Astronomy Cast Episode 40:
American Astronomical Society Meeting, May 2007

Fraser Cain: We're going to take a bit of a break this week and talk about some of the interesting research you picked up while you were there – some of the latest breaking news, the stuff that's going to make you have to go at your textbook with a pen to fix them.

[laughter]

So, you've got a bunch of topics, there's going to be no theme to this. Just to warn people in advance, in some cases the audio quality is a little hard to understand, so we apologize in advance and we'll take better equipment to the future conferences.

Where are we going to start?

Dr. Pamela Gay: I think starting with the very first press conference for the meeting might be a good place.

Fraser: What was that about?

Pamela: The first press conference, right off the bat, we had a young post-doc from your neck of the woods, from the University of Victoria in British Columbia. Jorge Penarrubia presented on the first virgin dwarf galaxy we've ever found, and if that title doesn't peak your interest, I think the fact that it just sort of came out of nowhere and is headed straight toward Andromeda… well, violence always attracts attention.

Fraser: All right, so where did this come from?

Pamela: Well, as near as we can tell, this small dwarf galaxy formed on its own and it formed away from the local group. As the Andromeda galaxy grew and grew and grew and became the large galaxy we know today when we look through binoculars, its gravity eventually got to the point that it was able to start sucking stuff from the nearby Universe toward it. One of the things it started to suck in is this new dwarf galaxy called Andromeda 12.

This is the first dwarf galaxy that anyone has ever found that hasn't already interacted with a giant galaxy. This is where the whole idea of it being a "virgin" galaxy comes from: it hasn't been touched gravitationally and hasn't had any of its stars, its dark matter, nothing with it has been disturbed. For the first time we can look at what a building block of a galaxy looks like before it's been incorporated into being used to build something.

Fraser: So every galaxy that we see has already had some interactions and has changed the way it looked. What role does the dark matter play in that?

Pamela: Rather than having me explain it, why don't we have Jorge explain it?

Dr. Jorge Penarrubia: So the dark matter from dwarf galaxies forms what are called tidal streams, and these tidal streams follow the orbit of the dwarf galaxies initially. Sometimes this dark matter gas distributes around the host galaxy and contributes to the dark matter halo of the host galaxy.

Fraser: Oh I see, so the dark matter is stripped out of these dwarf galaxies and added to the halo of the larger galaxy. All the dwarf galaxies we've already seen have already had this process happen to them.

Pamela: They've already been pillaged – and it's not just the dark matter that's been pillaged. Let's listen to some more of what Jorge had to say:

Dr. Jorge Penarrubia: For instance in the Milky Way you have the stars that were born here, and the stars that were born in other systems (like dwarf galaxies) – you have both things, and actually they're not isolated. For instance the in-fall of dwarf galaxies can actually trigger star formation. So it's quite complicated process and we're starting now to learn about – well, it's not really learn, we have a clear picture as to it.

Fraser: Right okay, so the dwarf galaxy slams into one of the larger galaxies, contributes its stars, gets dark matter torn away, you get star-formation and goodbye galaxy.

Pamela: Goodbye galaxy, and all that's really left behind is the stuff that forms our galaxy and occasionally when we're lucky we get to see some tidal streams, but we're going to be talking more about that later.

Fraser: Now is this going to happen to this galaxy?

Pamela: It's just a matter of time; it's currently on a heading that is sending it straight toward M31, the Andromeda galaxy. It's going to get there eventually and whip around, get its dark matter stripped out, get shredded into a tidal stream, and it also will eventually become part of our galaxy when our galaxy and the Andromeda galaxy merge. It's all a matter of timescales. I have to admit I didn't catch the timescale that Andromeda 12 is going to get to M31, the big Andromeda galaxy, so I'm not sure if we're going to merge first or if it's going to merge first. Eventually, all these galaxies are going to form one much, much larger system.

Fraser: Yeah, can we call it Milk-dromeda?

Pamela: [laughing] Something like that.

Fraser: Milk-dromeda Way? Yeah.

Okay, so what else did you learn?

Pamela: Later on in the week, there was a press conference on spinning black holes. Everyone gets excited about black holes, and these weren't just normal, run of the mill black holes, they were talking about what happens when you take two galaxies (say, the Milky Way and Andromeda), slam them together and you observe the super-massive black holes in their cores hopefully merging into an even more super-massive black hole.

Fraser: Okay, and so what were they expecting to see?

Pamela: Well, let's listen to what one of the researchers had to say. Laura Brenneman was kind enough to sit down and explain a little bit of their physics to us.

Laura Brenneman: Basically what we've done is we've created a new model that allows us to look at the x ray spectra from the accretion disk very close to the black hole. We're interested in the disk in particular because of the space-time that is as close to the black hole as we can get and still observe electromagnetically.

So when we look at spectral signatures from this material close to the black hole, what we expect to see is that rather than seeing narrow void profiles that you would expect to see in spectral lines in a laboratory, what we're actually thinking we're going to see is signatures of relativity, special relativity, general relativity, also Doppler shifting within the disk.

Fraser: So they're actually seeing effects on the elements around the black hole that match predictions from relativity?

Pamela: They're seeing special relativity, they're seeing general relativity, they're seeing massive Doppler shifting. All of these things are communicated through the line shapes of the elements that make up the accretion disk around these black holes.

Fraser: When you say "line shapes" what does that mean?

Pamela: When you take the light from something (anything, the Sun, say), and spread it out, you can create a rainbow. We've all seen this happen: bits of glass hanging in windows will end up casting bits of rainbows onto walls.

If you spread that light out enough, what you can start to see is dark lines where an element has absorbed the light out of the Sun. You might see a line that corresponds to a transition in hydrogen. You might see a line that corresponds to a transition in iron, where the atom absorbs the light and an electron jumps to a different energy level; lots of neat physics is happening.

Well, if you're dealing with something that's just like the Sun and hanging out near-by, not moving a lot relative to us, the lines are symmetric: they are the same shape on the red side and on the blue side, and they're just nice, gaussian profiles. When you start to add in all these other effects, what you end up with instead is a line that is really skewed toward the blue. You see massive peak in the blue and then you see it slowly tapers off, tapers off, tapers off, toward the red. This is because you have all sorts of other effects from relativity, from just the fact that the accretion disk is rotating really fast.

Fraser: How fast?

Pamela: That's complicated! First of all, there's the minor problem that we're moving, it's moving, time's relative. Ignoring that, with a 10^7 solar mass black hole, you end up with a rotation rate where it goes all the way round once every ten minutes for an accretion disk that is on the verge of spinning itself apart. This is where it's spinning so fast that the centrifugal force wins out over gravity and everything just sort of blows itself apart and you're left with a naked singularity.

Fraser: And that's where it has no accretion disk around it, because it's spinning so fast?

Pamela: Exactly. That means in reality, they're going to be rotating slower than that. But, we're looking at something that is rotating as fast as it can without blowing itself apart, and the inner parts are going around every ten minutes. Things are going significant fractions of the speed of light. It's scary physics in there.

Fraser: Okay. What's next?

Pamela: What is next is more tidal tails. This was a meeting that I have to say made me and my love of small things that are in the process of getting destroyed, very, very happy.

Fraser: I didn't know that about you!

Pamela: [laughing] Well, when it comes to celestial objects, they're much more interesting when they're getting destroyed.

Fraser: Okay.

Pamela: The next thing that was up was more discussion of tidal tails. This is sort of also a running joke in the press room of every meeting there seems to be a new press release on tidal tails.

Fraser: Hold on! What's a tidal tail, then?

Pamela: Instead of me explaining it, why don't I have one of the researchers explain it. Carl Grillmair of Caltech and IPAC was kind enough to sit down and talk to me for a while about this, and he had some really neat things to say:

Dr. Carl Grillmair: Well they're the relics of whatever was there. I think a lot of people are actually surprised right now that they're actually there. People had always assumed from the beginning that even if the galaxy cannibalizes dwarf galaxies and globular clusters and so on, it will quickly precess or be scattered into giant molecular clouds and random orbits, and it will just be this big soup of stars, which is what everyone assumed was what the halo was, and the bulge and all these things.

In fact, we've seen, like today I showed (well, maybe I didn't actually show you, but it was on my poster) there's an 84 degree – absolutely narrow, quarter of a degree wide for 84 degrees across the sky. That would've taken billions of years to form and it was still in tact. There was no obvious sign of scattering in any direction. The halo has to be extremely smooth.

Fraser: Okay, so we've got these long streams of stars and globular clusters in huge arcs across the sky – he said 80-something degrees. How much of the sky is that?

Pamela: So imagine something that stretches from looking at the constellation Gemini all the way up to the north star. They stretch from the horizon to zenith as you look out across the sky.

Fraser: Zenith is the… point straight up?

Pamela: The point straight overhead.

Fraser: Right, okay. So if I look down at the horizon, I would see the beginning of the tail, and then I could look straight up and see the end of the tail, and that is a dwarf galaxy that has been spaghetti-fied.

[laughter]

Pamela: Well, spaghetti-fication is reserved for black hole destruction.

Fraser: Right, right, right – but I think it's appropriate here.

But yeah – torn into a long stream.

Pamela: Idly disrupted.

Fraser: "Idly disrupted" that's a very fancy word for it

[laughter]

So what's the process then, that makes this happen?

Pamela: Tidal disruption! As they come in, their ability to hold themselves together is lost as they're getting pulled on by the Milky Way's gravity. As they fall in, the leading edges are going to accelerate forward, the back ends are going to be slower at falling in, and everything stretches out as they fall down the potential well.

What's really neat about these is as they go, they're falling downhill, basically. If you imagine our Universe as this four-dimensional thing where we see three dimensions and that fourth dimension is traced out by everything rolling around, the arcs, the streams these things shape on the sky… that is the path of rolling around in the bowl made by our galaxy.

Fraser: So what was the new research that they had come up with this time around?

Pamela: In this case, what he was primarily talking about was we found another one. As he and I sat down and talked, he also brought up the fact that as we trace these things further and further out, we're finding things that don't entirely make sense. They're turning up at the ends, so that implies maybe there's bumps (but not often) out in the halo of our Milky Way. Those bumps would have to be made out of dark matter.

So yes, the halo seems to be smooth, smooth, smooth. But occasionally, there is a little bump here or there. That was kind of neat to hear him talk about.

Fraser: All right: moving on. What's next?

Pamela: What's next is how life around M-type stars might not be quite as cushy as we would've thought a couple weeks ago when we started having all these press releases about Gliese 581.

Fraser: What's an M star?

Pamela: An M star is a little tiny dwarf star. In some cases, they're just 10% the size of our sun. They're really red, they're really cool and they basically live forever. They live sometimes as much as 40 billion years while still just burning hydrogen in their core.

Fraser: So in theory, that would give a planet a long time for intelligent life to happen.

Pamela: Exactly. The problem is these stars don't start out nice and calm. In fact, life's a little bit rough, but rather than me describe it, let's listen to Ed Guinan sit down and talk with us about it:

Dr. Ed Guinan: We found the relationships between coronal x ray machine. With age the young ones are very active – they have flares and lots of x rays. By the time they get to the age of Proxima Centauri, which is 6 billion years old, they've died down by a factor of 2 or 3 hundred, and then beyond that even more. This is mainly because the stars are spinning down; they're losing their angular momentum.

Fraser: Okay, so the stars start out quite violent, but then they settle down over time?

Pamela: And life could still be possible if you could find a way to get a strong enough magnetic field to create a strong magnetosphere around these planets. The problem is that to have a habitable world around an M-type star, you have to place the planet right next to the star. When you do that, you end up with tidal locking. Just like we have the Moon always shows its same face at the planet Earth, these planets always show the same face to their star. To get a magnetic field, you have to be rotating quickly. To be rotating quickly, you can't be tidally locked to your star, so there's this weird conundrum of how do you make something that survives this violent 1.2ish billion years of the star's early life so you can have a civilization that then stretches on for just about 40 billion years? It's problematic.

Fraser: Okay, so the planet might get that tidally locked really early on, and not get a chance to build up the magnetosphere and then just take it on the chin for millions and millions and millions of years with these bouts of radiation.

Pamela: These bouts of radiation don't just destroy any DNA of any life in the process of trying to form. These bouts of radiation also blow away chunks of the atmosphere. We're able to hold onto our atmosphere because our magnetosphere protects us from having all of these high energy particles raining down on the upper parts of our atmosphere. Without it, bad things would happen, things would get blown away.

Mars is representative: poor Mars has no magnetosphere, it's core already cooled off and its magnetic field already faded out as the core froze. So it's losing its atmosphere not just because its small and can't hold onto the fastest moving gas particles, but also because the solar wind is blowing away parts of its atmosphere.

So these planets, if they form, would have the star blowing away the atmosphere and they'd get blasted by radiation. Neither of these things is particularly inspiring toward the formation of life.

Fraser: So what were the results of this research, was it good or bad on that direction?

Pamela: The results were sort of like, "oh dear, we need to find a different way to get these planets into the habitable zone other than they form there initially."

One of the possible solutions is: if you have a planet that forms far away from the M star, and stays there for the initial few billion years, or creeps in very slowly and enters the habitable zone after the M star has stopped having these huge flares, these huge blasts of x ray and gamma ray energy, then (if it migrates in later), life can develop later.

So you have lots and lots of time, it's just a matter of figuring out how to get everything where it needs to be in the proper timescales.

Fraser: These are some planets around some of the smallest stars, but you actually looked at someone who was looking at planets around some of the largest stars too.

Pamela: In the exact same press conference where they were talking about these flaring M stars that can be potentially dangerous for planets, they also had John Asher Johnson talking about how you can find planets around really big, bright, A-type stars (or at least, around the relics of really big A-type stars). Let's listen to what he has to say about it:

John Asher Johnson: So we decided to look for planets around stars that are more massive than the Sun, commonly called A stars. You can't search for planets around A-type stars when they're on the main sequence.

Fraser: Okay, so these A stars are larger than the Sun. What kind of mass are we looking at?

Pamela: They're typically 2-4 solar masses, so they're bigger but not hugely bigger.

Fraser: If I understand the way astronomers search for planets, they use this spectroscopic method where you've got the gravity of the planet yanking the star back and forth and back and forth and we're able to calculate the velocity of the star moving toward and away from us, to be able to get a sense of what the mass of the planet is. So you get a more massive star, that's got to be hard.

Pamela: That's got to be hard, and it's even more complicated than that. But let's listen to how he explains it:

John Asher Johnson: What few lines they have are smeared out by their rotation. Broad, smeared out lines contain much less Doppler information than narrow lines. So the end result is you can only do it by the 100 meter precision. To give you some context, a hot Jupiter planet has an amplitude of about 100 meters per second. So you can't even see the hot Jupiter planets around these A stars.

Fraser: Okay, so he said that they're looking at stars outside of the main sequence. Why is that?

Pamela: Outside of the main sequence, these stars expand out. If you think of an ice skater, when she pulls her arms in, she starts spinning faster. Conversely, if you watch her put her arms out, she slows down. When these stars move off the main sequence, they bloat out and slow down their rotation. The lines they have become narrower – they're not Doppler spread out anymore.

The stars also cool off, and when they cool off there's more atoms that still have electrons available to create spectral lines. In a really hot star, everything's ionized. When an atom is ionized, it doesn't create spectral lines, it just sort of sits there going "ahh, I have no electrons!" Cool it off, let it collect an electron or two, and now those electrons are available to grab bits of light and create dark lines. Those dark lines we can measure using our spectrograph.

Fraser: So while the star is going strong, you won't be able to see the effect of the planet in the light.

Pamela: It's too hot to have a lot of lines to look at, and what lines you have to look at are spread out by how fast the thing is rotating.

Fraser: Now if you had a planet going around a star that was three times the mass of the Sun, would that be fun?

Pamela: As long as you move it out from the star, it's just fine. It's all a matter of placement. Where the Earth is in our system, we have liquid water. If you replaced our Sun with an A-type star we'd have boiling water (and that would be a kind of bad thing). If you replaced our Sun with an M-type star instead, then we'd freeze. So, where the appropriate place is varies with star. With an M-type star, you'd want to get in closer to where Mercury is. If you have an A-type star, you're going to want to move further out. So find your planet, put it in the appropriate location, and you can build a habitable zone for every star.

The other question is how long is that habitable zone a safe place to be? M stars… once you survive that first billion years or so, you're good for another 40 billion years. A-type star? Much shorter lived, so even compared to the Earth, you're just not going to have as much time to develop a civilisation before your sun starts doing things that just make life impossible.

Fraser: Right, but I guess it's just a new area of investigation, that up until now, astronomers didn't even think they could look at.

Pamela: No, and there are theorists out there who are making their living calculating where the habitable zone is for this type of star if you have this type of planet with this type of atmosphere and how long does that habitable zone stay there… it's really a fascinating question because you have to take into account so many different things, but we think we know what a lot of the things you have to plug into your models are. Now it's just a matter of writing the complicated software and getting enough time on the supercomputers.

Fraser: That was great Pamela, sounds like you had a lot of fun there.

Pamela: It was a really good meeting, and it was a smaller meeting than normal, so people took the time to sit down and really talk about what they had to say. There's very little that can be said about going to Hawaii that's negative. So, really – great location, people willing to sit down and talk, and it was just pleasant and fun and I learned a lot.

Fraser: So where's the next one at?

Pamela: The next meeting is in Austin, Texas, where I went to graduate school, and that one's going to probably not be so pleasant, but it's certain to be a lot of fun. Hopefully next time you'll be able to make it. The meeting after that is in St. Louis where I'm currently located.

Fraser: That'll be good. I'd love to. All right, we'll talk to you next week.

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