll spit the math out for us and then we sit there and go oh, where's the philosopher?

Fraser: So, at the rate we're going, I think we've got time for one maybe two more questions.... one more question.... so, is there anyone who has that last question? Right there...
Questioner 7: Got a question for Les.
Les: I thought I was going to dodge it...
Questioner 7: As we move from Apollo to the Shuttle to Constellation, how much knowledge do we lose every time we do that?
Les: How much knowledge do we lose?
Questioner 7: I mean, if we had to go back and build another Saturn V, and I realize the technology has improved over time obviously, but...
Fraser: But a lot of really wonderful launch vehicles have been scrapped...
Les: I think the overall knowledge base has actually grown, but what we've lost is the skilled technical labor to actually implement it. If you've been involved in a big hardware project, there's a difference between the engineering design and the guy who actually, or the woman, who really knows how to machine it or how to do this, that, or the other thing. I think what we lose is the art and the skill as opposed to the knowledge. If that's a subtle distinction, I know it's hard to rate, but to be really good at something you've got to be doing it... right? And to really learn and make it better every time, you've got to have that process of learning and improving and quality improvement, so we've definitely lost in that sense. People ask me all the time... I've heard that the plans for the Saturn V were lost and you can't rebuild it. That's not true... we could. I don't know that you'd want to because it's heavy, the machining... the alloys that are used in it are not commonly available anymore... we'd definitely want to do a new computer system, to redesign the whole thing. You essentially want to build that new house that you talked about earlier. So, it's a mixture of both. You learn a lot more, but you lose that day to day... which is what really lets you do it efficiently and effectively.
Fraser: Great. Well, I think we're out of time, so thank you very much for listening. Thank you for years of listening and all the wonderful email and feedback that we've gotten... we really appreciate it and we're really glad that we could show up in this one spot and be able to do the show live with you guys.