Astronomy Cast Episode 31:

String Theory, Time Travel, White Holes, Warp Speed, Multiple Dimensions, and Before the Big Bang

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Fraser Cain: So here's the problem: we get questions sent in every week about the topics in the title of the show, especially string theory. We try to kind of put them aside or hold off, but we need to address it.

One of our goals with Astronomy Cast is to present evidence that supports our current understanding of the Universe. If you think about our Big Bang show early on, we provided four different lines of evidence that support our understanding of the Big Bang. Thanks to science fiction, comic books, there's a lot of ideas there that do relate to space and astronomy but which don't quite have any evidence whatsoever, and yet they're in the popular thinking, so we get questions about them all the time.

So Pamela, what is the evidence to support all those topics?

Pamela: Absolutely none.

Fraser: None. All right, but let's try and cover some of these topics as much as we can to explain at least where there could be evidence. So let's start with string theory. What is string theory?

Pamela: String theory is a mathematical attempt to unify all the different forces. It starts off with the premise that our Universe doesn't exist just in the three spatial dimensions we experience, and time, but rather it has other dimensions as well. When we look at sub-atomic particles, what we're seeing is just one aspect of a particle that is a string if you're able to see it in the multiple different dimensions – this is where the "string" in string theory comes from.

One of the problems with string theory is, because it’s a mathematical invention, you can tweak the parameters to get it to fit almost anything. There are a lot of different versions of string theory that all build off of one another in slightly different ways and come up with slightly different predictions and the things that they're predicting aren't unique to just string theory, there are other theories based on the more standard model of particle physics that make similar predictions.

Fraser: But we don't want to disparage mathematical predictions, I mean many of the great discoveries of the Universe have been done in precisely that way. Think about relativity: Einstein worked out the math before anyone was able to see his predictions in reality. In fact, they're only just now starting to understand.

Pamela: But the thing with relativity is it made a unique set of predictions based on a unique set of observables. For one set of data in, you get one set of data out. With string theory you can throw in a bazillion different inputs and get an infinite number of outputs, it seems like. So in this case, you have non-unique solutions and physics requires at least probabilities of what your unique solution should be. This is where string theory gets itself into trouble: it's currently not testable.

A good scientific model has three specific characteristics: it is built on existing observations – you look at something, you see what happens, you write a theory to describe it. You then have to make predictions and then once you've made the observations of those predictions you can modify your theory to incorporate them but the theory itself shouldn't fall apart. Newton's theory of gravity didn't fall apart in the face of relativity, it was just modified and added on to. With string theory you currently – yeah, they're incorporating lots of present observations, but there's no one test that will prove or disprove string theory and what tests exist aren't unique to string theory.

Fraser: But isn't that a sign of all of the different thinkings going into string theory – isn't that a sign of its health, of the possibilities that could exist there?

Pamela: I think it's more a sign of it's youth. It's a theory that still isn't fully put together and it needs more work to reach the level of maturity where its able to stand up and stand with the other full-fledged scientific theories and make its unique predictions. It's not there yet, and some people are actually questioning will it ever get there, or is this simply a unique trick you can play with math that can get you in lots of different directions but doesn't actually tell you any fundamental truths about the Universe?

Fraser: Right. There are some great books out there, especially the one by Brian Green

Pamela: *An Elegant Universe*

Fraser: Yeah – which definitely explains the concept in a way you can understand it (and he also did a special on NOVA) so you can explain it. But I think that as it goes back to it, this isn't something that's been seen, this isn't something that's been observed, some evidence supports certain lines of string theory other evidence supports others, so it's almost all comes out as a wash in the end.

Pamela: It's a tool, it's just not necessarily a tool that is able to help us build a house.

Fraser: Right, so when you're thinking about the Big Bang for example, something that has so much evidence, and something like string theory as two different ways to understand the Universe… one is really giving some insight into how the Universe really looks, while the other one is so far purely math. I'm sure it's wonderful, elegant math that really connects together, but so far there's no evidence.

Pamela: And without the evidence, we can't really discuss it in detail in our facts-based show.

Fraser: The moment there's any evidence, we'll do a whole show about it.

Okay, time travel: What's wrong with time travel? Aren't we moving forward in time right now, one second per second?

Pamela: The problem with time travel is definitional. Most people when they say "let's travel in time!" want to go back in the past, they want to go on Bill and Ted's Excellent Adventure and bring Socrates to the future. But, time travel only moves in one direction, and that's forward.

It's possible for us to skip forward in time by moving extremely fast. If you or I were to take off running at 80%, 90% the speed of light, we'd see the people around us seem to age progressively faster and the Universe would go through vast amounts of history up until the point that we stopped running and our watch and the watch of the planet Earth started ticking at the same rate.

Fraser: Oh so if we ran around in a circle at 90% the speed of light, it would be like all around us was one of those sped-up movies.

Pamela: Yeah.

Fraser: Right.

Pamela: And we could be Buck Rogers in the 21st Century, although I'm thinking nowadays it would have to be like the 24th Century, but that's still only moving forward in time. Backwards in time we can't do. Physics says this arrow only points in one direction.

Fraser: But I've heard that many theories, or many formulas in physics have no need for time to move in any one direction; if you put time in the opposite direction the math still works out.

Pamela: Well, and any one thing, you can show that mathematically it is possible. Within the framework of the entire Universe, the Universe itself has this underlying "you will only go forward in time" rule to it. So, while one or two equations (or probably more than that) say yes, we can have things that progress the same way forward or backward or completely reversible, that doesn't mean that you can reverse the equation and set yourself going backwards in time. There are reversible reactions, things that you set them forward and then you can set them in reverse but when they're going in reverse, time is still moving forward; you're just seeing the reaction happening in reverse.

Fraser: I think it's a great – is it a paradox? – that if there is time travel in the future (it's almost like the one we did with all of the aliens), then there would be time travellers crawling around everywhere you looked because in theory there's an infinite amount of time in the future for time travelers to hop into their time machines and go back to any time that they choose and enough of them would choose to come back right now that we'd probably have five or six time travellers looking over our shoulders as we record this historic episode.

[laughter]

Pamela: There was in fact a conference at MIT where they said "okay, anyone out there time-travelling, show up here on this day and time" and no one showed up. So, there you go.

Fraser: There you go.

Okay, so what's a white hole?

Pamela: A white hole is the opposite of a black hole, in terms of… black holes, material gets into them and can't get back out. White holes (if they were able to physically exist) would be spewing light and energy out of them. The catch is that sort of breaks the second law of thermodynamics, and not only that but the second you get the smallest fraction of a dust mote, a single atom, a single electron near a white hole, suddenly the white hole becomes a black hole.

White holes are a mathematical invention of what happens if you look at all the geometry of a black hole and get rid of the mass in the centre. So mathematically, they're pretty cool. They do totally exist in mathematical formulas and they might have existed when the Universe formed, but we have no mechanism for forming one in the modern Universe. You can't collapse a star and get something with no mass in the centre. Even if any were created during the formation of the Universe, in the 13.7 ± 0.2 Billion years since then, it's safe to assume that some fraction of a dust mote has gotten near every possible white hole that was out there and converted it to a black hole.

So, we don't think they could have existed, because they go against the second law of thermodynamics, and even if they did exist, we don't think they exist now.

Fraser: I think with the staple of science fiction, they're used as some mechanism for allowing our heroes to travel back in time, or travel across the Universe or move to other dimensions

Pamela: Thus breaking other rules.

Fraser: [laughing] Yeah, but of course the moment they encounter the white hole it would turn into a black hole, I guess, so there it goes. So white holes once again, we have what's a mathematical construct that's just some physicists saying "I wonder what the math looks like if I remove something"

Pamela: [laughter] And that actually makes the mathematics a lot easier, it just makes the meaning of the mathematics a lot more nonsensical.

Fraser: Right, just because you can take that interesting mathematical formula doesn't mean that when you create a science fiction show based on it that you're basing it on anything.

All right. Warp speed and moving faster than the speed of light. Oh please let this be true…

Pamela: Well, and again it all depends on your definitions. Light travels at a constant speed in a given medium. So, if I have a vacuum, light is going to travel through that vacuum at 300 thousand km/s. If I have a bunch of rubidium gas at just the right temperature in just the right laboratory set-up, I can slow light down. In fact, there's a bunch of neat ways to slow light down and one of them is just a pair of glasses like you wear to correct your vision. Anytime light transforms from one medium to another, say from air to glass, from air to water, the light appears to bend and the reason it appears to bend is because its speed gets altered, it gets slowed down in a lot of cases.

So in theory, you can shoot a light beam through some sort of media that causes it to slow down and walk beside the media going faster than the speed of light. But you and light can't go the exact same speed in the exact same media.

Say you go out to outer space and fire your flashlight off and take off after it. You are going to be limited in that case by the rules of general relativity that say the closer to the speed of light you go, the larger your mass gets and if you try to move at the speed of light you're going to require infinite amounts of energy and that's never going to happen.

Fraser: Okay, that's just trying to move yourself faster than the speed of light. So, for example, in Star Trek they said clearly nobody can actually travel faster than the speed of light, we're just going to warp space. Why can't we do that?

Pamela: Well, first of all there's a few gravitational and energy constraints on that… the amount of energy needed to bend the Universe is slightly vast, you might say.

[laughter]

Fraser: How vast? Like all the energy in the Universe?

Pamela: Something like that.. and how exactly do you grab on to one section of the Universe and bend it into the current section of the Universe?

Fraser: Like, line up a whole bunch of black holes maybe, which bend…

Pamela: Yeah. So you're just creating a bunch of holes that you have to travel through when you do that. So yes, you can bend space but you're not going to be changing the distance between two points, you're just changing the geometry of the distance between two points. So we're sort of stuck and can't really warp the Universe.

Fraser: Right. Okay.

Now, one of the things that I think goes along with string theory, is talk about multiple dimensions

Pamela: Yes.

Fraser: Or with quantum mechanics is the concept of multiple dimensions, so here we are but there's another dimension just that we can't see but where other Fraser and Pamelas are recording Astronomy Show and maybe we could reach them.

Pamela: Well there's different ways to look at multiple dimensions. You can either look at it as perhaps there are multiple parallel universes. That model, we just can't test. We have no way of looking into the other universes.

The other way of looking at multiple dimensions is perhaps there are multiple spatial dimensions of which we are simply confined to the three dimensions that we experience. Think of it as being trapped on a sheet of paper: that sheet of paper has two dimensions plus time and it exists in a three dimensions plus time Universe. What if we simply live on a three dimensional surface within some Universe that has ten, eleven, thirty different dimensions, but all those other dimensions are either compressed such that we can't see them or we're simply confined to the dimensions that we're within and we have no way of getting out of those dimensions to experience the others.

There are some theories that are attempting to find ways to make predictions based on multiple dimensions existing. Some of these involve the decay rates of microscopic black holes, where they say "if we have more dimensions, perhaps these things can last longer, and if we ever find one maybe that will be proof" but beyond that there's no real ways of testing if there's multiple dimensions and no way of reaching out and touching the extra dimension.

Fraser: Isn't that one of the thoughts that (it goes back to string theory), that gravity is so weak because it is moving between multiple dimensions?

Pamela: That's one possible way, or it could just be that the Universe was created so that gravity is a significantly weaker force. The problem is how do we sort that out right now? We can build models so that the evidence fits both different scenarios.

Fraser: When I think multiple dimensions, I'm thinking of going through the worm hole to the other dimension, to the alternate reality.

Pamela: Right.

Fraser: I think that's a construct of quantum mechanics, right? Where with the uncertainty, every moment particles can do different things and then in one Universe the particle goes one way and then in an alternate reality the particle goes another way.

Pamela: That gets you into multiple universes where you have branching pasts and futures. So, every time you make a decision there is one view of quantum mechanics that says that to fit that decision causes the universe to branch. Where there's a universe where neither of us were sick, there's a universe where my voice didn't come back, there's a universe where you sniffled your way much more violently through this episode, and every possibility that could exist, does exist, in one of these multiple universes.

Multiple dimensions gets you into a slightly different picture though, where everything is chewing forward in the same universe. Where my decision only effects the dimensions that I exist within, but some of the dimensions I exist within may be dimensions I have no way of contacting, measuring, experiencing.

Fraser: So this is more out of phase, right? If we're talking about multiple dimensions. Like, instead of being in the 1, 2 and 3 dimensions that I'm used to, I'm instead transported somehow to the 4th, 5th and 6th dimensions.

Pamela: Exactly, and this again crops up in different Star Trek episodes where they're making contact with different life forms that have the majority of their reality in alternate dimensions so you see them as shadow beings flickering in and out.

Fraser: Do we have any evidence that there are additional dimensions that we can't –

Pamela: No.

Fraser: Okay, oka—

Pamela: No. We have none. There are people working to find predictions. If we find microscopic black holes that may be proof that we live in a Universe with more than 5 dimensions, but no one's found a microscopic black hole yet.

Fraser: I'll bet that someone's going to be looking for it in the Cosmic Microwave Background Radiation.

Pamela: Yeah, but that's where they look for everything

Fraser: Yeah that's what I'm saying – if you look hard enough, you can find everything you need in the Cosmic Microwave Background Radiation.

Pamela: The thing with these microscopic black holes is the numbers that they should exist in, imply that there might be some floating around in our own Solar System, so it might be the Mars Rovers (no, it won't be)… it might be in our own backyard that, (if they exist) we will find these microscopic black holes. But again, we have no reason to think that they're out there right now. But it might be one way of testing one set of theories that points toward multiple dimensions.

Fraser: All right. And I think the last one that I mentioned at the top of the show was what came before the Big Bang?

Pamela: And again this is one of those places that science just can't quite get to. The way I like to explain it is, the places that ancient mapmakers had no clue what was there, they wrote "there be dragons". In cosmology, the moment of the Big Bang is where we have to put "there be dragons".

Our scientific theories can't get beyond the cosmic microwave background in terms of observational data, so any theory that we build has to make predictions for features that we're going to see in the cosmic microwave background. These predictions that we make really can't go beyond the first moment in time to say what was before the first moment in time. First of all, it breaks the mathematics. If you have something before the Big Bang, you have something before time came into existence.

Beyond just breaking in terms of time, it also means that we have to start making approximations about what caused the Big Bang (we don't know). What if it was multiple universes? We can't prove that. What if it was just some sort of a quantum fluctuation and the entire Universe is a wave function that collapsed? Well, really we have no way of addressing that one either.

So there are theories that work mathematically, but beyond things that they can predict that we'll find in the cosmic microwave background, these theories don't make testable predictions. We can't go back and see what happened before, so now we've wandered into a mathematical subdivision of philosophy where you have to say "based on the evidence before me, I have faith that this is the theory that makes the most sense." At that point you're not longer talking about science.

Fraser: But I think that with the Big Bang, when someone asks me or someone wants to have a problem with the Big Bang and says "yeah, but you can't explain what caused the Big Bang" I just say who cares? It's not my problem. The Big Bang does a wonderful job of explaining the Universe from the moment of the Big Bang through expansion to where we are today. It's not its job to explain what happened before then. Some other theory – and people are hard at work with other theories (which right now are untestable and purely math) that work on that.

There's a really good analogy, I think, with evolution. Evolution perfectly and wonderfully explains how we get life the complexity of life on Earth, and yet obviously if you think all life on Earth is connected at a genetic level, you can trace it all back to some original ancestor. So the question of where that first ancestor came from… who cares? I mean, obviously one of the most important questions we could ask, and of course I care, but that's not evolution's job, to answer that question. Evolution only explains the moment that first creature came about, and same with the Big Bang. It explains where we got from the Big Bang on, before that is some other theory's job (and probably an untestable, only mathematical theory).

Pamela: A good way to think of it is science has to explain why a ball I toss into the air goes up and comes back down. Science doesn't have to be able to explain why I decided to throw the ball.

Fraser: Right. And I think that's a good thing about science; we don't need to know the answer, we can change our mind, we can really enjoy the process, we can be grateful of the predictions and the evidence that we're able to see, but we don't necessarily need to have any kind of hard and fast faith on what we're going to find or what the Universe tells us, you just kick back and enjoy the discoveries that are made and our increases of understanding. If it turns out that something is completely wrong… oh well. It was fun while it lasted, now we've got a new theory.

Pamela: Scientists are one of the few breeds of creatures that get jubilantly ecstatic when everything they thought was true turns out to be wrong, because then it’s a new problem, a new puzzle to have to try and figure out.

Fraser: So to wrap up, and what I don't want to do with this episode is I don't want to be too flippant about this. The problem is that a lot of the concepts we talked about this episode came out by some theorist somewhere, interesting idea but it was a hook that a science fiction writer could use to tell a story about people. "Wouldn't it be cool if…" So from that point on, they popularized something that wasn't mainstream, wasn't ready, had no evidence. The fact that you know about it, and the fact that many people are so interested in it is not necessarily because of the evidence that supports the theory, it's purely just that science fiction movie makers have popularized them and there isn't much more we can do until more evidence shows up.

Pamela: So we're left in a Universe with a lot of really hard to understand mathematics that makes really funky cool things possible within the framework of the math, but we're left with a physical reality that denies a lot of the math the ability to do its funky, cool things.

Fraser: So unfortunately, no good news for any of those topics, but as we've said, we're happy to be wrong, we can't wait for the evidence to show up that tells us that any of these theories is nice and well supported, and as soon as it is we'll report on it and move it firmly from pure math theory to evidence.

All right. Thanks Pamela, that was fun. Hope you get better, we'll see you next week.

Pamela: Thanks Fraser, it's been my pleasure.

This transcript is not an exact match to the audio file. It has been edited for clarity.