Astronomy Cast Episode 99:
The Milky Way

Fraser Cain: Ninety-nine episodes Pamela!

Dr. Pamela Gay: I know [Laughter] it's amazing how far and how long we've been doing this.

Fraser: The Milky Way is our home galaxy but we've only understood its true nature for about a century. We share this beautiful barred spiral galaxy with at least 200 billion other stars.

Let's trace back the history, see how we learned about the Milky Way and then compare it to other galaxies out there. What does the future hold for the Milky Way?

Pamela: The future holds death, because that's kinda what happens in the Universe. [Laughter]

Fraser: Shhh….we're supposed to keep that as a surprise! It all ends in tears. But, let's go back to the beginning. [Laughter] I find that kinda interesting. My dad had an antique book about Astronomy. It had all the constellations and stuff. It was back from like the 1920s or earlier. It had nebula for the Andromeda nebula and other stuff.

Let's go back like as far as we can and talk a bit about the history of the Milky Way. You could see the Milky Way in the night sky so people knew that there was something there. What did they think was going on?

Pamela: Well the term Milky Way is actually derived from a Latin term. We've had that name for it for a long time. It basically comes from the fact that there is this band of light that to the naked eye is perceived as this light patch, this illuminated patch that spreads in an arc across the sky.

If you've ever gone somewhere truly truly dark, someplace where the nearest light is miles away and there are no cities for hundreds of miles, in these truly dark locations when you look up and there's a cloud, the cloud is the blackest thing in the sky. When you see a band of light, it is just like what is that? That's not supposed to be there.

The Milky Way is that unusual band that crops up in the sky in dark locations and startles you. In our modern light polluted world, we're used to the clouds being the bright things in the sky. To someone living in a world illuminated by fire it was the Milky Way and it literally looked like someone had spilled milk across the sky and that's where the name came from.

It wasn't until we had telescopes that it was possible to look up at this band of what appeared to be continuous light and see that it was nothing more than thousands and thousands of stars all packed closely together.

Fraser: That was sorta the first major discovery. I thought it was Galileo when he turned his telescope on the Milky Way about 1610 I think and that's what he saw was just stars everywhere he looked.

Pamela: It sounds almost like an episode of 2001 – stars it's all stars. In looking at this band of stars what's neat is we see structures. We see dark striations through it. We see that it expands out and gets brighter when we look toward the Constellation Sagittarius.

As you travel around the globe you can see it from both hemispheres. It's something that we share. It comes up higher in the north and lower in the south so there is this ring of light that essentially goes all the way around our Solar System at this crazy angle and it is symmetricish so that we see the same amount in the north and south.

All of this says that we're basically embedded inside of a disk that's tilted relative to the Solar System and that we must be located pretty much in the center of that disk. If we weren't in the center of the disk then we'd see more of it to the north and more of it to the south.

When I say that we're in the center of the disk it sounds like you sorta stick your head in the center of a hoola-hoop and because you're head is in the center of the hoola-hoop, everything is orbiting around you.

Another way to perceive this is what if you're inside of a disk that's really big and you can only see a small section of it? That small section might appear to be a perfect circle that you're embedded in the center of. People originally thought hey, we're in the very center of - well not the Solar System – but at least in the center of the Galaxy. It turns out that's not the case.

Fraser: Right, I know that William Herschel took a shot at trying to map out the shape of the Milky Way. He counted stars in all the directions and drew a diagram and he thought that the Solar System was sorta in the center of the Milky Way. Herschel discovered Uranus, right?

Pamela: Right, yeah.

Fraser: He was one of the most famous Astronomers at the time so he took a good shot at it.

Pamela: In looking at the stars and counting the stars around us, you end up with equal numbers of stars more or less in all directions. Now the problem is there is also dust. So we can't see all the way out to the edges of the Milky Way using normal colors of light that our eyes can see, at least not when we look out through the disk.

If instead you look above or below the disk you can see these blobs of stars called Globular Clusters. If you start mapping the distance to the Globular Clusters, you start realizing that they aren't symmetric. There are more of them when you look above and below the Constellation Sagittarius.

There are fewer of them when you look in the opposite direction and as you start to plot them it looks like in reality we're roughly a third of the way out from the center of a spheroid that is marked by these Globular CSlusters.

Fraser: I see, so it's like you can see all of the Globular Clusters that are just above the center of the Galaxy. You can see the ones that are embedded in the disk with us, but all of the ones that are obscured by the dust on the other half of the Galaxy you just can't see them.

Pamela: Right. In plotting those that are above and below and trying to get at this three dimensional structure we realized the Globular Clusters form a halo of objects, a sphere of objects and we're not in the center of that particular sphere.

So, let's step back and figure out why is it that when we count stars, that doesn't work. The reason it doesn't work is that there is so much gas and dust blocking light that we can only see a little way out into the Milky Way's disk when we use visible light.

One of the neat things about light is different colors act in different ways. While the blue light that might come off of a party light bulb won't pass through the walls of my house, a wireless internet passes quite happily through house walls. Wireless internet is just a beam of light that is coming away from the little wireless router sitting in my kitchen and passing through floors and ceilings and walls and everything else I have in my house. That color goes through stuff. Wireless internet is really just a red shade. It's off in the microwave radio part of the color continuum. Often that part of the electromagnetic spectrum. Now as you get redder and redder in general, light is able to go through things more easily.

So, if you try and shine blue light through a cloudy fish tank, you're not going to get a lot of that light through to the other side. But if you try and shine red light through a cloudy fish tank, you'll get more of the light passing through. What is really cool is if you take a 2-liter bottle and put a little dried milk in it and shake it up with water and shine white light through it you'll see the blue light scatters left and right and the red light goes straight through.

Those little particles of dried milk in that 2-liter water you mixed up act the exact same way that dust in our Galaxy works. So blue light from stars in the center of the Galaxy gets scattered in all directions – it doesn't make it to us. But red light from stars in the center of the Galaxy can pass right through that gas and dust and get to observers.

You just need build the instruments to look at the center of the Galaxy, the infrared and the radio. By going to these longer wavelengths we've been actually able to see stars orbiting the central Super-Massive Black Hole in the middle of the Milky Way. We've been able to see that there are a lot more stars when you look toward the center of the Milky Way than when you look away towards the outer part of the Galaxy.

Fraser: So what finally clinched the argument? What finally told people that we live in an island of stars and that those other things aren't nebulae but actually other Galaxies?

Pamela: That was actually the first time that we were able to see variable stars in another Galaxy. When we looked out at the Andromeda Galaxy with a big enough telescope and were able to make out Cepheids there and work out the distance, that was the key. There are these very bright stars called Cepheids that vary in such a way that their period is directly related to how much light they give off. It is directly related to their luminosity.

When you look at one of these stars, you measure how long it takes to go from being really bright to being faint and being bright again. Then you look at a chart and you can figure out how far away that object is. We'd figured this out for the large and small Magellanic Clouds.

Globular Clusters don't tend to have those particular types of stars. We knew that pretty much all the stars in the large and small Magellanic Clouds are affectively going to be the same distance, the same way everyone in Beijing is the same distance from me even though there are slight variations depending on if they are on the near side or the far side of the city. The distance between here and Beijing is just that much bigger than the size of Beijing.

Using the relationships that we worked out using the Magellanic Clouds, Astronomers then went and looked at the Cepheids in the Andromeda Galaxy and basically had a moment of, "oh dear, I need to sit down now," and realize just how much further away the Andromeda Island of Stars, the Andromeda Galaxy is away from the Milky Way. They realized that's an entirely different type of object.

So, all of a sudden we were the Milky Way Galaxy, the Andromeda Galaxy and we started to sort out that these other spiral shaped and elliptical shaped, smudges in the sky in some cases were Island Universes – Galaxies all in their own right.

It took us awhile to sort out which object is a Globular Cluster, which object is a Planetary Nebula and this object is….we had to go through and build bigger telescopes to be able to make some of the final decisions on what the different smears of light were on the sky. We made it and we have an entirely new understanding of the Universe.

Fraser: With our current modern understanding of the Milky Way, let's talk about some of its dimensions. How big is it?

Pamela: [Laughter] This is actually one of those things that is kinda fun to look up because the numbers are all over the map.

Fraser: Oh, this is one of those textbook out of date questions, isn't it?

Pamela: Right, right. The problem is we can't see the whole thing. We're sorta inside of it and even if we weren't inside of it there are problems with looking in all the right colors to catch all the parts of the Galaxy.

It is only by mapping things in detail using infrared that we're able to finally make out the full extent of just the luminous matter in galaxies. There was a big science article a year or so ago where all of a sudden the Andromeda Galaxy pretty much doubled in size because we were able to find more stuff than we knew about when we started looking in infrared.

The canonical number that you see pretty much everywhere is the Milky Way Galaxy is 100,000 light years in diameter. You'll find numbers that go up to 120,000 light years when people start including tidal streams.

I suspect that number may still go up even further as we identify a shredded object in one location that clearly been completely destroyed and these stars now belong the Milky Way are just going to be claimed as our suburbs.

Fraser: Right. It's almost like you have to calculate what is the theoretical limit of the force of gravity from the Milky Way? That would give you a certain number and you won't be surprised if you keep turning up objects that fit within that.

Pamela: And it is also a matter of where are the edges of the gas and dust that has been stripped out of things? Where are the edges even to the Dark Matter Halo? That's really going to be the final answer of once something is embedded in that Halo it's ours. We own it?

Fraser: How big is the Halo?

Pamela: This is something that we're still sorting out. There are all sorts of different models that lead to different sized halos. So, as we get better at mapping Dark Matter hopefully someday in the future I'll be able to answer that question for you. Right now I'm going to stick to as far as we know the luminous part of the Milky Way is about 120,000 light years in diameter.

Fraser: Okay, we know the size, so what about the stars? How many stars?

Pamela: Well that's still up for debate. It's hard to find the little ones. Current estimates are somewhere between 200 billion and 400 billion. Which is a lot and it is just kinda cool that the number of stars is basically 100 times the number of people we have on the planet Earth.

Fraser: Isn't it like kind of the same number as the number of galaxies there are in the Universe or something like that?

Pamela: Well that presumes we actually know how big the Universe is.

Fraser: Right, right. We've done a whole show about that.

Pamela: Right we have no clue. [Laughter]

Fraser: Okay, are there any other interesting dimensions to the Universe then? How far away are we from the center?

Pamela: It looks like we're about 27,000 light years from the center. The other number that is kind of interesting is if you try and look at the thickness of the disk – how much above and below – us there is of gas and dust and stars that makes up this disk. Most websites you find will say it is about 1,000 light years thick.

But there is a group down in Australia led by Brian Gansler, an absolutely wonderful fellow who puts out more brilliant press releases than any other one person I can easily identify. His team decided to go through and work out those calculations.

When they worked the calculations they discovered that the number that everybody quotes is wrong. It turns out that the disk of the Galaxy is actually about 6,000 light years thick. It suddenly got six times bigger when someone bothered to redo the numbers. The way we get it is that we look at how light from Pulsars travel through the disk of the Galaxy. The light actually gets changed when it hits the gas and dust in the disk.

So if you look at a bunch of Pulsars that have known distances, and you measure how their light travels to us, the amount that it is distorted by the Milky Way gives us an estimate of how thick the Milky Way is toward that star.

You do this for a bunch of stars and you eventually figure out what is the thickness of the disk. They increased the number by six by just doing the calculation a new time. That's kinda cool.

Fraser: What kind of Galaxy are we? I know we're a spiral but more specifically.

Pamela: We're actually a Barred Spiral and this is fairly new knowledge. There has been a lot of work between Spitzer and the Sloan Digital Sky Survey and all these new great technologies that have only been around since about 2000. They have been systematically going through and plotting anything out there to be plotted in a 3-dimensional map of the Galaxy.

They found that on the inner part of our Galaxy is a bar that is about 20,000 light years in length. The center of the bar marks the center of the Galaxy. This bar is a completely new discovery. It has only been known really well since 2005 and this makes us a Barred Spiral Galaxy.

Fraser: Right and I think I've seen this. You take the center Halo of the Milky Way and you extend out two directions with a bar and then at the ends of the bar, you make right hand turns in both directions then you spiral out the spiral arms from there, right?

Pamela: Right. Exactly.

Fraser: So does that give us two spiral arms?

Pamela: We have two spiral arms but we didn't even know that until this year (2008). It was thought that well there were two spiral arms but we also thought we saw these two other spiral arms so somehow we had one bar and four arms and no one knew where anything was connected. This is kinda weird and doesn't generally happen in the things that we see when we look out in the Sky.

But it turns out that a couple of the bars were just places where we thought we saw more stars. When you take the time to observe in infrared and look through the dust and gas and see what's actually there, you see there are really only two arms. That was a kind of cool discovery.

Then if you can imagine flying out of the Milky Way and looking down on it from a great distance, it appears there is actually an outer ring of stars as well from something we decided to consume and just store as the ring.

Fraser: The arms have names. Which arms are there and which arm do we live in?

Pamela: Once upon a time when our Galaxy, which I think both of us have now called the Universe at least once in this show, we know it's a Galaxy but it slips. Once upon a time the Milky Way Galaxy had four arms.

We called them normones which I just find the funniest name ever for a galactic arm: the Scutum- Centorus arm, Sagittarius and Perseus arm. We live in the 'A' spur called the Orion Spur. It turns out my favorite named arm Norma isn't actually there and neither is the hard to pronounce Scutum-Centorus Arm. Now we're left with just the Sagittarius and Perseus arms of the Milky Way.

Fraser: There you go. We live in the Orion Spur which comes off which arm?

Pamela: The Orion Spur appears to be part of the Perseus Arm. It is still complicated trying to map out everything from the inside. But we're making progress so if you truly wanted to give the planet Earth an address, it would be: Planet Earth, in the Solar System in the Orion Spur of the Perseus Arm of the disk of the Milky Way Galaxy.

Fraser: Of the local group of the Virgo Super Cluster of the Universe.

Pamela: I'm sure that there is some sort of large-scale structure junction that we can say that we belong to.

Fraser: Right. I was such a Geek as a kid; I did that as my return address on letters that I would send out. [Laughter] I did Earth, Solar System, Milky Way, Local Group, Virgo Super Cluster, Universe. Yeah, I did that.

Pamela: I had a friend that I met at Space Camp and he and I would do that as well. And in retrospect now what amazes me is the U.S. Post Office. If you have kids' handwriting the Post Office will actually deliver letters that have that level of obnoxious addressing on it.

Fraser: Well if they will deliver to Santa Claus, you know….. [Laughter]

Pamela: That's true.

Fraser: So I think we have the characteristics, now how old is the Milky Way and how do we know?

Pamela: That's one of those questions that we can't really answer because what do you use to measure that? If we look out at the older stars – yeah we've got old stars. Some of the oldest stars we are part of the Milky Way. We don't know if those stars formed before the Galaxy, with the Galaxy or after the Galaxy.

We really can't say how old the Milky Way is. But what we can say is it is going to cease being the Milky Way in somewhere between five and seven billion years from now when it merges with the Andromeda Galaxy.

Fraser: But I guess the question is, did the Milky Way as a Galaxy form super early or is it one of those situations where it has just been a long collection of mergers between Dwarf Galaxies until you got something substantial? That's the controversy, right?

Pamela: Right, well that's actually not a controversy with our Galaxy. One of the prior controversies was how the Galaxy is formed. Is it a top up or a bottom down approach where they either form all at once or they form through the merger of a bunch of smaller objects?

It's now thought that some of the largest galaxies in the Universe did initially form right off the bat as giant Galaxies in place. With our own Milky Way Galaxy we have lots of evidence pointing to the fact that we probably were a merger of lots of smaller things coming together. We still see small things falling in today. We're in the process of eating a small innocent Dwarf Galaxy called the Sagittarius Dwarf Spheroidal Galaxy.

As we look with the Sloan Digital Sky Survey at individual stars in the Halo around the Milky Way we are able to make out all sorts of different Tidal Streams – elongated streams of stars that were left behind as the small baby Galaxies were disrupted as they fell in. We talked about this some in the last episode.

Everything indicates that we probably formed a bit at a time, coming together building our large Spiral Galaxy. What's kinda neat is as we look at star formation we can see that not all parts of the Galaxy formed at the same time. This is more evidence. The Globular Clusters seem to be some of the oldest objects in the entire Galaxy.

Also, as we look in at the bar, the bar of the Galaxy is made predominantly of old red stars. But what's kinda neat is in the very center of the Milky Way orbiting the Super Massive Black Hole are – depending on who you talk to – either one or two collections of very young stars including about 100 bright blue giant stars. So we know that there was at least one not too distant burst of star formation in the center of the Galaxy embedded in this bar of old stuff.

We also see a ring of star formation towards the center of the Galaxy. The disk of the Galaxy is just full with open clusters of various ages. The Orion star forming region will eventually be a full-fledged open cluster too.

Older systems like the Heyedes open cluster are just barely visible as a star cluster because they have spread out so much at this point. There are stars that are on their final legs. There are stars that are still forming. It's an active and lively population that is mixed in all sorts of different properties.

Fraser: And so how many of these Dwarf Galaxies, like the Sagittarius one, are recurrently consumed?

Pamela: Every time we have a new American Astronomical Society meeting there seems to be a new press release on new Tidal Stream just discovered. It's an ongoing field where thanks to every new data release of the Sloan Digital Sky Survey they get a little bit better and we find a few more of these.

We're about to have a new data release so I'm sure there will be more Tidal Streams in the future. We're finding these constantly. There are I think on the order of ten Tidal Streams now known enwrapping the Milky Way Galaxy.

And there's the Sagittarius which is just plunking itself into the disk and just dying as it does it right now. I'd say we know of order of ten and one that is particularly spectacular as it dives into the disk and more are going to be found.

Fraser: That's inevitable, right. It's an interesting way to do Astronomy – I'm on a completely different tangent here – in the past if you wanted to answer a question, you'd take a telescope and go out and look and record your images and come back and analyze them. Then you would do your science that way.

But now, a lot of Astronomy is being done with these surveys, these robotic surveys. You grind through a database of millions of stars to determine if there are more of one kind of stars in a certain location. You come out with interesting answers just like that.

More and more work seems to be done by the surveys of robotic telescopes that gather a tremendous amount of information about the night sky. Then Astronomers can kinda crunch through and follow their interests after the fact. A lot of stuff gets done. A lot of analysis of Quasars, discoveries of Asteroids…..

Pamela: It is completely changing how we do science. It used to be once upon a time any question I wanted to answer I had to go out and basically fill out a bunch of paperwork – because that's what Astronomers do – and justify to a Telescope Time Allocation Committee attack why I deserved telescope time. Often I wouldn't be allocated as much time as I needed to actually answer my question. So I would try to find shortcuts or change my protocol so it wasn't as good as it could be, all to try and get the very minimum data needed to try and answer my question.

Nowadays, rather than me going out and desperately pleading with a consortium of people who are going to choose my fate, I simply write a my sequel query and download all the data I need from the Sloan Digital Sky Survey. It doesn't answer a lot of questions.

Once you find something really cool using Sloan Digital Sky Survey, it's possible to then go to a Time Allocation Committee and ask for one specific question rather than a broad question requiring a ton of telescope time. It reduces the individual need to get lots of telescope time because you can first go out and use this community survey.

It's going to continue to change it as Pan Stars and Large Synoptic Survey Telescopes continue to come online and the amount of data available on the entire sky reaches terabites and terabites per night of newly acquired information.

Fraser: Thank you for following me on that tangent. There are two last things I just want to get through. What is the Super Massive Black Hole?

Pamela: We think that the Super Massive Black Hole in the center is about 3.2 million or 4 million Solar Masses. All that mass is confined to an area smaller than the Earth's orbit.

So take the Sun multiply it by 4 millionish and cram it within the Earth's orbit. Not only is it crammed within the Earth's orbit, but we think that it is actually crammed into a space one tenth the size of the Earth's orbit. That's just kinda cool.

Fraser: Yeah and I know that some of the most amazing Astronomy was done a few years ago where they were mapping the paths of stars as they orbited around the Super Massive Black Hole. They just make these U-turns. A star comes down it makes a quick U-turn and heads off in a completely different direction.

Nothing but a Super Massive Black Hole, nothing except something with 4 million times the mass of the Sun [Laughter] could crank a star into a whole new direction like that.

Pamela: There are hundreds of stars crammed into the inner parsec or so of Space in the Galaxy, crammed in close to the Super Massive Black Hole. We've been lucky enough to be able to catch some of these making basically fish hooks around that Super Massive Black Hole. This was the final piece of evidence that allowed Astronomers to say no, it's not 1,000 neutron stars, it's not 10,000 white dwarfs or I guess 4 million white dwarfs. It has to be some singular object crammed into a very small space.

It’s a beautiful piece of work. It was all done with infrared imaging but peered through the gas and dust. It was done with high speed imagers so you could stack the images that were getting distorted by the Earth’s atmosphere such that the least distorted ones from high speed images got stacked one on top another to catch the individual stars. It’s really amazing.

Fraser: And the last topic is the future. You already gave away the ending. What does the future hold for the Milky Way?

Pamela: In about 4 to 7 billion years we are going to merge with the Andromeda Galaxy. For awhile we’re going to look a little bit like the merger system called Mice or the Antenna. Over time we’re going to settle in to probably being a nice Elliptical Galaxy. We’re going to keep eating our children.

The large Magellanic Clouds will eventually become part of our Galaxy, not necessarily in that order. Then over time we’ll probably start merging with other Galaxies in the Local Group. The Local Group itself is going to join in with the Virgo Cluster and the Virgo Super Cluster is going to grow in mass and consolidate in volume.

Eventually who knows just how bad it’s going to get – there are those who say it’s all going to be one big Black Hole – I’d like to hold out that there are going to be a few white dwarfs that don’t quite get consumed. That’s trillions of years in the future.

Fraser: We’ve done two whole shows just about that. You can take a look back at those. Okay Pamela I think we’ve covered our home Galaxy the Milky Way.

This transcript is not an exact match to the audio file. It has been edited for clarity.
Transcription and editing by Cindy Leonard.