Astronomy Cast Episode 178
Mysteries of the Universe, Part 1

Fraser: Astronomy Cast Episode 178 for Monday February 22, 2010, Mysteries of the Universe, Part 1. 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're you doing?

Pamela: I'm doing well, Fraser. How are you doing?

Fraser: Very well. Had a great trip down in the United States. I took the kids on an impromptu road trip. We went down through California and Disneyland and San Diego Zoo and all that. It was really good. The weather was nice.

Pamela: That's awesome.

Fraser: Yeah, yeah, it was good. And you were in...

Pamela: South Africa. The irony of course is that you were in America while I was out of the country, but these things happen.

Fraser: And on the wrong side of the United States, but yeah...

Pamela: Yeah...

Fraser: So now we're all finished with the Milky Way, and it's time to move on to the biggest mysteries of all--the mysteries of the Universe. Let's wonder about dark matter and dark energy, and the very nature of reality itself. No answers today... only questions. So, let's just start with like a really easy one. I'm going to throw you a softball, and...

Pamela: Oh, it's always dangerous when you say that...

Fraser: I know, it totally is... and we'll go from there. So, the first question that perhaps astronomers might wonder about is what started the Big Bang?

Pamela: We don't know.

Fraser: Well, "we don't know" is going to be our answer for everything, so you can't say that. But I think, we've gone into this a couple of times... what's great about this is that the Big Bang... the theory of the Big Bang... is really that by looking at the expansion of the Universe, astronomers can look back and say, well the Universe is moving away from itself, and so it had to have come from a single point in space.

Pamela: Well, you have to be careful, because there's no center. It's all of space came from a single point.

Fraser: From a single point... that's right... not in space, just a single point.

Pamela: And so every point in the Universe is the center of the Universe.

Fraser: Right, and then you can say, well fine, smarty pants, where did that come from? And you just kinda go...

Pamela: This is one of those uncomfortable truths that some people have gone so far as to say well it was a quantum bounce and there was actually no beginning, it was simply a wave function that has changed over time.

Fraser: Maybe.

Pamela: Others are more definitive... it started from the quantum foam... cosmic foam... name a foam of choice... and ours is just one of many bubbling universes in a multiverse.

Fraser: Right.

Pamela: Again, not so satisfying.
Fraser: Well, it's as satisfying or as unsatisfying as any of these answers, right?
Pamela: Right, and the thing is at the end of the day we have this problem that time started at moment zero, and our ability to make calculations started at about 10^{-47} of a second after the Universe began. And we just don't have a way of sorting out anything prior to moment zero.
Fraser: And I think it doesn't... you don't... I mean obviously it would be wonderful to know... is it a chain of events? Is there some larger multiverse with membranes colliding with each other and starting new universes and big bangs, and all that kind of stuff. But, the Big Bang perfectly explains the Universe in its current state. It helps you understand as you look back in time and look back at earlier and earlier states, what came before it is a mystery, but it....
Pamela: It's sort of like a current World Atlas is really good at describing the world we live in and to understand how you get from Boston to Beijing. But that atlas will do you absolutely no good to understand the proto-Earth that had no continents prior to the Moon being formed. Things change. Things started out different from what they are now. But we have a firm understanding of the Universe we live in. We just have no clue where it came from.
Fraser: And it's the same with the theory of evolution, with any of these... This theory beautifully explains what we see... with evolution, with the amazing different kinds of life that we see on the Earth, and the Big Bang explains the movement and the motion that we see. And it doesn't need to explain anything else. It's a really interesting conversation to have with someone who may have a philosophical problem with the Big Bang. Where did the Big Bang come from? I don't believe in the Big Bang because I don't know where it came from. You can say, well, it doesn't really matter.
Pamela: It's just an unanswered question. The Big Bang describes the "whys" of the Universe... why do we have large-scale structure? Why do we have the set of abundances that we have? It doesn't explain the "hows" of how we got here. That's a different set of questions.
Fraser: And, it's entirely likely that we'll never be able to answer them. And, you know, what are you going to do? That's ok. I'm ok with that. It doesn't bother me in the least.
Pamela: It gives the people who work in the Humanities things to talk about.
Fraser: And it gives string theorists...
Pamela: And I love Humanities people...
Fraser: Yeah--no angry letters! And it gives string theorists their salary as well, so let's go on to our next mystery... so there you go... if anyone can solve that one, we'd be grateful. But if not... work on this one... The next big question, then, is what triggered inflation? Inflation being that moment of incredible expansion shortly after the Big Bang. When did inflation kind of get rolling?
Pamela: Inflation actually started in the first fractions of the first second. And it ended in the first fractions of the first second. It was a very brief period of time during which the universe violently expanded, where points side-by-side were moving apart from one another faster than the speed of light. Now, it wasn't that they were moving through space faster than the speed of light. It was that the whole universe was expanding such that two points seemed to be moving apart faster than the speed of light, which is completely legal according to relativity.

Fraser: Yeah, that's the only way that you're allowed to move faster than the speed of light is to be moving apart...
Pamela: ... is to be carried by the grid of spacetime.
Fraser: Right.
Pamela: Now, it lasted the briefest of instances, but without it, we wouldn't have the universe that, when we look outside, is the same to the north, to the south, to the east, to the west. Because the furthest galaxies in the north haven't had time for their light to travel all the way across the universe to interact with the galaxies we see to the furthest extremes in the south. Without inflation, when we looked at these two systems, we should see something radically different. But instead, we see something that seems to imply that the universe was well-mixed like a well-mixed batch of cookie dough... you don't have some clump of flour in one place and clump of egg in another. And the only way to get this thorough mixing or to instead, perhaps, just smooth things out so much so you don't see the differences, is to have a rapid period of inflation. Now, we're not entirely sure where it came from. Why it lasted as long as it did is another one of those things that has us kind of scratching our head. But we know that had it not ended when it ended, well we would have perhaps ended up with a universe so big that nothing could gravitationally collapse. Or, had it ended sooner, we might have ended up with a universe with nothing but black holes. So without it, our universe might not exist in the form it exists, or even something livable. And had it not ended exactly right, we would have been toast as well.
Fraser: Right, so inflation got the universe apart far enough that it wouldn't gravitationally all sort of pop back in on itself, or all of the matter would crush back together. It got far apart enough that you get stars and not black holes.
Pamela: And there's some interesting theories out there that actually say that while inflation ended in our part of the cosmos, that maybe there's this thing called eternal inflation--and this is work that Andrei Linde's been doing--where we have different pockets where the inflation took place for different degrees, and it's sort of rolling out forming bubbling universes that branch one off of the other in pockets of different inflation.
Fraser: Right, but the question that we're looking at right now is what got it going... why did it...
Pamela: We don't know.
Fraser: Right, so I mean, well of course we don't know! As with the Big Bang we don't know why or sort of why it started... what happened before it... and with inflation, some... it started at some discreet moment in time--something triggered it... and then it stopped at some discreet moment in time--something halted it.
Pamela: Yes, or at least it unrolled and then rolled back. But, yeah, it had a beginning, it had a middle, and it had an end.
Fraser: I think we've got a little more to work with than the Big Bang, right? Because the Big Bang is this opaque wall that you just can't see behind. Inflation happened in the universe... in the river of time, right?
Pamela: Well, unfortunately it also happened behind the cosmic microwave background, which meant that it happened during a period of time that we can't observe. So, we have more data. We know what effects it had, and we can work backwards to figure out when

it had to have happened. But we can't exactly see all the conditions in the moments before it, and we can't exactly experience during it to figure out why it stopped.

Fraser: Are there any reasonable theories out there?

Pamela: Well, there's a number of different theories in place. Allen Guth continues to work very hard on the problem. Andrei Linde's taking a look at it. And in their different models they're looking at roles of... so we have eternal inflation, we have chaotic inflation, we have people trying to play with different amplitudes of inhomogeneities in the field that might have triggered different things happening. There's a number of different theories, but right now we just don't have a way to sort between the different ones to figure out what's real and what's not. It's one of those things that it lies in the land of quantum mechanics and string theory, and hopefully as we get a better understanding of the particle world and quantum gravity, we'll also get a better idea of how all these things fit into it.

Fraser: But it started to occur after some of the fundamental forces of the universe had frozen out, right?

Pamela: Yes. It occurred after all four of the forces had separated.

Fraser: So, in theory, it couldn't have happened until they were there... until the separation had happened, and yet... it didn't exactly happen, right, at the moment after the fourth force froze out.

Pamela: Right, but one of the things that leaves us hoping that a better understanding of particle physics will get us somewhere is that several of the theories for inflation involve loop quantum gravity... and this gets back to the old joke from "Big Bang Theory"... do you like your gravity loopy or stringy? And as we work to try to figure out inflation, we need to know is our gravity loopy or stringy?

Fraser: Do you think... with the previous question I think it's entirely likely that it'll never get answered.

Pamela: Right.

Fraser: Do you think this one will get answered in our lifetime?

Pamela: I give this one more of a 50-50 shot. And I don't think it will ever be a definitive 100% I can beat up the crazies who email me saying no, we have three lines of evidence. That's what I love about the Big Bang is that you can point at multiple lines of evidence that say that our theory is correct. I think we will reach a point where we have a theory that everyone agrees kind of works but we won't have the multiple lines of evidence that say definitively that this is the correct theory.

Fraser: That's hope, anyway.

Pamela: It's hope.

Fraser: Alright, and this kind of ties into it, which is that will we ever be able to see beyond the cosmic microwave background radiation? And so this is that microwave background that's all in the sky and it's that afterglow from the Big Bang. But it's not the glow from the Big Bang itself.

Pamela: No.

Fraser: It's hundreds of thousands of years after the Big Bang.

Pamela: Right, so more between 300 and 400 thousand years after the Big Bang the universe cooled to the point that it stopped being opaque. For the first several hundred thousand years, any poor innocent photon trying to get from point A to point B wouldn't be able to do it because it was constantly being absorbed and re-emitted in a random direction. And this made the universe completely opaque to light. And that's the catch... it's completely opaque to light. So if we try to look in any color of light... microwave, gamma ray, doesn't matter... any color of light... at an object that existed prior to that moment when the universe cooled enough that photons could fly free without constantly colliding with stuff, well, we can't look there because light just couldn't fly.

Fraser: For an analogy, would you say like maybe the inside of a star would be another place that's opaque to light?

Pamela: Exactly.

Fraser: So photons are generated inside the core of the star and they bounce around through the radiative zone of the star and it's only when they reach the photosphere... when they get out of the star, that they get out into space and we can actually see them.

Pamela: Right, and the convective zone they're helped out, but yeah, it's a very similar idea that the light is constantly being absorbed and re-emitted. But while light was constantly getting absorbed and re-emitted and unable to travel in straight lines, gravity didn't have that problem. And so that it was possible for a gravitational wave to flow through this soup of high-density particles. And there are people who think that maybe someday as we get better and better at detecting gravitational waves... and by better I mean able to detect gravitational waves...

Fraser: Able to even detect one... ever...

Pamela: Right. Someday... far in the future... not in our lifetime, I don't think, we may have better ways of detecting gravitational waves and be able to focus gravitational wave detectors the same way we focus telescopes, which are really just light wave detectors.

Fraser: And for them, the Big Bang itself would be the wall.

Pamela: Exactly. That was the moment gravity started. Well, a few brief bits of time after the Big Bang, gravity began to exist.

Fraser: Right, and then in theory right at that moment, gravitational waves were being generated by the tremendous violence of the Big Bang itself.

Pamela: Well, the only question is with all these small bits of matter going in and out of existence, would they do anything more than create a gravitational wave background? Who knows? This is the type of thing theorists are still working on. But it's a neat idea that there is this one potential way to look behind the cosmic microwave. Now, like I said, there weren't any neutron stars combining, there weren't any supernovae exploding, and those are things we know give off large gravitational waves, but maybe something will come out when someday in our children's children's future we're really good at detecting gravitational waves.

Fraser: Right, do you think... is that our only hope to look beyond the CMB, or do you think there might be something else.

Pamela: I really think that's the only way we're going to be able to do it. We know we can't do it with light, and so gravity is the next option.

Fraser: And speaking of next options... ok, so here's another little one, he says... what is dark energy?

Pamela: This is the topic of "we don't know" again! But here at least here we have cool place-holder words.

Fraser: We have evidence...

Pamela: Well, we have evidence, too... you're right. So, back in 1998 a couple of different supernovae discovery teams were trying to measure the rate at which the expansion of the universe is slowing. You can use supernovae to measure distance very accurately, and you measure the distance to something, and you then measure its Doppler shift to see how quickly it's receding, and by measuring how recession rate changes with distance, you can start to measure how the expansion rate of the universe changes with time. Up until that point, we had all been taught that there were basically a couple of different options. The universe was going to slow enough that eventually it actually reversed directions and collapsed in on itself. It was going to slowly slow until the expansion actually stopped, or it was going to slow... but not so much that it ever actually stopped. So we had basically expansion forever, universe stops expanding, universe collapses in on itself. What we hadn't anticipated was what...

Fraser: Option D...

Pamela: Yeah, option D... the one that you don't get. Both of these teams, who weren't working together, but were rather working in competition, discovered instead that our universe is actually accelerating itself apart. The rate at which it's expanding is increasing with time. We don't know why. There is some sort of a pressure, some sort of a force, some sort of an energy, some sort of a something that we named dark energy that's out there pushing our universe apart. And what's really cool about it is as you look through space, the amount of energy that is needed for this expansion, this acceleration of the expansion, rather, is constant with volume, which means that as our universe increases in size, the amount of energy that's present... pushing it apart... is increasing as well and staying constant per cubic meter. And that's just one of those screwball things we can't explain at all.

Fraser: Right. And once again, it's like the best kind of science is the unexpected science... it's the unexpected discoveries... the oh, that's weird... I wasn't expecting that. And there's some great... uh, there's a Nova documentary that came out a few years ago that went into great detail and it's great just to see the two science teams both just going this couldn't be right, we made a mistake, we messed this up, we went back, we tried again, and no... it was still telling us that, you know... we went back... we recallibrated, looked again, you know... They're so convinced that they're wrong, that they've made a horrible mistake, and that they've botched up all this really valuable time with the Hubble Space Telescope and so now they need to go and pour through their data... And there's this constant message coming through to them... no, no this is the way the universe really is... it's not the universe's problem that you weren't ready for it.

Pamela: What's so amazing, though, is that no one saw this coming. None of us wanted it... it made all of the cosmological equations ten times harder to deal with, and you can no longer assign them to undergrads. It makes us rewrite all of our textbooks. This was an expensive new discovery that made us redo lots of stuff. But in a single year, the entire community let loose a few expletives, and then accepted and embrace the fact that this is the universe we live in.

Fraser: And I think this is a great example of a discovery that can do that... that can turn the whole thing on its ear, that the evidence was so good... it was independent, it was with good instruments, it was presented well, everyone looked at it and almost everybody just said well, yeah, I guess that's the way the universe is. There wasn't a lot of crying and complaining and people being vilified for their bizarre theories. So for all the people out there who have these alternative theories of the universe, this is one that completely turned over the whole idea of cosmology. The astronomers all accepted it and moved forward and modified their theories accordingly. So, it's absolutely possible... you've just got to come with wonderful evidence.

Pamela: Right. And it helps if you happen to be at some of the best institutions in the world.

Fraser: And so the question being... the one that we're pondering here today is... what is it? And I know you don't know...

Pamela: Yeah, so some of the guesses are that it's some sort of a vaccuum energy which is to say that all of space has a certain amount of energy in it, and out of this energy you get this bubbling of particles. Now, the problem is that the people who've run the calculations to sort out... ok, so if you consider that you constantly have this flux of matter and antimatter particles that are perfectly allowed to pop into existance and cancel each other out and pop out of existence and you look at what the leftover energy might be due to this, that, and the other thing... if you run all those calculations, what you find is the reality and the calculations are different by a factor of 10^{120}. That's a 1 followed by 120 zeros.

Fraser: More than a googel zeros. But wouldn't you even if you had particles popping into existence, wouldn't that just make the universe more dense? If I'm eating a muffin and it's got blueberries in it, and they're more blueberries popping into my muffin... it's just going to make a yummier blueberry muffin.

Pamela: Well, this is more like you have a blueberry and an antiblueberry... I'm not quite sure what that is... a huckleberry?

Fraser: Yeah, right...

Pamela: You have a blueberry and an antiblueberry and they cancel each other out and together make it no more tasty, no more nice. But imagine you had this blueberry and this antiblueberry, and somehow while they cancel each other out... they always leave one grain of sugar because of some asymmetry.

Fraser: Right, and that would eventually leave me with a big pile of sugar... I get it. So you're saying that people have run the calculation and it doesn't work... it doesn't hold up.

Pamela: But this could again be a matter of we're still trying to figure out particle physics. Now, the other theory is that there is some sort of quiescence... some sort of field that permeates all of space and time. And that's another one that these are people working in string theory, loop gravity, we need to figure out is the universe loopy or stringy, we need to be able to prove is string theory right? And this is something that we've brought up before in the show that right now there aren't any definitive experiements that say it's string theory and not something else.

Fraser: And so the thinking being that as you have more universe you have more of this field and therefore you get more universe... so it's like this positive feedback loop?

Pamela: Or perhaps just our universe is embedded in the field?

Fraser: Whatever that means...

Pamela: Well, and this gets to the... people always ask what's outside the universe, and you say well we can't answer that because the universe is everything...

Fraser: Stop asking stupid questions is what we say...

Pamela: Right... exactly.... but this is sort of... well, outside our universe is... the parts of the quiescent field that aren't inside our universe... and that's just kind of ugly. But that's just one way of looking at quiescence... there's many different ways of looking at it. This is the problem with the early days of theories is you take five theorists and you throw them in a room and they give you ten different contradictary ideas.

Fraser: But none of theme sound as gelled as... we don't have time for it this show but next show we'll talk about dark matter... in dark matter there's some pretty robust ideas of what we're looking at, and they've narrowed down the parameters, and you're starting to look for some very specific things.

Pamela: And I think it's the age. We only in 1998 were confronted with dark energy whereas dark matter has been around longer than I have.

Fraser: And dark energy's super weird. And so...

Pamela: Well, dark matter was super weird when it was discovered, too.

Fraser: I suppose... yeah... and so I think the one I'm most familiar with is this one that you're talking about with virtual particles popping into existence. And that's true... I mean it's not just... there are experiments that do show virtual particles popping into existence, so once again it's not in the realm of bizarre.... the Casimir effect?

Pamela: Yeah, we just don't know if there's enough leftover bits to justify what we see.

Fraser: Right, so with dark energy there is... does that theory... well, my eyes glaze over.... well, it's a field, you know, of virtual particles communicating with each other... and you're just kinda like whaaaa? Well, you know, it all depends on if it's loop gravity or string theory... whaaaat? You know, and I can just imagine cornering one of these cosmologists and taking the better part of a day to really nail down in layman's terms... I'll do that sometime... Explain that to me again? Why is it a loop? But, to get to the bottom of that, obviously there's no necessity for their theories to be elegant, for their theories to make sense to the layman... that's my problem, it's not theirs...

Pamela: Well, you know there is this certain anticipation that there is an underlying elegance... it's not a valid thing to want but F=ma, $E=mc^2$, the Maxwell equations when written in tensor form are stunning. So we find over and over a simple elegance underlying the universe. And string theory looks kind of like mathematical spaghetti that died. There's nothing pretty about it. So there is always this hope that it will reach the point where even a mere experimentalist will be able to understand the workings of the universe.

Fraser: And so, how do you like your odds on this one?

Pamela: I think dark energy may not be in our lifetime, but it will be in at least our children's lifetimes. So, tell your little ones... keep their ears out and they'll know the truth.

Fraser: That's sad.... I want to know. Oh well...

Pamela: It may happen, it may happen... Vera Rubin's still alive and we're figuring out dark matter...

Fraser: No, no... I've already stated that I'm ok with mysteries and I'm going to be ok with this one, too. Alright, well, I think we're out of time Pamela, so thanks a lot and we'll talk to you with more mysteries next week.

Pamela: Sounds good Fraser... talk to you later.