Episode 54, The Way the Dog Ran Away
Dramatis personae:
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- Erin McGathy
- Amanda Bauer
- Rupinder Brar

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Ben: Never be afraid. There's nothing which is known which can't be understood. There's nothing which is understood which can't be explained. For over 50 episodes now, my team and I have brought you to the very frontier of knowledge in physics and astronomy. And still our mission goes on. To present you with your birthright: an understanding of the Universe. I've traveled the world seeking out a certain type of genius. Masters of not only their academic disciplines but also at explaining their research in understandable ways. And I've bestowed upon these women and men the title of Titanium Physicists. You're listening to the Titanium Physicists Podcast and I'm Ben Tippett. And now... *allez physique!*

01:11

[Intro song; *Tell Balgeary, Balgury Is Dead* by Ted Leo and the Pharmacists]

01:46

Ben: The Milky Way is an enigmatic feature in the night sky. There's a glow to it and bumps and swirls to it, there's a river of stars banded with a long black strip. It can be seen from the northern and southern hemisphere so it's not surprising that different cultures from around the world have stories describing or explaining it. These stories and many others can be easily looked up on a Wikipedia page about it. And here's a sampling of them, please pardon my pronunciation. So the Greek name for the Milky Way is Galaxias /Γαλαξίας/ and it's derived from the word "milk". The deal is that when Hercules was a baby, Zeus (who was Hercules' father) decided to let him suckle on Hera's milk. Now, Hera wasn't Hercules' mother - she was Zeus' wife. Okay, so, when she figured out what was going on, she punted the baby and the resulting spurting milk became the Milky Way.
The Kaurna aboriginal people from south Australia see the Milky Way as a river in the skyworld. They see the dark patches marked dwelling places of a dangerous creature called the yura. The dark parts are called Yurakauwe, which literally means "monster water".
Now, the Cherokee people from North America have a story about a dog that stole some cornmeal and got chased away. He ran north, spilling the cornmeal along the way and thus the Milky Way in the language of Cherokee people is called "The Way the Dog Ran Away".
And in Japan the Milky Way is known as the River of Heaven and there's a famous story from China the Japanese like to tell. There are these two deities in heaven: Orihime /織り姫/ - the star Vega - and Hikoboshi /彦星/ - the star Altair. Now, Orihime was a weaver and she weaved beautiful fabric on the edge of the River of Heaven every night and so she was really sad and lonely sitting on the river banks weaving all the times so she was introduced to Hikoboshi who was a cowherd and then they fell in love and got married and promptly stopped doing their jobs so there was no more beautiful fabric and now there are cows wandering all over heaven. So, the two lovers were immediately separated and they were placed on the opposite banks of the River of Heaven and they both cried so much about it that they're allowed to meet one day a year on the seventh day of the seventh month when a bunch of magpies come in and make a bridge for them to cross.

Anyway, the counterintuitive thing about the Milky Way is that it's not obvious. I mean, it's this big, cloudy, milky river thing and we've been looking at it and telling stories about it since forever but it represents a cosmological structure an order of magnitude so large that we never even recognized it. The Milky Way is a galaxy. It's the galaxy we belong to - it's our galaxy, and in fact the word "galaxy" comes from the Greek name for the Milky Way. The reason that it looks like a line of stars is because we're trying to look at it from the inside of it.
We didn't even know what the galaxy was until like a hundred years ago when telescopes and astronomy had developed enough for us to recognize that the universe was full of these giant clusters of stars, containing bazillions of stars in orbit around their communal mass. The prettiest of galaxies are spiral galaxies, the shapes like discs of stars, pancakes of stars, all rotating around the center with prominent concentrations of bright stars lining up in spiral shapes, radiating from the center.
And the Milky Way - this river of light and dark that crosses our night sky - we've recognized that it too was a spiral galaxy. It contains something like 300 billion stars and something like a 100 thousand light years across and we are kind of in the middle there. We're about 27 thousand light years from the center. And that's a lot of numbers. So let's put this in human history terms, right? So, mankind evolved in Africa and then spread out to all the other continents in the world, so the question is: imagine we have an observer sitting right in the middle of the galaxy, pointing their telescope right at Earth. What epoch would they see? I mean, light takes one year to travel a light year, so what would somebody in the middle of the galaxy see? Well, the center of the galaxy is so far away from us, that person looking at Earth through their telescope would see humankind learning to weave baskets! That's how long ago he would see. I mean it's an incredible amount of distance. And if we had somebody on the far edge of the galaxy looking at us, the light they would see is so old that they would see Homo sapiens living in a time when the Sahara desert was all wet and fertile! You know, an era so long ago that the end of this era was what pushed Homo sapiens from Africa to all the other continents. It's a crazy amount of time ago!
So the Milky Way is huge. So huge in fact that all the other stars we can see in the night sky are actually part of the galaxy as well. But we can study our galaxy. We can study it by looking at all the other galaxies in the night sky. We can get a sense of how galaxies evolve, what happens to them in the long run, where do they come from. And this can tell us about our own history. On this episode of the Titanium Physicists Podcast we're talking about our home - the Milky Way galaxy. So, speaking of star-crossed lovers, whose lives of love and regret are visible to everyone on Earth, today's guest has her own podcast called "This feels terrible" where she and her comedian friends talk about their shameful and regretful memories of love. It's an extraordinarily brave show and it's absolutely fantastic. She's a comedian and a writer and she performs at the Upright Citizens Brigade theatre in Los Angeles. In fact, she has a show coming up, on February 13th. A "This feels terrible" storytelling show. And she's also a regular on the HarmonTown podcast - welcome to the show, Erin McGathy!

07:08

Erin: Hello!

Ben: Hi!

Erin: Thanks for having me, hi!

Ben: Hooray! Okay, so Erin, for you today I've assembled two fantastic Titanium Physicists, very old friends who haven't been on the show in a cattle herders age.
Arise, doctor Amanda Bauer!

Amanda: Whzzzzzzzum

Ben: Doctor Amanda is in Sydney, Australia at the Australian Astronomical Observatory. She got her PhD from the University of Texas at Austin and she studies galaxy formation. She has a notable public figure on the Internet where she blogs under the name astropixie. Now, arise doctor Rupinder Brar!

Rupinder: HrrrHrrrrrr Hrrrrr

Ben: Doctor Rupinder is one of the friendliest people I know, he's so good at making science fun that in 2010 he won tvo lecturer of the year award. He got his PhD from Queens University and he's currently a senior lecturer at the University of Ontario Institute of Technology. Okay everybody, let's start talking about the Milky Way.

08:01

Rupinder: Erin... So, the way I like to think about the Milky Way galaxy is... it's sort of like an ecosystem in a way. So like when we talk sort of on a granola crunchy level about everything on Earth - the plants, the mushrooms, the people - we like to think of it all as... we all influence each other and they all influence us. We're all connected in a way. To me that's what the galaxy is, too. Every star, every black hole, every piece of matter, planet, whatever human, alien you might find in this galaxy, it is all connected together. We have a shared history. And so I'm sure that a lot of people have heard this idea of us being made of star-stuff. I think it's equally important to argue that we're made of galaxy-stuff. Without having this structure, this factory if you will, all of the raw ingredients that make us up wouldn't have coalesced into being able to make our solar system, our cellphones and us at all.

09:09

Erin: Hm. Alright, prove it.

Rupinder: [Laughs] Okay. So... what is a galaxy, right? I mean, gravity is the most important ingredient when we talk about the galaxy. Like, what is holding us together, what is separating us from the next galaxy over. Essentially all of the little pieces that I mention are gravitationally interacting. We're all orbiting the center of our galaxy. Just as we can easily imagine the planets, asteroids, comets orbiting the Sun, us as a solar system, the whole Sun, everything in our solar system, the Earth, we're all going around the center of our galaxy. And so are all of the other stars, so is the dust, the gas, the dark matter and all of the other exotic things that we're gonna find in our galaxy. As far as what our role in that galaxy is, we're in a very interesting spot, called the disk of the galaxy. I want you to imagine the galaxy, if you can. Like, we all know what a spiral galaxy looks like. We've all seen a picture here or there but to me, the important part of the galaxy that I wanna talk about is a pancake.

10:24

Erin: [Chuckles] Alright.

Rupinder: You love pancakes, right?

Erin: I do, I do love pancakes.

Rupinder: Yeah, the best kind of pancakes/ they're not those European skinny pancakes where there's nothing in them.

Erin: Are you talking about a crepe?

Rupinder: Yeah, yeah. No crepes. We're not talking about crepes. We're talking about like really good fat pancakes. Maybe flapjacks.

Erin: I know this isn't a breakfast podcast but just in case you ever go to France, I think they'd be offended if you called their crepes "skinny pancakes".

Rupinder: Skinny pancakes. You might even be putting apples in that batter.

Ben: There's lots of baking soda, it's puffing up.

10:52

Rupinder: And so basically, we're not sitting still in this pancake, we are also orbiting the pancake too. And so us as a solar system, we're all moving together through this galaxy and it's taking us about 200 million years to go round one time. Just like it takes the Earth one year to go round the Sun a single time, it's gonna take the Solar System 200 million years. And it's a bit more interesting than that even. Instead of us just going around in a nice, smooth circle, we're actually bobbing up and down. We're bobbing up and down in a skinny part of the pancake as we go around the center as well. Sort of like a carousel or a merry-go-round.

11:35

Erin: Do we go faster? Or like... as we get further out to places in the galaxy where it's thinner, do we move faster?

Rupinder: So for the most part, we actually keep the same distance away from the center. Our bobbing motion is happening sort of in the up and down direction, if you were looking at the pancake edge on.

Erin: Okay. So.. Okay. Were we once in the middle of the merry-go-round and everything is spreading out and that's why it's in that shape?

Amanda: Probably not.

Rupinder: No. No.

Erin: Probably not. Okay.

12:04

Amanda: Okay, thinking about how the Milky Way actually formed. It would've formed from a big cloud of gas and dust and that would've been kind of a big spherical thing. So, bringing the food back into it, imagine if you're making a pizza crust. So you have to make the pizza dough and you've got this big ball of dough.

Erin: Mhm.

Amanda: But you know how you can flatten it a little and then throw it up in the air and spin it a little bit and it just flattens and gets thinner and thinner and thinner?

Erin: Yes.

Amanda: So, in terms of the Milky Way, when you've got that big cloud of dust, that's a little bit more dense than the regions around it, it starts to collapse under the force of gravity and this would've happened very early in history of the Universe, so very soon after the Big Bang. So as it started to collapse, it was sort of like that pizza dough ball that was spinning. The gas naturally starts to spin as it collapses under the force of gravity and so it flattens out like the pizza crust. So it flattens and flattens and flattens and then other sorts of crazy things happen - it isn't quite as simple as that pizza dough flattening out - but we end up flat, sort of like the pancake.
But then there are little regions in that, that start to form into the spiral arms, so you get kind of density waves that move through and that's where you get these tiny little clumps of gas that form new stars. So the Solar System would've been formed in one of those clumps of stars that form in that gas that would've been in one of the spiral arms.
And then we keep moving in that circle around the center of Milky Way. We never quite move out or in, we stay about that distance, but we do move a little bit faster than the spiral arm, so we kind of catch up to different spiral arms over time and our speed changes a little bit as we approach one of those spiral arms and go through it and come out and then forward and on the other side.

Erin: So the galaxy is shaped the way it is just because of the Big Bang, not because of like the current movement of the galaxy, it's all kind of stayed in the same spot?

Amanda: The Milky Way formed in a pocket of gas and the size of it is essentially because of what happened right after the Big Bang.

Erin: Okay.

Amanda: But then how it collapsed and everything that is sort of conservation of angular momentum and gravity and just the basic physics that we think we know. So that was all post-Big Bang stuff.

Erin: I think the thing that's confusing me is that it's almost like the opposite of the way that a ball of dough is spread out from spinning. The reason that it's doing what it's doing is because it was that shape and the gravity of that shape is...

Amanda: So the Big Bang happens and the whole Universe is like expanding everywhere. But it's not exactly completely smooth everywhere. There are tiny, little clumps of regions all the way throughout the Universe that are little bit more dense than other ones. So it's almost completely smooth but not quite.

14:46

Erin: Okay.

Amanda: So in each of those little regions that happen to be a little bit more dense...

Erin: Mhm

Amanda: There's billions of these, all the way throughout the Universe, soon after the Big Bang. Those little over dense regions like that one little cloud would've collapsed under its own little local gravity.

Erin: Okay.

Amanda: And so that one little cloud would've then proceeded to form itself into a galaxy. And there are billions of those, all the way throughout the Universe soon after the Big Bang.

Erin: They're forming because they're... collapsing? I don't understand the idea of something collapsing and then creating a galaxy.

Amanda: That's a major field of study. [Laughs]

Erin: [Laughs] If there were/

Amanda: At first what is collapsing is only gas. It's only/

Erin: Okay.

Amanda: /hydrogen.

Erin: Okay.

Amanda: And then, as that starts to collapse, it starts to get denser and denser and denser.

Erin: Oh-kay.

Amanda: And then we've got little clumps then they start to form the first stars.

Erin: I see.

Amanda: So at the beginning it was only a gas cloud. A big one, but only...

Erin: Now I understand. Okay. I get it. I guess instead of thinking about gas collapsing in on itself I was thinking about just like matter and stars and things.

Amanda: Aaah. Right. So soon after the Big Bang there was only hydrogen, there were only particles and then as soon as these first stars started to form, when that gas got dense enough for stars to form, then those things started to churn out all of our other elements, like carbon and oxygen and all that stuff. And gradually, over the next 13 billion years, they formed all of the constituents, the gas and the dust and the black holes and all that stuff that make up our galaxy.

Erin: Ah.

16:13

Ben: We were getting to the question of why it forms a disk. The idea here is that before the structure of the Milky Way formed, there was just a whole bunch of gas in space. Right? It's a little bit denser at one point than anywhere else and then all of the gas says "Hey, I'm being gravitationally pulled towards the slightly denser region". And then all of the gas in a great big ball ends up trying to collapse down on the center.

Erin: Gotcha. So it's the opposite of pizza dough.

Amanda: We haven't jumped to the pizza dough stage yet.

Erin: [laughs]

Amanda: We're still taking the flour and adding the, you know, the other stuff so that it can get to that pizza dough ball. [laughs]

Erin: [laughs]

Ben: So in the pizza dough explanation you start with that little ball and then you spin it, so it's flat. Right? What happened to this big ball of gas is that/ like, okay. So the reason the Earth doesn't fall into the Sun is because it's in orbit. It's moving sideways relative to the pull of the Sun. So the Earth feels the pull towards the center of the Sun but because it's moving sideways relative to that pull, it can manage to go in a circle around the Sun instead of falling into the middle.
Same thing with this big ball of collapsing gas. All the gas is gonna end up collapsing down into the middle unless it's moving sideways relative to that pull. And this is just kind of a/ you know, there's some natural variation about where each glob of gas in this bigger ball of gas is moving. Some of it's moving left and right and so, you know, it sorts itself out over the course of its evolution so that the only gas that doesn't end up falling into the middle is the gas that was rotating in orbit. And so a big disk of orbiting gas forms, which is why we had this pancake shape, because it's pretty much all of the gas that wouldn't get sucked into the center because it ended up in orbit.
When we think about galaxies, what we look at is stars, right? You imagine this big vast ocean of stars. But the real story in galaxies is this dust and gas that's always collapsing down and is kind of in orbit around the middle, because it's that dust and gas that is collapsing down and forming stars, right? And so the deal is, the star formation mirrors where the gas is slightly more dense. So, the reason we see spiral arm in the galaxy with this nice swirly spiral patterns, is that there's kind of overconcentrations of dust as it orbits the center in these weird spiral shapes. There's a little bit denser dust there and so that's where the stars form.
There's a Canadian skating game, called "Crack the whip", where everybody is on skates, you know, you hold hands and you start wheeling about the center and then the person at the end gets thrown somewhere and breaks their neck and then you can't play it anymore.

Erin: [laughs] Okay.

Ben: Okay, so it looks when we look at the spiral galaxies from above, it looks like the stars are kind of doing that. Like there's a big train of stars but that's not quite what's actually happening. What's really happening is: there's a long train of dust, a big overconcentration of dust that's spiral-shaped and that's where the stars form.

Erin: Got it.

19:10

Ben: Okay.

Rupinder: Ben, if I can? Do we wanna talk a little bit about how we can tell what the Milky Way looks like? So, I like to use this sort of twisted problem, if you can. We're inside this thing, right? And so, like, to figure out what the shape of it is, how big the spiral arms are... I mean, we can see a very, very small fraction of the number of stars in our own galaxy. So the challenge to actually, first of all understand that we're in a galaxy and then to actually be able to physically describe it is a crazy hard task that astronomers have been working on for about a hundred or so years.
And the analogy I like to put, if it doesn't freak anybody out here: imagine yourself, kidnapped. And you wake up in a room. And you can't get out of that room, but you can look out of the window and for some reason your kidnappers left a phone in your room. You call the police and they're like, "Well, describe the house that you're in". That's essentially what the problem astronomers have is.

We're confined to a small piece of this house and we can't even see the outside of it. But we do have one advantage in that we can see that the houses in the neighborhood - luckily, we're in a suburb, a suburb built by a single builder - and we can describe the houses in our neighborhood. And essentially understanding that and, you know, getting a sense of a little bit about "Oh, we have this many rooms" or little tiny features help us understand overall what our own Milky Way galaxy looks like. Unlike our solar system, where we've explored things, we haven't seen the Milky Way galaxy in any point of view other than being confined inside of it.

Erin: In this scenario, does our planet have enemies?

Ben: Do you mean like, are we supposed to be paying a ransom so that we can get out?

Erin: [laughs] I mean, it's just such a funny analogy/

Rupinder: Yes

Erin: Just the first thing I think of when I think of being kidnapped is like "Who did this?"

Ben: [laughs]

Erin: And it's got nothing to do with what you're/

Rupinder: It was clearly the Andromeda galaxy did this. We/

Erin: Maybe our planet had a night where they went to a party where they were feeling self-destructive and had too much to drink and maybe met somebody and woke up in the morning and maybe they hear the noise of someone making pancakes/

21:36

Rupinder: [laughs]

Erin: But they don't know where they are, they know they weren't kidnapped but they know that they're in some sort of a home and then they call their friend and they describe where they are so they can get picked up.

Rupinder: [laughs] I like that one. I'm gonna use that one with my eighteen-year-old students now.

Erin: [chuckles] Thank you.

Ben: What does this have to do with comparing the stars nearby us to/

Rupinder: Galaxies nearby us.

Ben: Oh, we're looking at galaxies nearby us?

Rupinder: Yes. When you're looking out of the house and you're looking at the neighborhood around us, we're looking at other spiral galaxies. Like Andromeda, like distant M51 or something like that/

Erin: Oh, okay.

Rupinder: Because we wanna know what our house looks like. And it helps us to get a picture but/ I mean Amanda can speak more on exactly what we're doing inside our own galaxy to understand the big picture. How all these stars kind of fit together to give us an overall shape.

Erin: I thought that you meant that, like, we were placing ourselves within our galaxy. But you're just saying, you're kidnapped and you look outside the house you just wanna know what the other houses look like. We're just seeing what everything else looks like to understand what we look like, not necessarily where we are, because we know where we are?

Rupinder: Exactly.

Erin: Okay, alright. Got it. Maybe if you were moving into like a new tract housing neighborhood and you were looking at the other/ well, that doesn't make any sense.

22:57

Amanda: Or if you're in a place where you don't have any mirrors, you've never seen yourself and you're kind of looking at everybody else's face to say "Oh, I have these eyes, that's what that person has", "Oh, I've got a nose, too - that's what they have".

Erin: Yeah.

Amanda: You're trying to figure out your own structure by looking at everything else around you to see if you're similar or not.

Erin: Right.

Amanda: The challenge with that is, say in the southern hemisphere you can look out and see the Milky Way stringing across the sky and just next to it you see these two tiny little galaxies called the Large and Small Magellanic Clouds. Full disclosure, astronomers are not very good at coming up with names.

Erin, Amanda: [laugh]

23:31

Amanda: So these are entire galaxies that we can see and they just kind of look like little smudgy white fuzzballs floating in the sky and they're absolutely fantastic but they're these little tiny galaxies that are stuck to the Milky Way. The Milky Way is like the big one in this picture and these two other ones are stuck to it so they're actually orbiting around us. And eventually they're gonna fall in and become part of the Milky Way. But right now they're separate and we can see them and they look absolutely nothing like the Milky Way. So that's a bit of a challenge to this "we can figure out what we look like by comparing ourselves to the other galaxies around us that we can see".
So, there are all sorts of tricky little ways that astronomers have come up with to try to figure out what we look like from the inside. The current count of spiral arms that we have is four, which is actually a change from what we thought even up to a couple years ago. So we thought for a while we only had spiral arms but again, I can't jump in my space rocket and shoot out and have a look. [chuckles]

Erin: Mhm.

Amanda: So, we have to guess by taking really detailed observations of as many stars in our galaxy as we can and it turns out that the huge challenge in astronomy is still determining how far away things are. So, I can look at the stars and say, "Oh, there's five stars in a clump right over there", but that doesn't mean that they all actually live in the same physical space. It could be that two are really far away and just bright, and two are kind of close by but faint. But they look to our eyes that they're in the same place in the sky.

Ben: It's like when you take a photo of yourself high-fiving the Statue of Liberty.

Erin: [chuckles] It's funny.

25:04

Amanda: So, people are taking on this huge surveys of different sections of the sky and trying to map out exactly how far away the stars are and then seeing if physically they line up so that they could be in the positions of where there's a spiral arm or not. So there was a study that was going on for about twelve years and it just came out last year and based on the distribution of stars in our sky and figuring out how far away they actually are, they've mapped out that we have four spiral arms and that our Sun is just kind of at the edge of the Orion arm.

Erin: So, from within our galaxy what is it we see when we are looking at the quote-unquote "Milky Way", like what is/ is that one of the arms?

Amanda: Oh, it's actually a whole huge chunk of the Milky Way that we see. So have you ever seen the Milky Way?

Erin: Yes.

Amanda: Have you ever gone out and looked at it?

Erin: Mhm.

Amanda: So it looks like a smooth thing across the sky.

Erin: Egh (...) no?

Ben, Amanda, Erin: [laugh]

Amanda: Good answer.

Erin: [chuckles] It looks like it's all over the place. Just a/ looks like a cloud. A long/

Amanda: Yeah, it looks um/ it looks kind of patchy. It's not like/

Erin: Right, right.

Amanda: smooth stroke. There's some really bright glowing bits and there's some dark patches.

Erin: Mmm.

26:20

Amanda: And so that's as on the surface of the pancake and you pull the pancake up to your eyes and you try to look through it. And you see the collection of all that stuff. Like from the inside, we're looking through that whole edge of the pancake. And a lot of it is stars - we see the collective glow of all the stars in that direction but some of that is dust. And the dust actually blocks the light of the stars behind it. So like on a cloudy day on Earth you can't see your shadow because the clouds are blocking the sunlight?

Erin: Mhm.

Amanda: These dusty clouds in the galaxy are actually blocking the light from the stars. So some regions of that big milky road that you see across the sky are a bit darker, they're patchier and that's just 'cause there's more dust in that direction.

Erin: Oh.

Amanda: Then in the other directions where you've got more of a glow and are bit of a brighter that is the Milky Way.

Ben: So if there was no dust, it would look like there was a large huge disk all the way around. There would be like a/

Erin: Really? That's crazy.

Ben: Yeah. It's blocking out the middle. And it's blocking out what/ I mean we can't see through it, to what's behind the galaxy on the other side.

Amanda: Not with our eyes.

Erin: [laughs]

Amanda: Yeah, we had to invent a lot of other technology like infrared. So infrared can actually see the dust glow and some other wavelengths, um/ radiowaves for instance can see through some of that dust. So we've come up with all these different sorts of eyes to allow us to see different components of the Milky Way and then map them out that way. So if you look in the infrared, you don't/ it doesn't look like as many as the pretty little stars but you see this big glowing gas clouds. It's pretty cool.

27:54
Ben: You know, when like there's like a manhunt going on, and like they're trying to chase down some dude using one of the helicopters.

Erin: Mhm.

Ben: And uh (...) the person's hiding under a bunch of trees, 'cause he's like "No helicopter can see me when there's trees in the way" and can't in visual but then the helicopter has infrared sight and, you know, using this other waveband of light that passes through the leaves, they can see the person hiding under the tree. It's essentially that.

Erin: Do astronomers hate dust? Does that translate to your everyday lives? Like, when you're really cleaning surfaces and stuff?

Rupinder: Some really, really do hate it but others actually study/ the dust itself I think it's very, very fascinating.

Erin: There's got to be a name for those astronomers, right? Like the/

Amanda: Dust mites?

Erin: Dust bunnies or like that, what you have

Amanda: [laughs]

Erin: Like, "Oh, that guy's a dust mite, stay away from that guy, he just studies dust".

Amanda: You know, you can say it in a derogatory way but I have nothing but respect for them. Because it's a difficult problem and I really have no interest/

Erin: [laughs]

Amanda: I try to look at places that are the least dusty. So, I respect them a lot.

Erin: They're good people, those dust bunnies.

Amanda: Somebody's gotta do it. Another method that astronomers have come up with to try to figure out where the stars in our galaxy have come from and also how old they are?

Erin: Mhm.

29:11

Amanda: So if you look at an individual object in the sky, it could be a star or a really distant galaxy or anything. But pick a star. If you take that starlight and you put it through a prism, you see it's whole rainbow. Right?

Erin: Mhm.

Amanda: We enjoy the rainbows from our Sun all the time. Other stars have their own little unique rainbows. So each star has its kind of rainbow fingerprint that tells you all about the chemistry of that particular star. So using this rainbow fingerprints of each individual star you can tell how much hydrogen it has in them, how much helium, how much carbon, how much nitrogen. And the ratio of all these things tells you when it was formed. Because early on in the history of the galaxy, early on, soon after the Big Bang, remember there's only hydrogen and maybe a little helium. So stars that were formed way back then would only have hydrogen and helium in them. But over time more of these elements were formed, so stars that were born later would have more carbon and more nitrogen and more of the other elements. So, we look at individual stars, at/ we're trying right now to look at about million stars in our galaxy to see what their chemical makeup is by looking at these rainbow fingerprints and then dating them to see how old they are and where they could've formed and if they would've moved over time. So that's one of the ways we age our Milky Way, it's trying to figure out how old individual stars are.

30:40

Erin: Sounds cool.

Ben: There's a fun story you can tell about deducing things about our galaxy. So Rupinder was talking how we're like stuck in a house, we only have one perspective on this galaxy we live in... You know, we can look at other galaxies all the way back to the start of galaxy formation, you know... Have you ever heard about the Hubble Deep Field image?

Erin: Uh... yes.

Ben: Great! So they took a camera and they pointed it at the darkest patch of the sky, the one with no stars in it. And they focused on this tiny little dot and then they finally had an image - it was full of old galaxies! The deal is, as far as you can look in any direction, as long as there isn't dust in the way, you can see a galaxy. Which is pretty cool. That's not my point.

Erin: [laughs]

Ben: My point is that/ because we have this catalogue of different galaxies, we can just see so many of the galaxies, you can get a sense of how they evolve. You know, this big cloud of dust collapses down and then over the course of its collapse it'd form a disk but then little pockets here and there of stars will form. And the deal with the stars is/ the reason stars glow is that in the center of stars the hydrogen is fusing together to make heavier elements. And a really, really big star will start burning, we call it "burning" - it's not oxidizing like a fire but uh/ the elements are turning into heavier elements and in doing so releasing energy. Which is why a star glows, right? And so a really heavy star will end up burning some really heavy materials and explode in a supernova and that process, in essence, it starts out: a big ball of hydrogen gas, that gas would collapse down into a star, the star will make a whole bunch of heavier elements like metals and weird lithium, whatever. And then it would explode in a supernova and in the process of exploding it will release a bunch of these heavier elements back into the soup of gas that's, you know, flowing down into the middle of the galaxy and doing it's gassy stuff.
And so the soup from which the stars are made, the chemical composition of the soup is changing over time. As a lifetime of the galaxy goes on, the soup gets doped with heavier and heavier elements and we can see that chemical composition change over the lifetime of the galaxy. So what you can do is, you can look at clumps of stars and a clump of stars from the same big ball of gas and so they would all have the same chemical elements and you can say "okay, that clump of stars is moving in this particular way, it's located here; we knew that at one point of time there was a big ball of gas there and that it was moving in this way". And so if you kind of trace where these older stars are, you can get a sense of how the gas once moved through the galaxy, as the galaxy was evolving. Does that make sense?

Erin: Yeah! I know, I believe I'm following you. Um, go on. Is our galaxy uh... mapped out? How do directions work with the galaxy? Like, are there hemispheres? Is there/

33:28

Amanda: Ooh.. good question. When you look across the night sky and see the Milky Way, so we're looking through the disk, that's actually called for lot of astronomers like myself, who study other galaxies, so we try to look out/ Since that disk has such a concentration of dust and it's really hard to see through it with optical, we actually call that "The Zone of Avoidance".

Erin: Whaa... [laughs]

Amanda: [laughs]

Erin: That's great.

Amanda: All of the observations, like the Hubble Deep Field and these really deep images we've taken of the Universe are in the absolute opposite direction from that disk. Because we want to avoid all that dust as much as possible. [laughs] So then yeah, I guess it depends on what you're trying to study. It's not really split into quadrants per se like going from the center, it's more from our location. So we'll have often a certain angle then we'll take that one section. But, I think different kinds of studies call them slightly different things. The one I'm most familiar with is the Zone of Avoidance.

Erin, Rupinder: [chuckle]

Erin: What made you want to study galaxies that weren't ours?

Amanda: So I guess fundamentally it was my question the first time I saw the Milky Way with my eyes as to "what it is?", like "why is it there?". But then I learned pretty quick that it's really hard to answer these questions for our own Milky Way 'cause we can't get any perspective on it. So, I started to look at other galaxies, 'cause the pictures that we saw, that we made with the telescopes were stunning. You could see all kinds of different sort of spiral arms and shapes among them. So I just started looking at more and more and more of those and realising how different each galaxy really is even though the all fit into certain general categories like whether they have spiral arms or not. And ultimately I think it is answering the question how we got here and what the Milky Way is and what's gonna happen to it over the next many billions of years but I just kind of like the variation in all these different galaxies out there.

35:22

Rupinder: Yeah, yeah. I agree with Amanda. When we're in our own galaxy, again it's really hard to see the forest from the trees but if we look at these far away galaxies, we can almost treat them as single system, like all the cool things that are happening are all part of a single picture. But being too close to this one, inside of it in fact, you're just kind of studying bits and pieces of it and it's really hard to make it into a singular dynamic object, even though it is.

Ben: We were mentioning earlier that the galaxy has different constituents, right? It's made up of different stuff. There's stars, stars behave in a particular way. They tend to just barrel through, they tend not to bounce off things, 'cause stars don't usually hit each other. Gas does hit each other, so if two big clouds of gas try to push through each other, they'll kind of bounce off each other and you'll get another big cloud of gas doing its own thing. But there's also like dark matter. And we weren't sure how much dark matter there would be and then there was the question of what do black holes do? We know that there's a big black hole in the center of the Milky Way Galaxy, we're not sure when that formed.

And so, these ideas would be really speculative but we have computers. And so what we can do is: we can tell a computer, we can say: Okay. We know how all these things interact. We know how dark matter kind of flies around, we know how gas tries to pass through each other and bounces off each other, we know how stars interact and at what rate they form. Let's just simulate a galaxy. And so they set up computers and simulate galaxies and then they compare to see what kind of galaxies they make, what time kind of timeframes galaxies form in and then compare that to what we can see observationally. And what we can do as a result, is come up with a good sense, a modelling sense, of how early or late the black hole in the center of the galaxy formed. Whether it forms near the end of the galaxy formation or whether it forms early on; what kind of role the gravitation of the dark matter has on the gravitation of everything else.

It turns out that it looks like the black holes at the center of the galaxies form really, really early on. We know that it looks like the clumps of dark matter... dark matter kind of clumps together in these, you know, giant orbiting balls before any of the gas has time to collapse. So it looks like, stage wise, first it's the dark matter and the black hole and then all the gas follows in and collapses down where the dark matter has collapsed in and then it forms the disk and all the interesting things happen. So if you're in Rupinder's shed, all kidnapped and you have nothing but time on your hands, you see how long it would take to build a house and you get a sense of how houses are built; you're like "okay, we can't build the roof first".

Erin: Ohh.. Rupinder's shed is the name of my next novel.

Ben: [laughs] Let's talk about the end state of the Milky Way galaxy. So the deal is that we can see a lot of different of types of galaxies when we look out into the Universe. And so we can have a sense of different stages of the evolution in a galaxy and so as a result we understand what's gonna happen to our own galaxy in the long run.

38:25.0885

Amanda: So, I said before the Large and Small Magellanic Clouds are eventually going to fall into the Milky Way and become part of it. Well, we live in a little neighborhood called the Local Group - thrilling name, is it not? - and the Local Group is made of us, we're one of the big galaxies and the Andromeda galaxy is the other massive big spiral galaxy and then there's all these tiny little dwarf galaxies. The Andromeda and the Milky Way galaxy are barreling towards each other directly and we'll ultimately crash into each other and become one massive galaxy system, which hopefully has a name better than "Milkomeda"

Erin: [laughs] Wait, is that the working name?

Amanda: Kind of a working name, I keep seeing it/

Erin: Milkomeda?

Amanda: Milkomeda.

Erin: That's awful. I wanna give science my friends' contact information.

Rupinder: Ask Canon.

Amanda, Rupinder: Yeah!

Amanda: Please.

Rupinder: We've got some time, Amanda? There's a bit of time to work out the name?

Ben: Yes [Laughs]

Amanda: We've got about four billion years to work on it.

Amanda, Erin: [Laugh]

Amanda: I'm gonna try to push for "Androgyny Way", 'cause I think that's better.

Amanda: So, after this collision happens, after about six billion years from now, we'll sort of settle into one big elliptical galaxy. We won't have our pancake shape anymore for a while. And then we will to just evolve. We've got some other dwarf galaxies that will crash into us.
But at some point dark energy is going to take over and the expansion of the Universe is gonna be so rapid that we won't be able to accrete more galaxies. We'll be isolated in our own existence. And actually the bit of the Universe that we're able to see starts to shrink and shrink because of the finite speed of light even as the Universe expands and expands. So, our supermassive black hole will get a little bit bigger, it'll start feeding on some of the material around it and stars that exist in the galaxy will go through their evolution.
We'll have a few more generations of new stars forming but then we won't have enough gas to actually be able to form new stars. So stars will stop forming. I just looked this up for this show actually. The age of the Universe that we're in right now is called the Stelliferous Age. So, the stellar age, the stelliferous.

40:49

Erin: What's the span of the Stelliferous Age?

Amanda: So it's between now for another trillion years.

Erin: [laughs] Okay.

Amanda: So, once all the stars burn out, then we'll be left with Universe with just supermassive black holes, who are left to their own evaporation through Hawking radiation and that lasts for like trillions and trillions of years and it's not entirely sure what's gonna exist after that. Probably just an age where there's the leftover particles from the black hole evaporation floating around. It's gonna be very cold and very dark. And that brings us to the end of our story. Yay!

All: [laugh]

Ben: So, how do we know that when we collide with Andromeda that it won't make an elliptical galaxy?

Amanda: All of the simulations that we've done and images that we've taken of other galaxies that are in the process of colliding. Because we're coming head on, and because of the angles that we're at and because of the other smaller dwarf galaxies involved, there's probably no chance that we're gonna redeem any of our disky features. So it's just gonna be a really chaotic billion years or so and all of the mass is gonna be shoved down into the center, so we're gona build a very big/ it's called a bulge at the center and just lose all of our disky shape. We actually don't know what is exactly gonna happen to our Sun. So as the Milky Way comes, all of our constellations are gonna completely redesign themselves because the stars will be changing their positions relative to us. And it's likely that our Sun will probably get moved towards the outside of this final galaxy system but it's really hard to predict that, even with the sophisticated models that we have.

42:32

Rupinder: One thing that won't happen though is that our solar system is not gonna hit another solar system. Our stars aren't gonna collide with one in Andromeda. The funny thing is, even though there are 300 billion stars in each of these galaxies, they're so far spread apart that no two stars may even collide during this interaction.

Amanda: Yeah, that's always fascinating.

Erin: [laughs]

Rupinder: I mean, really as far as what it's gonna look like from Earth is we're gonna have like double the number of stars in the sky.

Ben: So, Erin, to put the question I asked Amanda a second ago in context: there are kind of two different broad classes of galaxies we see when we look out. There are nice spiral shaped ones, where everything's in a disk and you get that nice spiral-army-looking thing. And there are other ones that just look like it's like a swarm of bees. It's just a swarm of stars, all orbiting the center. And those ones are called elliptical galaxies. And it looks like the way the elliptical galaxies form is that two smaller galaxies once upon a time collided. And then, in the process of colliding, a whole bunch of gas ended up getting smushed into the black hole in the center of one of them. And in doing that, released a whole bunch of radiation. There's something called a quasar, when matter falls into a black hole. I'm not sure if you saw the Interstellar movie?

Erin: Uh, I have not.

Ben: Well, there's this fantastic pictures of like black holes where there's a swirling like disk of gas around it. I'm not sure if you've seen the photographs from the movie. So the deal is that matter that falls into the black hole gets really, really hot and really, really bright and so if you pour a ton, a galaxy worth of dust into one of these supermassive black holes what they'll do is they'll shine so brightly, the light of it will come out so hot that it will blow away and ionize all of the gas and dust in the galaxies. And because there's no more dust and gas, new stars can't form.
And the reason we see our galaxy being disk-shaped, it's like I said: it's a story of what's happened to the dust. The stars form where the dust is, right? And so, what's happened is: all this dust and gas in our galaxy has formed in kind of a disk shape and so all those new generations of stars have formed following this disk shape. So that's why our galaxy is kind of disk-shaped.
So what happens in those galactic collision is, because all the dust and gas blows away and ionizes, you don't get any new stars. And so nothing's forming a disk and so none of the stars are growing in a disk and so all you end up with is this big swarm of old stars. And so my question to Amanda is: how do we know that that's not going to happen to the Milky Way when it collides with Andromeda. And I guess the answer is they did the simulation, so it looks like it's not gonna happen to ours. This particular time.

Amanda: Well... why wouldn't that be an active phase? I guess it just depends on how much gas actually gets fed down into that very central region of the galaxy. 'Cause it only gets active if that gas gets really, really close to it.

Ben: Well, that was wonderful. Thank you Amanda, thank you Rupinder. Your efforts have borne fruit and that fruit is sweet. Here's some fruit. Rupinder, you get a blueberry pancake!

Rupinder: Om nom nom nom nom

Ben: And Amanda, you get an apple pancake!

Amanda: Yum yum yum yum yum

Erin: [laughs]

Ben: Wonderful. I'd like to thank my guest, Erin McGathy. Thank you Erin for coming on.

Erin: Thank you for having me.

Ben: Everybody should be listening to her show, "This feels terrible" and it's about relationships and stuff and it's pretty cathartic.

Erin: [chuckles] Thank you. [laughs]

46:07

Ben: Alright everybody, it's announcement time. So, first I hope you're enjoying the Question Barn episodes. If you'd like us to answer your questions, send your questees to tiphyter@titaniumphysics.com. Second good news, everyone: our patreon campaign is doing very well. We've reached our second fundraising goal, so now we're transcribing a first and a past episode. And so I've got a backlog of the transcription for the transcription guy to do. I'm very happy with it. We're uploading them to the website since he makes them in PDF format. If you've got any ideas what to do with them, drop me a line. On that note, I'd like to remind you that we're now accepting donations. We'd be grateful to receive your support, of course. And you can make a one-time donation using PayPal through our website or you can set up an automatic donations on the Patreon website. This particular episode of the Titanium Physicists podcast has been sponsored by a collection of generous people. First I'd like to thank the generosity of a man named Dennis H, a man named Joshua, Mr. Bobby Richter, a Mr. Aaron Fisher, and a Mr. John Keese. I'd also like to thank Ryan Close, Peter Clipsham, Mr. Robert Halpen, Elizabeth Theresa, Mr. Paul C. and a Mr. Brian Noule, Mr. Adam K, Thomas Sharay and Mr. Jacob S, a gentleman named Brett Evans, a lady named Jill, a gentleman named Greg, thanks Josh and Steve. Thanks Mr. James Classen, Mr. Devin North, a gentleman named Scott, Ed Lollington, Kelly Weinersmith, Jocelyn Read, a Mr. S Hatcher, Mr. Rob Abrazado and Mr. Robert Štětka. Thanks to Brett Knob for remastering our intro, I appreciate the help. So that's it for Ti-Phy this time. Remember that if you like listening to scientists talk about science in their own words, there are lots of other lovely shows on the Brachiolope Media Network and keep listening after the end music, this time there's a fantastic bit of discussion following it. Yeah, it's really great. Okay. So, the intro song to our show is by Ted Leo and the Pharmacists and the end song is by John Vanderslice. So good day, my friends. And until next time, remember to keep science in your hearts.

[Outro song; *Angela* by John Vanderslice]

49:08

Rupinder: And so imagine this pancake. It's fat in the middle. If you look at it, sort of face on, it looks like this beautiful round circle. And let's say we put some syrup on that's sort of the shape of the spiral arms. Go ahead.

Erin: I'm harping on this crepe thing. But if you took two crepes and put fruit in the middle maybe that would look more/ I mean, it's a/

Rupinder: I like that.

Erin: Isn't it scientifically impossible to have a pancake that's thick at the middle? Or but you're saying you would put more while it was cooking? I won't understand the galaxy at all unless you clarify this, this apple/

Rupinder: No, no, I disagree. I had plenty of pancakes that are like fat in the middle and they thin out to the edges.

Erin: Really?

Rupinder: Those are the best ones.

Erin: Are you cooking on a convex pan?

Rupinder: I'm not actually cooking it but my mother-in-law is making these exact pancakes. And they are stuffed, I don't know if that helps. Maybe there are blueberries and apples sort of in the middle and that helps make them fat in the center?

Erin: Interesting. Do you know why she puts the fruit in the middle of the pancake?

Rupinder: I don't know that she does. Maybe it like spreads out. So what if you took like a spoonful of batter and you like chunked in the middle of the griddle and then the batter sort of spreads out naturally but the fruit will remain where it sort of plopped down.

Erin: Okay, I don't believe in space anymore.

Ben: [laughs] Rupinder, your explanation was so confusing that she doesn't believe in space anymore.

50:57

Ben: Does the reason our galaxy is pancake shaped make more sense now?

Erin: Yes, I do, I do understand. I also think that someone's mother-in-law is making pancakes incorrectly

Ben: Poor Rupinder

Rupinder: They're the most delicious pancakes in the entire world.

Erin: I'm sure/ I'm sure that they're the best. I mean, she's doing them wrong, she should call them [incomprehensible, Erin laughs] I/ Yeah, I do

Ben: I think the thing about this pancakes is there's a viscosity issue. I think the viscosity of the batter she's using is less thick than the ones you're used to using.

Rupinder: Absolutely, absolutely.

Ben: And so, her pancakes, when she glob on some dough, the dough/ the fruit all stays in the center but then the dough is so runny it spreads out wider than the center.

Erin: Right

Ben: But pancake dough should be viscous. Erin's right, Rupinder. You need to have a word with your mother-in-law.

Erin, Rupinder: [laughs]

51:55

Erin: Over the course of/ and I don't know how long all of you have been career scientists but like/ have there been any like earth-shattering, maybe life-changing like/ discoveries that have happened? Like, 'cause I'm assuming you guys are all relatively young; has there been anything that's/

Rupinder: I'm 21 actually...

Ben: [laughs]

Erin: I mean, I know you guys aren't in your sixties, so has there been any, like, big career discovery, like a thing that's kinda like changed the game?

Rupinder: Yeah, it happens every five years, I'd say. Something really/

Erin: Really? That's so cool.

Rupinder: Oh, yeah.

Erin: So then why is anybody so like arrogant about anything they believe ever, as everything changes every five years?

Amanda: That's a really good question.

Ben: I feel like a lot of the changes are/ you know, I've mentioned that there are lots/ too many theories and not enough goats in the trees, pruning off the bad theories?

Erin: Right.

Ben: I feel like a lot of the big revelations that happen aren't new theories that crop up but instead somebody finally sticks a goat in the tree and it chomps off/ and so there's been a wonderful theoretical discoveries over the course of my/ like, they discovered the Higgs' boson a couple years ago.

Erin: Yeah.

Amanda: But also, we're sort of expecting things to change. Like, I know that there are things that I don't know. So, for instance, the discovery of planets around other stars.

Rupinder: Yeah.

Amanda: There were so many years where I had to listen to talks where people were saying: "okay, we're still looking, we're still looking, we haven't found any yet but this is my technique and this is how sensitive I am and this is/ you know, we're almost there but I haven't found any". And then all of a sudden, I don't know, 10 years ago, even maybe less than that, the techniques started to get better and better, they were refining and building better telescopes; since that you're able to see that like small little flicker, a little bit more than you could the year before and we started to find these planets. So, it's kind of like we knew it was coming and we just had to get better at what/ at how we were looking and so all of the sudden now there's an explosion, there are thousands of planets around other stars and it's like every day there's more that are being announced. But it took a long time to get to the point.

Erin: And how do they announce a star? Is it like a ball?

Ben: Does everybody dress up in tuxedos and then they open an envelope?

Erin: I was just imagining the stars/

Amanda: The first few probably, but now it's kind of a/ [laughs]

Erin: I mean is there an e-mail? Is there a, like "oh there's this new star" and then who/ the stars are named after the person who discovers them, I'm assuming.

Rupinder: No.

Amanda: No.

Erin: Ooh.

Ben: They all have names like 112AB Giselle K.

Erin: Oh no!

Amanda: I guess that astronomers are not very creative in naming things and mostly stars are named after their/ um/ either a survey that discovers them or the location that they are in the sky, so their like coordinate. And then the planets that would be around that star are that star's name A, that star's name B.

Erin: That's not/ My God, that's a whole betrayal of the culture of looking at stars, isn't it? Like, for ancient people coming up with these great stories, we're just giving them numbers?

Amanda: Because there's a lot of them. [laughs] There/

Ben: Yeah.

Amanda: There are billions and billions and billions and billions of stars.

Erin: I happen to know a professional namer, which sounds like a joke, but I'm friends with like the premier person who names things. Like, she mostly names cars and a ton of other things. But like I'd say like more like luxury products like cars and things.

Rupinder: Uh-huh.

Erin: She was a poet. Her name is - and this is not her real name, unsurprisingly - Canon Wing.

Rupinder: She named herself?

Erin: She did! She named herself, 'cause that's her job. Um, that's her whole calling.

Ben: There's something kind of deific about that, isn't it?

Erin: Oh, absolutely! Of course there is.

Ben: First/ You're so good at naming that first you name yourself and then you name everything else.

Erin: Yeah, I don't know/ her and I are just acquaintances because I've [incomprehensible] her if I'd have her/ because she's someone who names everything. It's just/

Ben: Yeah, you might get a new name

Erin: [laughs] She renamed herself Canon.

Rupinder: Canon.

Erin: That's how I know her. But I feel like these stars should have a name. I have a question that I'm sure is probably pretty tired for Amanda.

Amanda: Mhm

Erin: What is it like/ like what's the culture of being a female astronomer? I have no idea how many female astronomers there are, is there like a, is there a certain light that's cast?

56:21

Amanda: Certainly, the longer you're in the field, the fewer women there are. So when I did my PhD, there war half female PhD students, half male. And that's about, you know, it's maybe forty to fifty percent women at the PhD level, maybe forty percent. Pretty close to worldwide. I mean, there's changes in that. But then it becomes more difficult to stay in the field. Or there are just more forces acting against you to make things more difficult as a woman in the field.

Erin: What are some of those things?

Amanda: There's kind of the obvious ones about if you want to start a family, if you want to take some time off. Different countries give you different abilities to take maternity leave. Or give you some leeway when you wanna come back to the job. Um, there's just the general/ like, if most of the people who I work for are men, then there's not a whole lot of role models, there's not a whole lot of people to kind of look up to that have gone through the sort of same things, there are definitely instances of sexism and bullying and harassment and things like that around, as much as we don't wanna admit it. And a lot of it is kind of accepted culture. And when it does happen, if it's sexual harassment or just harassment, it's harder to make the decision that you're going to make an official complaint against it, because most universities will have a whole bit of paperwork and formalism that you have to go through in order to make that complaint but that faculty members/

Erin: Yeah, and if your peers or like the people that are above you are doing that it's not like you're in the business, so you're not doing what you wanna do.

Amanda: It's a huge power play. That's the reason most of them can get away with it. And me, as a/ I experienced it for instance as a PhD student. I just wanted to get on with my work. Like, I just wanted to study, I wanted to get myself away from this person as much as possible but I didn't know how to confront him. I tried to sort of go up the ranks but everything got smoldered and he never really got reprimanded for it. And little instances of this happening over and over and over really start to burden you, despite the fact that you just wanna get on with doing your research. I'm not saying that every woman experiences those things but most of the ones that I know do and after a while I think a lot of people just kind of get sick of dealing with those things over and over. And there might not even be one blatant instance of it but just gradually it builds up and it's so exhausting.

Erin: Yeah, are you friends with other female astronomers? Or has everybody built up this armor that makes them/ I mean I'm projecting but like the/

Amanda: I do know a lot of female astronomers, I do know some who have never experienced any sort of issue at all, I know some who have dropped out of the field because of it. Um...

Erin: Really?

Amanda: Yeah.

Erin: It's such a shame. Just for/

Amanda: For the ways they were treated/ um, by some blatant harassment and then if they take it up to the senior level, the peers of that person who is doing the harassing tend to defend the harasser. Because that person's senior, they've been around for a long time, you don't wanna shake the boat. Why would you wanna ruin the career of this person who's been here, as opposed to thinking about the person who's been harassed. Like what happens to that person's career.

Erin: Yeah. Rupinder, as a man have you witnessed that? What is your experience with the women in astronomy and like? I have no idea how many/

Rupinder: Yeah. Uh, I mean there's just not enough of them as far as I'm concerned. I do everything I can at the undergraduate level, this is where I interact mostly with students. I don't take grad students and that. And so I'm purposeful of my mentoring of undergraduate students and trying to get them excited and engaged and doing research and that kind of thing and hopefully leading to the picking this as their career.

Erin: Yeah.

Rupinder: But I'd like to ask Amanda: do you find that our generation is better or do you see the harassment coming from all ages?

Amanda: It definitely tends to be a power issue in that it comes from senior people to junior people. That's the typical form. The challenge is going to be: are my generation and my peers willing to step up when they see something and when they're told that something's happening. One problem is, if there's a senior person who is, say, harassing me, I have to find/ okay, I'll give you an example of an incident. I had to find someone who is a senior person, a peer of that harasser and go to that person and say: this has happened, and I'm uncomfortable and I'm not sure what to do about it. That person of mine, who interacts/ like, those two seniors, those peers interact constantly and my safety person in this instance had never witnessed anything or had never been aware or even suspected that this person would do it, and once I said something, all these other stories came out.

Rupinder: Wow.

Amanda: So there are ways that you see it but you just wanna ignore it, you don't wanna get involved. And what needs to happen is more people need to step up and say, you know: I'm an advocate, I'm on your side, if you need help or just kind of go and step in on a conversation or don't let somebody get away with being an asshole because they always have been an asshole. [laughs] That's not okay.

Erin: Yeah.

Rupinder: Yeah.

Erin: And getting each other's backs. I think about the hardest things is dealing with people living with the harasser who has been given a pass by so many people over and over again and no one wants to shake the boat or make their life about the harassment they're receiving.

Amanda: Yeah, and maybe sometimes, I'm gonna be honest, sometimes they don't even know that they're doing it. But the guy who lived with it so much for so long that they've kind of kept pushing and pushing and pushing and until somebody that they respect says "you know, you're making this person feel really uncomfortable by that behavior", they're never gonna change.

Erin: I mean, it's kind of good news that it's people that are older but I understand that like if the culture isn't changing it's just gonna continue on and people are gonna be grandfathered into that system.

Amanda: Yep. That's a challenge. So it needs to be talked about and it needs to be acknowledged and it needs to be recognized when it's happening and it doesn't/ it can't just be the women who deal with the burden and support each other/

Rupinder: Yeah.

Amanda: We need men.

Erin: Yeah.

Rupinder: For sure.

Erin: Oh no, absolutely, yeah.

Rupinder: I think some of the other things that I've tried to do as well is give examples even in the course of lectures of historical injustices to women as sort of you know, "check out this ridiculous situation". Here's the story of Jocelyn Bell or here's the story of Annie Jump Cannon and these like great women of astronomy who basically did this really, really important work but for considerable amount of time they didn't get any credit because they were women. And then in the countless others who, you know, didn't get the shot to do that because they were women.

Amanda: Yeah.

Rupinder: Hopefully that helps.

Erin: [laughs] As a woman pursuing something that is traditionally male, I think that the most powerful thing from a teacher is the expectation that your offering is going to be just as scrutinized as anybody else and like there's going to be/ everyone is gonna be recognized in certain way and there's not gonna be like "oh, we got the/ the girl is gonna do that thing". Did you ever/

Amanda: I just read a quote from Björk today that was along the lines of "A man will say something and it'll be heard the first time he says it. And you could say the same thing as a woman but you have to say it five times before you're actually heard".

Erin: [laughs] Yeah.

Amanda: And I do feel that sometimes. But then the interpretation is that I'm a bit of a bitch because I keep pressing the same point. [laughs]

Erin: No, I know, it's going to be/ it's super fucking unfair and it's going to be unfair for a while, it is. I just read this thing this last week which is the fifth study that I've read about the same exact thing, which is about women in the workplace complaining about/ they're not even complaining about things that happen but just like going over women's reviews vs men's reviews and unequivocally across the board if a woman's in a leadership position, she's a bad person and she's doing something wrong and she's a bitch. Erm, and that's just the way [laughs]

Amanda: And I think it's not just in the science and it's um/ when you look at the fraction of CEO's that are women or you look in political positions, a lot of these things are kind of the boys' network. And it's/ you have to be pretty tough to stick in for a long time to make it through. But we need people in senior positions to act as mentors and to act as advocates for diversity in these roles which needs to happen worldwide.