Astronomy Cast Episode 65:
The End of Our Tour Through the Solar System

Fraser Cain: All good things come to an end - we now find ourselves in the outer reaches of the solar system where our Sun is hard to distinguish from the other bright stars in the sky. But we're not done with the solar system, there's some stuff that's leftover. Where are we going to go next, Pamela?

Dr. Pamela Gay: We're going to explore the last little bit of where the Sun starts to interact with the interstellar medium surrounding our happy little solar system.

Fraser: What kind of interaction are you talking about here?

Pamela: Our Sun is constantly spewing out a solar wind of particles, electrons moving at a high velocity (something like 400km/s) through the solar system. This blast of wind from our Sun is pushing out the interstellar medium. Where it collides with the interstellar medium, it causes shocks, it actually slows down and we can see the effect of our Sun on the rest of the galaxy in what we call the heliosphere.

Fraser: Okay, so the sphere of material flowing away from the Sun is entirely called the heliosphere?

Pamela: The outer area of where it starts to interact with the interstellar medium beyond the solar system is pretty much the heliosphere.

Fraser: Right, so we wouldn't say the solar wind nearby the Earth is part of the heliosphere.

Pamela: Right.

Fraser: It's just out there.

Pamela: Yeah, we're talking about a region that's about 75-90AU (depending on how much the solar wind's been blasting) out to basically around 230AU.

Fraser: Right. Okay. So if I was to just go and grab a chunk of that space in my hands and examine it with my lab equipment, what would I see in that volume of space?

Pamela: It's sufficiently empty that you'd probably grab a big handful of absolutely nothing. That's one of the weird things about talking about these things.

We talk about things like the speed of sound through the solar system, because scientists actually refer to the speed of the solar wind as being supersonic – faster than the speed of sound – but there's no sound in space.

The idea is that there is a certain amount of stuff out there that's moving and flowing. If you do the physics to figure out if you did have a compression wave like sound moving through this mostly empty nothing, how fast it would be going. What we find is particles are moving faster than a compression wave (a sound wave) would be moving through this not-quite-nothing in the solar system.

Fraser: Right, okay. So they're ejected from the Sun, they speed out through the solar system at faster than the speed of sound, but at the same time they're bumping into the universe? The Milky Way?

Pamela: The galaxy.

Fraser: The galaxy.

Pamela: The interstellar medium.

Fraser: Right, and what is the interstellar medium, then?

Pamela: Between all the different stars there's remaindered gas, the stuff that's leftover. If you've ever seen a construction site, you have a nice pretty building in the centre of the construction site and all around it is junk. There are leftover pieces of wood, leftover bricks, scattered nails, random McDonald's cups.

Fraser: I've had that job.

Pamela: (laughs) So the refuse leftover all around the construction site – that's sort of what's out in the interstellar medium.

Fraser: All right.

Pamela: The stuff that wasn't used in building our solar system – or building other solar systems.

Fraser: Right, and could end up in a solar system in the future, but right now it's just out there.

Pamela: Exactly.

Fraser: So is it just leftover stuff, or is it from solar winds coming off of other stars?

Pamela: The interstellar medium itself is made of three different constituent materials.

First there's the stuff that's left over from the formation of the universe. This is the raw gas that has never once been recycled through a star. It's just hanging out hoping to someday be needed by something.

The other constituent of the interstellar media is the stuff that came out of supernova, that came out of past stars having stellar winds. It's the stuff that survived one or more times of being part of a star, and then was shed and sent out to be recycled.

Then there's just the leftover stuff our own Sun is constantly blasting out. So we have all these things in the interstellar medium around our Sun.

Fraser: I wonder though, the other stars aren't generating solar winds as well? I can imagine bubbles around stars where they're all packed together. Is that happening?

Pamela: That's exactly what we're finding.

Fraser: It is? Okay.

Pamela: That's exactly what we're finding. Each little solar system has its own bubble of space its own stellar-sphere, the way we have a heliosphere. Beyond that sphere is where the interstellar medium lies.

Fraser: Okay. I know astronomers delineate the heliosphere into a bunch of pieces. How do they break it down?

Pamela: The first place is where the solar wind finally gets braked down to the point where it stops going faster than sound, where it starts going at subsonic speeds.

If you imagine these particles in the wind from the Sun… it's racing out, but it's constantly getting slowed down a little bit through its interactions with all the other stuff out there. At this point that we call the termination shock, about 75-90AU out, it breaks down to going at subsonic speeds. In the process it creates a shockwave.

Fraser: I was going to ask that – something interesting does happen at that point? It's not just a milestone that you might reach, just a mathematical interest – there's actually something physical that happens at the termination shock.

Pamela: At the point the material goes past this magical speed of sound there's actually a shockwave the same way you get a shockwave when an airplane transitions from going subsonic to supersonic – we also get a shockwave when we have materials make a similar jump from going faster than the speed of sound to slower than the speed of sound.

Fraser: Okay.

Pamela: It's kind of cool.

Fraser: But it wouldn't do anything to a spaceship or anything?

Pamela: We've actually had a spacecraft go through the termination shock. Voyager 1 on its way out to explore beyond our solar system passed through the termination shock and nothing bad happened. It's still plugging away on its happy little journey out of the solar system.

We think in the next year, Voyager 2 is going to make its first pass through the termination shock. The thing is, both thee crafts are probably going to have to go through this shockwave more than one time, because our Sun in different years, has different powers of wind. Some years there's enough force in the wind that it makes it a little bit further out. Some years it doesn't make it quite as far as it battles against the interstellar media around our solar system.

Fraser: So in some cases the spacecraft is going to plough through the termination shock, and in other cases the termination shock is going to plough past the spacecraft and it will have to go through it again.

Pamela: Yeah, so we have this back and forth tug-of-war of where this shockwave is, and as it goes back and forth, the Voyagers can get stuck going back and forth through it multiple times while continuing to go in the exact same direction relative to the Sun.

Fraser: Okay. What's next, then? What's the next part of the solar system called?

Pamela: Beyond the termination shock we have a heliosheath. It goes from about 80-100AU. This is where the solar wind is still pushing, but it's going slower. There's a lot of turbulence as the solar wind mixes with the interstellar media and everything is mixing together.

Think of it this way. If you turn a faucet on into a full sink of water and you blast it really fast, where the water hits the bottom of the sink it will spray out and you'll get this disk of fast-moving water that's pushing out on the water around it. At a certain point, that disk breaks and you end up with this turbulent area of water around the smooth disk.

That smooth disk of outward moving water is sort of like the termination shock. Beyond that, where you have the turbulent mixing is more like the heliosheath. This is where the subsonic (slower than sound) moving wind is starting to mix with material from beyond our solar system.

Fraser: Then it's just smooth gradient. It goes from just below the speed of sound down to… stopped.

Pamela: To basically where the wind stops, and we call that the heliopause. The solar wind takes a break and just sort of stops and sits there and goes, "oh no. I'm outside of the solar system now." At that point, you're outside of the solar system and you're dealing with the material from around us.

Fraser: I can imagine then, that as the Sun's output of solar wind rises and falls, you'll have material that is briefly stopped and then the heliopause will shrink and now that material just gets blown away by the interstellar medium and that's that. Other times when the heliopause expands outward and gobbles up additional material and then loses it again as it expands and contracts.

Pamela: We're actually planning to map out where the termination shock is, where the wind makes its sonic/sub-sonic break in speed by looking at different charged particle reactions that you get happening. We can do this from the orbit of our own planet.

There's a mission called IBEX, for Interstellar Boundary Explorer, that's in the process of trying to map out this transition point and see how it changes, how it's asymmetrical, the differences when you look north, south, or the direction the Sun is moving through the galaxy.

We think there's a bow shock in the direction our Sun is ploughing through the interstellar media. As the material from the interstellar media effectively moves toward us (because everything's in motion in the galaxy), that it also creates its own shockwave as it brakes against the interstellar media that we've already slowed down through the mixing with our own stellar wind.

So there's a shockwave, just like the bow wave of a ship moving through the ocean. In this case the bowshock is through the gas of the galaxy.

Fraser: It's almost like, then, that the Sun looks like a comet. It has a tail stretching behind it where material is stretching behind it, and yet at the point where it's actually ploughing into the interstellar media, it bunches up and there's attractions.

Pamela: What's neat is a comet is shaped¬ by the material getting stretched out. If you look at the shape of our solar system as it ploughs through the interstellar media, the shape is the emptiness of where all the material has already been swept up or pushed out of the way by the Sun. So we have a comet-shaped, mostly empty space that our solar system has created in this cloud of material.

Fraser: That's it, right? Have we got anymore solar system?

Pamela: We're not quite sure. There's this potential object. No one knows if it actually exists. Most scientists think this is a crazy idea, but there's a group of scientists who have done calculations and noticed that it looks like, every 26-32 million years (depending on whose papers you read), there's a new round of stuff sent from the Oort Cloud into the inner solar system.

The only way to really explain what would cause that to happen is if there's an extra star, an extra planet, some object that's on an extremely large orbit that, every 26-32 million years, ploughs itself through the Oort Cloud.

Fraser: So it would be on some kind of elliptical orbit, and when it reaches some point in the orbit it passes through the Oort Cloud and disrupts objects with its gravity.

Pamela: A highly elliptical orbit. The centre of gravity of the Sun and this other object is well outside the Sun at some point closer to the Sun than the other object, but out in the outer solar system somewhere.

This object might possibly actually be some known red dwarf star that we've already identified but we haven't been able to see that it has a motion that corresponds to an orbit. We have a lot of trouble trying to measure distance of red dwarf stars. You can only really measure the distance through parallax measurements, and you need nice, bright, easy to measure, easy to get good centroids on objects to get good parallax measurements. Red dwarfs are kind of faint.

Even worse, it might be a brown dwarf star. Those are extremely hard to detect, so it could be there's some really faint, really tiny star out there we can't easily see. Or there's some red dwarf star you could see with a backyard telescope, but we haven't plotted its motion well enough to know it's only about a light year away and happens to be gravitationally bound to our solar system.

Fraser: Are we going to have those kinds of interactions with other stars? I can imagine with such a large sphere of influence around the Sun, we must bump up against other stars from time to time – not bump like bonk into them, but disturb one another.

Pamela: No, it is true that as our solar system moves through the galaxy, we do interact with other things. Another theory for what could be causing this Oort Cloud disruption every tens of millions of years, is that as we orbit through the galaxy, we move up and down relative to the disk of the galaxy. As we do this, we pass through thicker regions of the interstellar media that are able to affect us.

We also look at where the stars around us are, the directions they're moving in and the direction we're moving in. we work backwards to see who they last interacted with, and we work forward to see who we might interact with next.

Our last interaction might have been with the binary star Algol, which is considered to be the most unlucky star (if you're a superstitious person) in the sky. The next thing that we'll probably interact with in about ten million years ago is Gliese 710, a red dwarf star about 63 light years away from Earth. That could also effect our Oort Cloud and cause comets to rain into our solar system.

Fraser: The Voyager spacecrafts aren't the only things out in the outer solar system right now. There's also the Pioneer spacecraft, right? There's a bit of a mystery with them, right? Since we're in the outer solar system we thought we'd lump that in. Why don't we talk about that?

Pamela: There's this thing called the Pioneer anomaly, where as people go through the 30 years or so worth of data that have come off of the Pioneer missions, they notice that we can't fully figure out why their motions are what they are. We can figure out where the planets are, their gravitational pulls and everything else. It looks like the Pioneer missions have gotten slowed down more than they should've. They're not escaping the solar system at as high a speed as they should be. We call this the Pioneer anomaly because there seems to be some sort of a weird, Sun-ward force, Sun-ward acceleration acting on the Pioneer missions.

People aren't sure if this is some weird physics we don't understand, or if this is some weird computer phenomena we don't understand. The Planetary Society wants to get to the bottom of this, and NASA hasn't had the money to really address this question. There's a lot going on and to sort out this problem you have to invest a lot of money into getting some really old computers working again so we can read the data from the Pioneer mission that dates all the way back to when people used punch cards.

So the Planetary Society raised a bunch of money to take the problem off of NASA's hands and get some archived computers working to read the archived data and translate all the data into a nice, consistent, machine-readable form.

Then people can go through and re-analyse and see if the problem is that we've changed how we analyse the data over the years, or if it's actually an Earth-pointed problem that would indicate there's something we did wrong.

Maybe there's really some Sun-directed acceleration that we can't explain that requires us to start considering things like maybe the electronics are heated up to the point where the heat is causing some sort of energy slowing them down. Maybe it's something to do with leaky gas on the different craft that as it leaks out is slowing them down.

There's lots of things this could be other than weird physics, but of course most of the people who sensationalize this and ask for money are like, "we don't know! It could be weird physics!" Everyone's always interested in trying to prove and disprove weird physics.

Fraser: Yeah. I don't have much to say about that. IN this kinds of situations, there's a lot of magazines out there (we're not going to name any names) that will sometimes take the most sensational conclusion to weird mysteries. Sometimes it's just cool to have a weird mystery and not really worry too much about what the solution is until you're able to get your hands on more data. This is one of those situations where until people really get the data, they're not really going to know.

This is a huge mystery, and I see papers on this in journals – a couple a month.

Pamela: There have been entire commissions, entire meetings dedicated to trying to figure out what's going on. What's so frustrating is it's not like we can go out and look at the rocket and see if there's a gas leak. Because the two Pioneer spacecraft are basically configured the same way, seven different analyses of the data have come up with the exact same weird anomaly.

Fraser: For both spacecraft separately.

Pamela: Yeah, so it doesn't look like we're making a mistake in how we process the data. It's not like we're making a mistake in our calculations. We could've made a mistake in how we got the data from 30 years ago and the data from today all put together on the same set. So this is where it's so important to get the archived computers re-reading the archived data to get everything into one systematic format.

Fraser: I think at some point down the road – maybe when there's more data out there – to really talk about what's going on there. Even just the investigation of it is pretty fascinating stuff, to see how scientists work both how someone goes, "huh, that's funny." Which is the way the best discoveries are made, to trying to gather the data and be precise with measurements. It's a pretty fascinating story. I've published a few stories about it and people always find it really interesting.

Pamela: What I really like about this is it's one of these problems where NASA said, "yes, this is cool. Our budget is limited, we can't deal with this." The Planetary Society responded by saying, "Okay, we'll raise money and get the people to do this." And NASA was like, "okay."

Fraser: Something similar happened with the Voyager spacecraft. They were going to take them offline – they didn't have funding to listen to them anymore. People organized rallies to try and get funding. I think in the end NASA was able to come back and continue keeping the offices open.

Pamela: I think it's so cool that if you let the US population – and the world population – know, "look, we're honestly out of money," and NASA only gets half a percent of the US budget. If you let people know there's a real need and if they give money it will go directly to this cause, people are willing to fund intellectual investigations. People are naturally curious, and they'll put their money out to help learn the answers to the things we're curious about.

Fraser: Yeah. It's like the government or the space agencies just have to give people more benefit of the doubt and more credit for being genuinely interested and wanting to support this kind of scientific discovery. Not everyone is grumpy about it and thinks we should solve the problems on the Earth first, before we explore space.

Pamela: Like I said, half a percent of the US budget goes to NASA. It's a small amount to pay on the grand scheme of things to better understand the universe around us.

Fraser: And what this has to do with the solar system, I'm not sure. Before we get totally off-track, is there anything else with the solar system we should bring up? Or are we done?

Pamela: We've reached the edge of our solar system and we're now standing in intergalactic dust bunnies.

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