Astronomy Cast Episode 177
Mysteries of the Milky Way, Part 2

Fraser: Astronomy Cast Episode 177 for Monday February 15, 2010, Mysteries of the Milky Way, Part 2. Welcome to Astronomy Cast, our weekly facts-based journey through the cosmos, where we help you understand not only what we know, but how we know what we know. My name is Fraser Cain, I'm the publisher of Universe Today, and with me is Dr. Pamela Gay, a professor at Southern Illinois University Edwardsville. Hi Pamela, how're you doing?
Pamela: I'm doing well. How are you doing?
Fraser: Very well. So, we're going to continue on with our tour through the mysteries of the Milky Way. We survived our first group of mysteries, so now we move on to our second set of stuff... of amazing Milky Way mysteries... how many spiral arms does our galaxy have? And why does everything keep dying every 60 million years or so? Alright, well, let's move on to the first mystery which is how many arms... how many does our spiral galaxy have? Is it four? Is it two? Is it 20? How many do we have?
Pamela: It depends on what color you look at the universe in.
Fraser: Right, so we look out into the universe and we see spiral galaxies with these beautiful arms, and there's a bunch of different kinds, right?
Pamela: Yeah, there's the sunflowery ones that we call flocculent spirals that you can tell they're spiral, but their arms aren't well-defined, it's just a whole bunch of basically spiralling-together petals. There are beautiful grand-design spirals like M-51 that clearly have 2 distinct arms. There are systems that appear to have many clear arms, but they don't all make it to the center of the galaxy.
Fraser: And there's barred spirals where there's a big bar in the middle and then the spiral arms twist out of that bar. And as we talked about in a previous episode, the arms aren't actually there...
Pamela: No, they're just collections of stuff that gravitationally piled together.
Fraser: They're a density wave... the density wave is moving through the galaxy and so everyone gets to take their turn being part of the spiral arm.
Pamela: Right. And the issue is, as you look at galaxies in different colors, how prominent the arms are changes... This is why typically anyone who does galaxy-arm classifications is supposed to look at the galaxy in one particular color of light and make all their decisions based on how the galaxy appears in just that one color. But as we start looking at things in ultraviolet, as we start looking at things in infrared, as we start looking at things in radio, the morphology--the shape--of galaxies changes. And in our own galaxy, as we look out, trying desperately to figure out what it is that we live inside of... if we look out in radio, we start seeing all sorts of different clumps. We see what look like--well, to the group of scientists who looked at it... Evan Levine, Leo Blitz, and Karl Heils out at University of California Berkeley... they saw in radio what looked like four different arms winding away. And then at the same time, you instead look at the galaxy in star counts... if you look at it using the Sloan Digital Sky Survey, we reduce our galaxy to a bar with 2 distinct arms. So, it all depends on what color you look at. And so we have to try to put together a piece of what would it look like if we could get a good

distance a way, look down on it properly, and then only see it in blue light to give it to give it the same type of classification we might give M-51 or Andromeda.
Fraser: So, only in blue light?
Pamela: Well, that's how you're supposed to do it. That way everything is nice and symmetric. The problem is dust obscures things. So, in some cases when you start looking at galaxies in colors that either highlight where all the star formation is like ultraviolet, or allow you to look through the dust like infrared, you start being able to see structure that you can't see when you look at it in nice, normal blue-filtered... B-filtered light. And so the color matters, because it determines what you can and can't see.
Fraser: And so, if we were to look at our galaxy from far away with that blue light, how many spiral arms do we have?
Pamela: Probably... probably... two and some fragmenty things wanting to be arms.
Fraser: That's amazing that they could figure that out. You know? It's like you're standing in the middle of your house and you don't know what color your house is, and you're like... quick... what color is your house? And you're like well, I can see reflection of my house off that window from that other house, so I think it's white... but I can't really tell... yeah, that's amazing that they can do that.
Pamela: And we still can't see the other side, so there could be chunks of arms that we can't see.
Fraser: Alright, let's move on to our next question... our next mystery... Where are all of our sibling stars? Where are all the stars that formed out of the solar nebula with us? And I guess we can see... when we look out in space we can see star clusters at various points, right? There's these nebulae like the Orion Nebula, these star-forming... the Carinae nebula... the star-forming regions, and then we can see these open clusters of stars where there's a large collection of stars, like there's the Pleiades where they're still kind of together and they're surrounded by some nebula material, and then these wider open clusters, and then they break apart and they're completely gone. So, where are all of our siblings?
Pamela: We don't know.
Fraser: Should we be able to see them? Is that puzzling that we can't see them, or is it just normal to expect after 4.6 billion years you won't be able to see the stars that you formed with?
Pamela: Like all siblings, you go through a period of not liking to talk to one another. The problem is with stars, you never get past that period. Initially, everything starts out bound together in a nice knit star-forming region where you still have wisps of dust spanning from one object to another as they all collapse together and warm up their star-forming region. But over time, they blow away the dust, and over time as they orbit around the center, the objects that are closer to the center of the galaxy race forward, and those that are further out from the center lag behind and the entire system stretches out until eventually you are spread out over such a distance and you're mixed together so much with other stripped-away torn apart open clusters that you can't tell just by looking at motions necessarily who began with whom. The best way to start looking for siblings is to very carefully analyze the chemical composition of stars. Look to say... ok, our sun had to have been born out of a star forming region that had this particular chemical composition, and try to find stars that exactly match it. But, more than one thing can match within error... and so it starts to get challenging to say, ok I know this star isn't one

I was born with... its composition is completely wrong. But, these over here, maybe... And then you start recreating their kinematics, recreating their motion around the Milky Way. And you have to do both parts... you have to first look at the chemical composition and then recreate the motion. And then you can say maybe... but you can never say anything more than maybe.
Fraser: It's kinda similar to the way that we've discovered... we've... astronomers have discovered tidal tails of other galaxies that have been destroyed by the Milky Way. You can see this stream of stars that are separated, but they all have a very similar direction and they in many cases have a similar chemical composition, and so you're going to say oh, those used to be together.
Pamela: And they all have the same age...
Fraser: Yeah... yeah... and so at some point, those all got brought in together as part of the Milky Way, but... we can't seem to find our... but how far apart could they get over the 4.6 billion years? I mean could our siblings be on the other side of the galaxy at this point?
Pamela: Yeah, they could. And that's the thing is that we could've fully ringed around the galaxy over time and interacted with other stars, flung some of our siblings out towards the outer parts of the galaxy... all sorts of different things are possible over this many years. And so it's a challenge. All we can do is guess and say "this one could be." But, dating a star... figuring out how old it is... is an imprecise science. Because there are so many different interactions that are possible, it's hard to say with certainty that these two objects have been travelling in similar ways.
Fraser: And it's like the... there's too many stars that look just too similar to us... it's really hard to say oh yeah, absolutely, two peas in a pod... and there's the third one, and there's the fourth one... all in this big long line... that would be incontrovertible evidence, but in this case it's too squishy... it's too hard to tell. Yeah... that's a hard one.
Pamela: Yeah, and it's only every 225 million years that we go around, so we've gone around a whole lot of times.
Fraser: Not a lot, though. I mean we've only been around a handful... a few dozen times since the sun formed. I find that quite amazing that we've only been around... it's like what, 220 million years or something like that... yeah, anyway...
Pamela: 225 million...
Fraser: Yeah, so we've only been around a handful of times. Alright, well let's move on to our next mystery. So, why does everybody keep dying every 60 million years?
Pamela: I love the way you phrase that.... everyone dies every 60 million years...
Fraser: Great... everybody's dead again... is it 60 million years again? Yeah...
Pamela: Yeah...
Fraser: So we have these extinction events where like clockwork-ish, every 60-ish million... 60-65 million years, we have a mass extinction event where 90% of life on Earth is destroyed.
Pamela: Yeah, this was a very disturbing result, again, to come out of the University of California Berkley people...
Fraser: Thanks, Berkley... yes, yes... we get it, we get it... the universe... trying to kill us. But the last big one was the one that killed the dinosaurs that happened, oh... you know, 65 million years ago, in fact... we should be due, shouldn't we?
Pamela: We are coming up...

Fraser: We're due... you know, give or take a few million years. So, ok, is this true? Is that for sure happening?
Pamela: Yeah. This is work that came from Richard Muller and his graduate student Robert Rohde, and they went through the marine records. They went through all of the fossil records to keep track of when did all the extinctions occur... and it's every 62 million... plus or minus 3 million... years. And, it's just like clockwork. Everything dies. And that's never a good thing to discover. But, it's what they found. And so people have been trying to figure it out. We know that we tend to get hit with things--asteroids, comets, stuff like that. This explains the extinction event at the cretaceous-tertiary dinosaur extinction boundary 65 million years ago or so... making it due for death again at any moment. So the question is why... why does this keep happening? One of the things that's getting looked at is our solar system basically bounces its way around the galaxy, and as it orbits and orbits and orbits it essentially goes up and down through the disk and it's thought that as it goes through higher density and lower density areas perhaps one of two different things is happening. Either we're getting bombarded with more cosmic rays which is bad for life and causes mass extinction, or by going through higher density areas it's causing asteroid infall, it's causing more comet infall and perhaps that's causing death, destruction, extinction. But, we're not exactly sure what it is. But, we're on the right track and knowing that things die every 62 million years is at least the start to preventing death at any moment.
Fraser: Right, so we can imagine like a warped record going around a record player, if anybody still remembers what a record is...we need a new analogy... it's like a warped CD. And so it's like a warped X-Box 360 game--do you kids know what I'm talking about? going around. And so the sun is bobbing up and down in the disk of the Milky Way, and so when it reaches the top it almost kind of pops out of the disk of the Milky Way and gets exposed to too much cosmic radiation from the rest of the universe. And then is that fairly solid science? Is our Milky Way actually protecting us from cosmic rays?
Pamela: It's one set of research papers...
Fraser: Right. So it's like the Milky Way has a great big magnetic field all of its own, or it's able to protect us with gas and dust and stuff like that.
Pamela: Which paper you read gives slightly different results. This is all completely new science, that's what's so cool about this. It was only back in 2005 that the 62 million year cycle was discovered, and so now we're going backwards and trying to figure out ok, what's the cause? what's the cause? And we don't have enough data. And so we're looking at models, we're trying to use models where we don't necessarily have all the measurements we want to reconstruct what's going on, and so there's conflicting theories.
Fraser: Right, and then the flip side is as the sun bobs down into the galactic plane you get some more dense areas and then that jiggles up all of the Oort cloud and the asteroids around us and we get hit by more of them.
Pamela: And as it passes in and out of arms, and as it passes in and out of high-density areas... all of these things are getting looked at and blamed currently.
Fraser: Right.
Pamela: We're due.
Fraser: And we're due. But you know, don't worry about that. Don't think about that...

Pamela: And if you read the literature we're actually undergoing one of the highest rates of extinction ever measured.
Fraser: Yeah, but that's kind of our fault, right?
Pamela: Yeah, yeah, we do things to frogs and stuff like that....
Fraser: Wait... yeah... oh my God, it's like the Twilight Zone, right? It was us! It was Man who was the most dangerous animal! It wasn't the universe trying to kill us at all! No, the universe is trying to kill us. Alright, so let's move on to our next mystery. So, where are all the G-dwarfs? What's a G-dwarf?
Pamela: It's a nice, happy, normal, regular hydrogen-burning star that should still be around no matter when it was formed. These are nice happy long-living objects.
Fraser: So, these would be a little smaller than the sun? A little less massive than the sun? And so should have a little longer life span than the sun?
Pamela: Yeah.
Fraser: And smaller stars are more common than bigger stars? You follow my line of reasoning here?
Pamela: Yeah.
Fraser: So there should be more of these small, longer-lived stars than the larger stars, and yet there aren't.
Pamela: Right. And our sun is actually one of these G-type stars. But it's even stars smaller than this that are missing. We start noticing it with the G-dwarfs. As we look around, our sun still has 5 billion years to go... we're a nice, happy metal-rich star, able to form planets, all sorts of really cool stuff. Now stars that formed in the first moments of the universe, G stars forming in the first moments of the universe, should be just barely on their way out, in some cases. 13.7 plus or minus .2 billion year old universe, sunlike stars live10-ish billion years on the main sequence, we're not seeing them. And the problem is that you'd expect to see these stars that have almost pure hydrogen-helium atmospheres, that haven't been polluted by supernovae. We call these population III stars. And we don't... we look around, we see plenty of metal-poor stars out in globular clusters, out in the halo, but they've still got some iron in them, they've still got titanium in them, they've still got metal. It's just not a lot. And we don't know where the things without metal are.
Fraser: So there should be a group of stars that formed right after the Big Bang, from the primordial hydrogen and helium created in the Big Bang, but yet weren't large enough to detonate a supernovae. They should have just been happily plugging away for 13.7 billion years only half way through their life span. And we should see these.
Pamela: Yeah.
Fraser: And we see none?
Pamela: We haven't found a Pop III star yet. We've found things that come close, but we haven't actually found a Pop III star yet.
Fraser: And there should be Pop III red dwarfs everywhere.
Pamela: Right.
Fraser: And we don't see any of those either...
Pamela: No.
Fraser: So, clearly that idea is incorrect... something different happened. It's not like we had the primordial hydrogen, it collected in stars of varying sizes, the biggest ones detonated as supernovae, other ones have died as white dwarves. There should be a pile

of stars out there... in fact the vast majority, right, when you think the vast majority of stars are red dwarves... The vast majority of stars out there should be these ones left over from the primordial hydrogen, but to find none?

Pamela: I wouldn't go so far as the "vast majority," because the problem is there is this problem where little stars form last... it takes them longer to crunch down, it takes them longer to gravitationally collapse. So, the really big stars... the ones that blow up as nuclear bombs in the matter of a few million years--they form first. So they do live and die before the littlest stars have a chance to be born. But, there should be stars in between. There should be these intermediate-mass ones. We don't know how much mass was tied up into the very first generation of star formation. The universe was still collapsing, it was still forming structures. It was still just basically neutral hydrogen gas everywhere until that very first generation started to go supernovae and ionize everything. Now, the problem is... how do we get *none*? And so when we try to understand none, the way we get to none is to say, well, maybe when stars are made of only hydrogen and helium, with no metals, they have difficulties doing basic forms of radiating light that need the metals. You get cooling when you have metals involved. Maybe without the metals there to radiate in specific lines, you only get giant stars, and that's the explanation that we work from. In a pure hydrogen helium environment you get giant stars that don't exist in the modern universe because now we have metal. That's one explanation. The other explanation is that the first stars were so giant that they lived and died before any small stars could form so you didn't have any G dwarves, you didn't have anything capable of still being alive today, that formed before the first generation of supernovae.

Fraser: And those first stars polluted all the remaining material with their metals.

Pamela: Yes. So you can find things that have evidence of one or two supernovae infecting them, but you don't have things that have zero supernovae infecting them.

Fraser: Right. It's a mystery!

Pamela: Yep.

Fraser: Alright, I think this will be our last mystery for the day. Which is... where are the intermediate black holes? So... the intermediate-mass black holes. We've got the stellar-mass black holes that come from stars exploding, we've got the super-massive black holes that come from millions and millions of stars-worth of mass coming together, but why is there very little in between? You'd think that you'd have stars being put together, creating larger objects, black holes merging together, collections of stars collapsing down together, or maybe even some of those we've talked about... those monster stars in the beginning... maybe they would only have a 100 times the mass of the sun or 1000 times the mass of the sun... But we don't see that at all. Why not?

Pamela: We don't know. This is probably going to be one of the most boring mysteries. Yeah, stellar-mass black holes--we get them, we find them, they're sitting there in binary systems waiting for people to discover them and watch gravitational radiation take place and get Nobel prizes--life is good. We see them in the centers of galaxies and super-massive black holes and maybe someday someone will get a Nobel prize for that... but it was two different research teams that argue about it so who knows? But intermediate-mass black holes... well we tried looking in globular clusters--they looked like a good place... didn't find any. We've tried looking in dwarf galaxies...maybe these little tiny systems will support littler super-massive black holes, intermediate black holes?

Fraser: Right, you get a dwarf galaxy's version of a super-massive black hole.

Pamela: Right. And the thing is, we haven't found any there either. You look at systems like the Ursa Minor dwarf spheroidal galaxy and it basically looks like a poofed-out globular cluster that happens to still have a little bit of gas in it if you look at it in the radio. So these things thus far just aren't being found. It's one of the frustrations. We know that somehow they have to exist... somehow you get from stellar-mass black holes to super-massive black holes. We just haven't figured out where and how.
Fraser: But haven't there been some hints of them? In the last few years there's been a couple of... you know... "Intermediate-Mass Black Hole Finally Found!" You know... question mark? Finally found?
Pamela: There are cases in ultra-luminous x-ray sources where when we look at nearby galaxies you see these things that appear to be 100 to 1000 solar masses that are giving off a lot of x-ray light. And so they seem to be associated with star clusters in some cases. And maybe these ultra-luminous x-ray sources that we're seeing with Chandra and other missions, maybe those are going to turn out to be intermediate black holes. But right now we don't have the evidence of things whipping around them close enough to them that says only a black hole can sit here. And it's that extra little bit of data that we're missing that makes it hard for us to definitively say, "Yes we've found them... some." We've found things that might be them... maybe? maybe? We don't know.
Fraser: Right. Right, 'cause if you can calculate the orbit of the object moving around, that'll tell you with incredible precision what it's mass is.
Pamela: Right.
Fraser: And we just don't see that so we can't know for sure.
Pamela: There is a mysterious object that's a black hole... well, we think it's a black hole... it's a high-density object in a cluster of 7 stars that's a little over a 1000 solar masses and it's in the core of our own Milky Way. But it's still a far cry to go from the 1000 solar masses of this object up to the tens of thousands of solar masses that we see in the centers of galaxies.
Fraser: Hmmm.... it's a mystery.
Pamela: It's a mystery.
Fraser: Alright, and I think that's all of our time for mysteries today. So, next week, we might have run out of Milky Way mysteries, and we'll move on to cosmology mysteries. Who knows? It's a mystery.... Alright, well, thanks a lot Pamela. And we'll talk to you next week.
Pamela: Sounds good. Talk to you later, Fraser.