Astronomy Cast Episode 43:
Questions, Questions #5

Fraser Cain: All right, so it's about that time again: we figured we'd head back to the astronomy cast mailbox and see what's new. We have a bunch of new questions from listeners that we thought we'd tackle, and the cool thing here is we have lots of audio questions, so thanks to everyone who sent in your audio – it makes the show even cooler.

All right, so first up we've got Kevin Wilkinson, who wants to know about our rotating universe, so let's hear what he has to say.

Kevin Wilkinson: Hi, my name is Kevin, from eastern Washington. If matter is in a state of motion relative to all other matter, and this mass (with the help of gravity) will coalesce into larger objects, and these objects eventually fall into some kind of circular or rotational system, like moons to planets, planets to stars, stars to galaxies, my question is on the grandest scale, is the universe in a state of rotation? Is there anyway to detect this?

Fraser: That is a great question. I suspect I already know where your answer's going to come from, but would there be a way to know if the universe is rotating?

Dr. Pamela Gay: So the question is rotating with respect to what?

Fraser: I knew that's what you were going to say!

Pamela: (laughing)

Fraser: I guess the question is if you have a merry-go-round and you're inside the merry-go-round and it's rotating, you don't have to be rotating with respect to anything: you can still feel that centrifugal force pulling you to the outside of the merry-go-round, wouldn't you?

Pamela: But there you have an axis of rotation that you're going around.

Fraser: Which is on the Earth or in the universe.

Pamela: Right, so our universe… where would the axis of rotation be? We can't define such a thing that we know of. There's no random centrifugal force pointing in some direction that everything seems to be heading in that we can detect. We've done really careful redshift surveys of the universe around us, and everything seems to be expanding but it's not in a way that seems to track with some mysterious centrifugal force with what axis is it rotating around.

I think this is one of those crazy things where because our universe is its own thing (which we can't get out of and we can't define anything outside of), that we can't really say the entire universe as a whole is rotating.

Fraser: I think if people wanted to wrap their heads around why the universe is all that, they'd have to listen to our What Is the Universe Expanding Into show

Pamela: Exactly.

Fraser: Because we covered that concept for half an hour

[laughter]

But from that scientific point of view, it sounds like some scientists have had that question, they've looked at the redshift, the speed of galaxies moving away from us in all directions, and said, "is there some kind of direction that they're more moving towards" are they moving more in – for example, the Earth is spinning, the galaxy would be moving in a certain direction toward the equator, but not so much toward the poles, right?

Pamela: This is what we see. We have very carefully measured both the motion of galaxies and also Doppler shifts within the cosmic microwave background. We have this nice, uniform background light that we can measure a motion against. The part of the cosmic microwave background that we're moving toward, we see blueshifted a bit. The part we're moving away from we see redshifted a bit. We can account for all the motions that we see and none of them point toward the universe itself being in rotation.

Fraser: So if the universe was rotating within some larger thing, then we would detect it. Because it's not, either the universe is in some larger thing but it's not moving (not rotating) or the question is meaningless because the universe is all there is.

Pamela: Right.

Fraser: All right. I don't think we should start this show with a headache, but there we go…

Pamela: (laughing) But why not?

Fraser: Why not… Okay, let's move on to the next question then. This is from (I hope I get their name right), Tom Chirpich.

Tom Chirpich: This is Tom from Kansas. What is space? How does it differ from nothing? We have lots of things in space: matter, photons, gravitational attraction, magnetic and electric fields, even possibly gravity waves travelling through space. Gravity is said to curve space, implying something's being curved. So if we've got two things in space, how does that space between them differ from having nothing between them? What does space have that nothing doesn't? what is being curved?

Fraser: Okay, on to our next headache then!

[laughter]

I can't even understand the question right. How does space differ from nothing? Is there less than space?

Pamela: So when I think of nothing, I think of a three-dimensional zero. Let me see if I can try and explain that. I can have one of something, I can have a metric cubic metre of something. I can have zero of something, and I can have a volumetric nothing.

Fraser: Volumetric.

Pamela: So when I say that I have nothing, it's a expression of zero that is defined over space. So actual space, when we say the word "the astronaut went to space" is a location. The dude left the surface of the planet. The word space is just a place that you go to.

We also use it in the vernacular to say, "oh this house has a lot of space," meaning there's a lot of volume to it. When I say this room is filled with nothing, I'm not being mathematically accurate because a room is filled with air, it's filled with dust mites, it's filled with energy from sunlight (if you have windows). So an actual space in a room in a house that my eyes perceive as being filled with nothing, actually has lots of stuff in it. Mathematically, physically, when I say there is nothing somewhere, it's a zero.

Now, that we know of, there's no place in space that is actually a volume of nothing. There's at least going to be gravity permeating a cubic metre of space. There's at least going to be photons from the cosmic microwave background. So when I say "empty space" I'm usually just meaning there's no measurable amount of mass within that volume.

Fraser: Okay I see. So if we look across the whole universe, it's almost like there is something everywhere, it's just different, varying densities. Sometimes you're passing through what we would call vacuum. In there you'd find photons, gravity and the occasional interstellar dust. Other times you're passing through the Earth, or the Sun, or a black hole and there's a much larger density of material.

Pamela: So it all ends up being… well, we have the definitions we use in everyday speech, the way we talk to our friends and family, and then you have the mathematical definitions. So a room full of nothing, mathematically, we don't know how to get there. In the vernacular, it's just a room you don't have furniture in.

Fraser: Is there a way that we could zoom in and zoom in and zoom in to the point that maybe there would be some place with nothing?

Pamela: Well, how do we detect that? That means we've zoomed in to some place with no photons. I'm not sure how you get to a place that doesn't have gravity permeating through it. There's no light coming from it, because the light is a something.

Fraser: Isn't there a general background radiation of particles, virtual particles, appearing and disappearing in quantum fluctuations?

Pamela: And there's background neutrinos left over from the big bang… in reality there probably is no such thing as a space filled with nothing. There's always ---

Fraser: but isn't there…

Pamela: Go ahead

Fraser: Sorry, too many questions! Is there anything different then between the something and the nothing? Could you break them apart, so you've got the matter and then you've got the nothing, or does that not even make any sense?

Pamela: But then, what about the energy?

Fraser: Break the energy to two, so you've got the energy and matter over on one side, and the space in between them on the other side. If you took away all the energy and matter, would have nothing? Would you have something that's nothing?

Pamela: You'd have to get the energy and matter infinitely far away, or their gravity at least, would be there. Gravity we think arises from a scalar field, so you have this field permeating space and you have graviton bosons permeating through space and so, in the real universe, we're never surrounded by nothing. We're always surrounded by something.

Fraser: Hmm. I hope that's going to meet Tom's needs, but if not Tom, come back at us because I think this is one of those hard ones to answer. Let's move on though.

Pamela: Okay.

Fraser: That could turn into another half-hour show: what is nothing? All right.

Pamela: We need to invite a philosopher if we're going to do a half-hour show.

Fraser: Yes, maybe…

All right, the next questions is from Steven Williams and he wonders if a human being can really withstand the inhospitable vacuum of cold in space unprotected, for a short period of time. Say you're trying to make it from the mothership about to self-detonate, to the life pod which was ejected by accident. Or you're running out on the surface of Mars (though I guess there's a little bit of atmosphere on Mars).

So what would happen to a human being if they were out in space?

Pamela: This is one of those times where I have to say one of my favourite sci-fi shows got it totally right. I love *Battlestar Galactica*, I have loved *Battlestar Galactica* since I was five and didn't totally feel betrayed by the new series. They did, in an episode last season, a show where a couple of characters get trapped in an airlock and they can't get back onto the main part of the ship because a door's locked. They're running out of air and the only way they can get out is to open the airlock and jump into the open part of another ship.

They discussed all the different problems that are going to happen. First of all, there's going to be the extreme cold that you withstand, that will cause frostbite. The low pressure of space will cause the bends, it will cause bruising of your skin and blood vessels are going to explode. But for a very short period of time, you can actually survive this.

You want to keep the amount of time as low as possible. You want to keep the amount of skin exposed definitely as low as possible, but for brief moments the human body can withstand it. If you hold out too long, your skin is going to lose structural integrity, the blood vessels are going to rupture, you're going to freeze solid (which is always a bad thing), and the bends will kill you.

But, in might be a way to survive if you have to. For a brief moment.

Fraser: But you're not going to explode like I think I've read in comics and seen on movies and TV shows a long time ago. That's wrong, right?

Pamela: Your skin will eventually start to pull itself apart, and your blood pressure will cause blood to spurt. All sorts of bad things will happen, but it won't be an instantaneous, cartoon-character explosion of human bits.

(laughing) such a charming topic!

Fraser: Well, no… but it's a real plot device used in many of those television shows and comic books, and always it's the most horrific way you can die, but in fact I think you're right. The way they handled it in *Battlestar Galactica* was great. It was a very tense scene, and very dangerous with them knowing what they had to do. So I think that was great.

Good, good question. All right, moving on.

Scott: Hi Fraser and Pamela. This is Scott from Columbus, Ohio, and I have a question for your question show. The question is this (it's kind of complicated, so give me a second to set it up): Space and time are, according to Einstein, composed of four dimensions (three spatial dimensions and one time). They all seem to be part of the same thing. We've pretty much accepted as cannon that space is expanding (since Hubble and all that).

My question is does time also expanding? Are points that were adjacent to each other in time, separating? If so, what does that mean? Is there going to be a point where the expansion exceeds the rate at which time passes, so time will eventually stop?

Also, I was wondering if since space is bound by gravity, is time also? In other words, are there pockets of faster moving time and slower moving time in the universe? What does that mean for data we might be receiving from far away? If we're looking at a quasar for example, how many of these fast and slow pockets has the light from there travelled through, and wouldn't that compress and expand the spectrum of the light as it's coming, which would seem to me to make some of the data we think we're seeing, not valid.

Say we're seeing a spike in the oxygen area, how do we know that spike didn't actually migrate from another area within the spectrum?

Anyway, that's my question. Thank you.

Fraser: All right. Normally I like to summarise the questions, but I don't think I really get that one.

Pamela: (laughing) I think I actually might, but then I might not. If I don't Scott, please email us back and I'll try again.

So our universe is expanding. We have this initial point from which we all came from and inflation carried that point outwards further. Gravity attempted to slow down the expansion of the universe (failed), and dark energy is now accelerating the expansion of the universe, but this is all spatial. The galaxies are getting pulled farther and farther apart.

Now, is it possible that as the universe itself expands, that time is expanding, that the beat of a pulse between some universally defined second is growing longer. Mathematically, the way to put it is because we define everything off the speed of light, is the speed of light slowing as the universe expands?

Now, the thing is.. how would we measure that? How would we know? This, I don't know how to answer. Time, as far as we know, is defined strictly off of the speed of light. The speed of light is a constant in everyway we try to measure it. So the real question is, if the universe is expanding, what's happening to the speed of light? The speed of light seems to remain constant, but the colour of light – if you start off with a blue light beam at the beginning of the universe and let it shoot off and not interfere with anything, the colour of the light is going to get redder and redder and redder.

But that's not the speed. Every colour of light travels at the exact same speed. So in everyway we know of how to perceive time, time remains constant as the universe expands. If time was slowing, would we have a way of knowing it? This, I don't have a way of answering.

Fraser: But didn't you say at one point that photons don't experience time in the way that we do?

Pamela: Exactly.

Fraser: Because they travel at the speed of light, they experience… I don't even know how to wrap my head around it. They experience no time.

Pamela: Right. Time stops when you go the speed of light.

Fraser: Right, except that you're moving in time, but only from the perception of someone else. So this is one of those situations that would require some way to get outside the universe. I see what you're saying, that if time is slowing down, then you would notice because you're caught in that time as well, so speed of light would be changing and time would be slowing for you but it would all wash out. It would all just feel like the same amount of passage of time. You'd need some way to get outside of the universe and look inside and go, "okay, time's slowing down there" because the universe is expanding.

Pamela: Exactly.

Fraser: But nothing predicts that this should happen.

Pamela: No, no. We have absolutely no reason to believe this is happening.

Fraser: Right.

Pamela: It's one of those, "Oh, that's neat to think about." There are a lot of things in physics where we have no testable way of figuring out what's going on, and it sort of lends itself to a lot of cool, philosophical thinking. But that's not science – just stepping back, saying, "it's cool." But we can't get there via the scientific method.

Fraser: Right. Great question Scott.

All right. We'll move on.

This is cool. This has got to be our youngest *Astronomy Cast* listener. So this is Carl Cohen's son, eight-year-old son, has a question for us.

Carl Cohen: Hi Pamela and Fraser. My name is Carl Cohen, and my eight-year-old son Scott has a question for you.

Scott Cohen: What kind nebula was the Sun born in, and what were some stars around it?

Fraser: That's a great question, because we see all these cool different nebulae: the Orion nebula, the Helix nebula… what kind of nebula, if we could've looked at our Sun from outside, would we have been born in?

Pamela: As far as we know, we were born in a nebula not too different from the Orion nebula, although perhaps it was smaller. So we were born in a cluster of stars in a giant molecular gas cloud.

That gas cloud, for whatever reason, began to collapse, began to fragment into a lot of different stars. The stars each individually formed – some of them had planets like our own solar system. This large family of stars (that all came out of the same parent cloud) slowly orbited around our Milky Way galaxy.

Some of these stars were a little bit closer to the centre of the galaxy, and some were a little bit further. So as they orbited, the ones that were closer went a little bit faster, and the ones that were a little bit further out went a little bit slower. Over time this family of stars separated and spread apart and moved apart and began to no longer associate with each other.

So now, as we look around the Milky Way galaxy, we see stars that have similar compositions to ours, and we think, "well, maybe they were born with us," but we don't really have a good way of saying, "yes, we know that star is one of our siblings." It's sort of like looking around and saying, "wow, that person has brown hair, brown eyes and similar facial structure to me. I wonder if we have the same ancestors." It's something you can make speculations about, and if you do indeed find someone who's your exact twin and you're adopted, you might actually go, "let's get DNA testing" but we don't have a way of saying for certain who our siblings are.

We do know we came from a system very similar to the Orion Nebula (although perhaps a bit smaller).

Fraser: About how long would that process take? I know the Sun's been around for 4.5 billion years and so have all these other stars, apparently. How long would it take before they got so separated apart from each other that it's hard to trace them back again?

Pamela: Here's one of the neat things: if you go outside on a winter's night, you can look around and look at the Orion Nebula. That's a system that still has lots of gas, lots of dust, is still actively forming stars at this moment.

You can then look a little bet to the right (well, depending on how you're standing and what side of the planet you're on) – you can look over toward Taurus and up, and there's the Pleiades. The Pleiades is a slightly older cluster. It's used up most of its gas and dust, it's not currently forming stars, but the stars are still packed together quite tightly.

If you look between those two systems in Taurus there's the Hyades cluster. That's an older cluster that's harder to see as a cluster. Basically, if you scan your binoculars around the sky, you'll simply see, "oh, this region has more stars than this other region" but they don't necessarily form a tight ellipse or tight circle of stars.

These are three systems at three different ages. Orion is the youngest, and the Hyades is the oldest. It only takes a few billion years – less time than the Sun has been around – for an open cluster to completely take itself apart. Our open cluster's already destroyed, and now we're watching the last days of the Hyades cluster as we look out into the nearby universe.

Fraser: Hmm. That's interesting. I'd never thought about where the stars who we started with have ended up. That was great! Thank you very much for the question, that was great.

All right, moving on. Our next question is from Brian Russell. He wants to know how we know that dark energy is pushing everything away – here's his question:

"Why do we think dark energy is pushing everything further and further apart? Is evidence pointing to dark energy only being created behind us, where we've already been, closer to the centre of the big bang? Or is there anything saying it could not suddenly appear in front of us, or to the side, and that its only interaction is not only pushing us further apart and further out, it could also be pushing us toward each other or back toward the epicentre of the big bang? Could there be a large mass of it somewhere out ahead that could stop us? Or the same situation exist for other galaxies?"

That's a good question. We imagine dark energy as this mysterious force that's accelerating the expansion of the universe, but couldn't it be doing other things? Could it be pushing one side of the universe one way? Or also, pushing us back in the middle as well? Shouldn't it all even out?

Pamela: One thing that has to be understood is "dark energy" is a placeholder name. We observe this thing going on and we don't know what's causing it, we don't know the physics behind it, we just see this phenomenon. Because we can't simply say, "the thing that has all these characteristics," (and list all the characteristics) in conversation without getting bored, we have named this phenomenon with all these specific characteristics "dark energy." We don't know what it is, we just know it's characteristics.

So what are the characteristics? As we look out at the universe, we can say, "okay, there's this much mass." That mass is causing things to attract one another. We can get at what's called the mass-density of the universe in a lot of different ways and figure it out. Using that, we should know the rate at which the universe is slowing down in its expansion. But the universe isn't actually slowing down. The universe is actually expanding, and accelerating as it expands.

So we had to come up with a reason for why it's expanding. Then we needed to figure out if it's always had this acceleration going on. So people a lot wiser than me, and a lot more mathematically and theoretically inclined than I, have gone through and done dynamic models of the universe. They've said, "we have this much mass and this much mass spread out over this much volume should be self-attracting with this much force, so the expansion rate of the universe as a function of time should look like this."

When they make these plots, they realise, "wait – there's always been something pushing the universe apart. As near as we can tell, that something that is doing the pushing is constant with volume. So when the universe was tiny, it had a certain small volume. If you take that small volume and multiply it by this "this is how much pushing dark energy does per unit volume" value, you can get the universe's expansion rate.

If you then let the universe expand for a while and say, "okay the universe now has this larger volume, and I'm going to measure this larger volume by this dark energy expansion acceleration amount, you get a new number.

As near as we can tell, the dark energy that's doing the accelerating of the expansion has always been there, pushing. It's every volume of space that is pushing the same amount, so the amount of space my coffee cup takes up is pushing outwards. The amount of volume my trackball takes is pushing outwards. Every single volume of space is pushing outwards on every single other volume of space.

This is the rising bread. In rising bread you have yeast mixed (hopefully) consistently throughout all of the bread, so all of the bread expands, not just some small bit (unless you forgot to mix the yeast). For the part of the universe we can observe, the expansion is consistent everywhere. The dark energy is mixed in well the same way you hopefully have yeast mixed in well in bread.

Fraser: So I guess it's different from dark matter in that situation, because in dark matter there does seem to be evidence that it can clump and form into large structures that are pulling with gravity on galaxies and so on. In the case of dark energy, it's everywhere, at every point in space, and I guess the reason why it doesn't, say, blow your coffee cup apart is just because the amount of force is just too small.

Pamela: Right. My coffee cup is held together through atomic and molecular bonds, and lots of neat electromagnetic forces are taking place. Then there's the weak force and the strong force and all the atoms are holding themselves together, and dark energy is really, really weak.

Fraser: So this has got to be one of those questions they've asked: is dark energy consistent everywhere? Is it clumping, is there one side of the universe that's expanding more quickly or is there something that's buffering some other part of the universe. From the observations so far, it's perfectly smooth and even everywhere you go.

Pamela: The weird thing is that as the universe increases in volume, the dark energy in the universe increases at the same rate. This is something we just don't know how to make sense out of. But it's the way the universe is built.

Fraser: Make sense of it right now. No? Yeah, I guess that's all we've got.

Pamela: For now.

Fraser: For now. I think one of the things we get – I get on the forum and we've heard this a lot – people don't like dark matter and dark energy. They just don't like it. It bugs them.

And yet, as you said, you have that list of all of the features, all of the mysteries, line them all up, put them in a collection and go, "there, explain that," and they'll come up with something. They'll call it something different, but at the end of the day it's the same phenomenon, the same collection of problems that need to be solved.

Sometimes it's okay. If we need to have a collection of problems that we don't know the answer to right now, that's fine. Who cares? So I think that's a good way to go about it.

All right. That's it – I think that's all we've got time for this week, so we'll put the rest of our questions back in the box and we'll get them in another few weeks.

Pamela: So send us your audio, send us your questions. You guys are asking really hard stuff and it's a lot of fun reading the things you send us, so keep it coming.

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