Astronomy Cast Episode 55:
The Asteroid Belt

Fraser Cain: I must have got 10 emails, 20 emails, in the last couple weeks saying, "Talk about the asteroid belt. Don't go straight to Jupiter, what about the asteroid belt." So we're going to talk about the asteroid belt. Your wish is our command.

Now, I am very well versed in this topic, thanks to video games and science fiction movies and television, like, "asteroids," the video game, where there's asteroids coming at you from all different directions, or, "The Empire Strikes Back," where they're flying the Millennium Falcon through that asteroid belt and the asteroids are bumping into each other and it's a dangerous place. Or, like, that recent *Battlestar Galactica* episode where there's a dogfight in the middle of an asteroid belt against a really tough Cylon, so how well prepared am I for this episode?

Dr. Pamela Gay: You're not. The real asteroid belt just isn't that dense. It's just not that exciting.

Fraser: Alright, then why is it called an asteroid belt?

Pamela: Well, there is a lot of little chunks of stuff that are out and they do form a belt. And if you put a little dot for every one of these asteroids on a diagram that fits on a piece of paper that diagram is going to be almost packed solid with little dots representing asteroids. Well the problem is that real asteroids are often a couple hundred kilometers across at most. And the real solar system is a whole lot bigger than your piece of paper, so the scales just don't carry over real well.

If you were to go out to the real asteroid belt and just sort of saunter through it nonchalantly you'd have about a one in a billion chance of accidently plowing head first or side first or whatever first into an asteroid. They're just not that dense out in the asteroid belt.

Fraser: I wonder then, when the mission planners are sending their missions to Jupiter and out o Saturn did they really worry about it?

Pamela: Well, you have to worry about it if you don't that's when you're guaranteed to be that one in a billion who gets clocked. And they also worry about it because they can get secondary science. So you take off from Earth, you're headed towards Mars, you're going to go not trough the asteroid belt but you're plowing along and you might see some of the things that have orbits between Earth and Mars, you're going from Earth out to Jupiter there you have to go through the asteroid belt and that's a time to stop, check all of your sensors, make sure they work by getting some science on an asteroid.

So you figure out where the asteroids are not just so that you can avoid them but so that you can actually purposely encounter them and purposely try and learn a little bit of this little bit of mass that's hanging out between Mars and Jupiter.

Fraser: Alright well I want to talk about the asteroid belt from a controversial point, because wasn't it almost predicted, like at one point people thought, that there should be another planet in that area?

Pamela: So right after Uranus was found by Herschel everyone got out there and they're like, "there must be something out here, there's this mathematical relationship that says there has to be a planet out at the location where we did eventually find the asteroid belt.

Fraser: Is that true? Is there a mathematical relationship between the planets?

Pamela: There is quite coincidentally, and we haven't been able to find this relationship in any other known solar system. There's this mathematical relationship, the Bode Relationship. So, Johann Bode suggested that, well, maybe there's going to be another planet out where we found the asteroid belt, based on the ratios, the distances, between Mercury and Venus, Venus and Earth, Earth and a gap, and the gap and Jupiter and Jupiter and Saturn and Saturn and… we just kept going and the same ratio just kept working and working and working.

We can't find a reason, scientists have looked for a reason, we've looked for this relationship in other places and it just seems to be one of these really strange coincidences that is just out there laughing at us. There might be underlying physics, we can't find it, so as far as we can tell, this is that time that the monkey decided to type hamlet.

Fraser: Stupid Coincidences

Pamela: But we did find the asteroid belt while looking very hard for a planet that fit this Bode relationship. Now, the first one they found was Ceres, it's the biggest of all the asteroids, and it's even really tiny, it's really tiny compared to the moon. It's the only one of the asteroids that we call a dwarf planet. Pluto fell into the same sorting bin.

Fraser: I was going to say that. It's no longer an asteroid, right?

Pamela: Yeah, it got promoted out of the asteroid category and into the dwarf planet category.

Fraser: So everyone's griping about Pluto, and yet poor Ceres got promoted and no one cares. See? Astronomers giveth and they taketh away.

Pamela: Exactly

Fraser: If you took all of the asteroids in the asteroid belt and mashed them all together into a nice, big planet, would you have another Mars?

Pamela: No. In fact, all the mass of all the main belt asteroids add up to about four percent of the mass of the moon. There's just not that much stuff out there.

Fraser: That's pretty small

Pamela: Stepping back, the stuff that's current living in the asteroid belt, we think from theoretical models, that this only represents about a tenth of a percent of the original mass that was located where the asteroid belt is today. That are of the solar system experiences all sorts of crazy gravitational pulls and pushes because of interactions with Jupiter. Jupiter's sort of a big gravitational bully in the middle of the solar system.

There are all sorts of different places within the asteroid belt where an asteroid can get trapped in gravitational residence with Jupiter and when this happens they get flung to other parts of the solar system. So Jupiter's out there just constantly pulling stuff out of the asteroid belt and sending it to other parts of the solar system.

So it's estimated that in the first million years after the stuff in the asteroid belt had formed out of the original solar nebulae that 99.9% of that mass got flung to other parts of the solar system, it collided into planets, it got eating up by Jupiter, flung into the sun, flung in all directions. There was originally enough stuff to make a planet. It couldn't form a plant because of Jupiter's gravitational bullying and what's left is the stuff that's been able to survive the past 4.6 billion years or so of torture.

Fraser: All right. Now, let's talk a bit about the kinds of asteroids that we may find, because once again you talk about those science fiction shows that are all big tumbling potatoes. But I've got a chunk of an asteroid on my desk and it's a hunk of iron. So what's the difference?

Pamela: Just like planets are made up of different materials, asteroids, which are the stuff that attempted to make a planet, are made up of different materials. We generally group asteroids into three different groups. There's C type asteroids which are carbonaceous. These are about 75% of known asteroids. These are basically rocks. Go outside, grab yourself a giant rock, torture it in outer space for awhile, and you have a carbonaceous asteroid.

We also have about 17% of the known asteroids are S type asteroids. These are siliceous asteroids, they are made out of siliceous. There's silica hanging out in space all over the place.

Fraser: so, like, sand.

Pamela: Yeah, exactly. These are sand, these are glasses, and so that makes up the second largest group of asteroids. And the third group, the 8% rare group, is the L type asteroid, which are metals. These are metallic asteroids.

What's neat is when we look out at the asteroids we group them based on how much light the reflect, what type of light the reflect, we can do some amount of spectrometry on them based on how they reflect light and we also look at their motions. And we can find families of asteroids that we think are probably the result of something bad happening to a once upon a time larger asteroid where this family of asteroid, all the little piece have similar orbits and they all have similar compositions so they were probably all once one larger, but still very small, object earlier in the solar system.

Fraser: and so I have got a chunk of an L type asteroid on my desk.

Pamela: you have one of the 8% rare asteroid chunks. And that's kinda cool.

Fraser: Yeah. Ok, so let's talk a bit about the formation. Where did the asteroid belt come from?

Pamela: Once upon a time when our solar system was young we had this hot star trying to form in the center, periodically blasting things with radiation, not particularly stable, and around it was this disk of material that was slowly working to build up planets. There were different areas within this disk of material. There were areas that were getting blasted so much that all the moisture got blown away, there were areas where water was allowed to exist and it was above the temperature of freezing, then there was a snow line water beyond that formed ice, and in all these different areas of the solar system we end up with different types of objects forming.

We end up with the terrestrial planets forming close in, we end up with the gas giants forming out beyond the snow line, and then out in the very edges of the solar system we end up with the icy Kuiper belt objects, and their more distant kindred that can turn into long period comets forming out even further beyond that. Right smack in the middle of the asteroid belt is where the snow line occurred. So within the main belt you have inside of it, Mercury, Venus, Earth, Mars all happily working to try and form themselves and they're getting blasted and they're dry and they have no water on them in this early part of the solar system. And then you have this region of space from about 2AU to about 3.3AU where there's stuff that would like to be a planet but Jupiter keeps knocking it with its gravity.

We think that Jupiter might have started a little bit further out and as it crept in it sent waves of gravity through the asteroid belt area that helped disperse stuff all over the solar system. And, so, in this belt there's stuff that is allowed to have water, there's, in fact, proto-comets in this area, there's cometary asteroids called main belt comets, there is stuff that would like to be the core of a planet, our metallic asteroids, there's stuff that would like to be the surface of a planet, our carbonaceous asteroids, but the gravity won't let them lump together. Every time some of them try to get together, they get torn apart so everywhere else in the solar system, when matter collides it sticks together and gravitationally builds bigger and bigger objects.

In the asteroid belt Jupiter keeps stirring up the pot and every time things start to try and lump together, Jupiter comes along and whacks it apart. It's a kind of frustrating experience if you're trying to build a planet, but it led to a kind of neat asteroid belt that periodically sends stuff our way that, as long as it's not too big, just creates interesting fireworks.

Fraser: It's interesting though, because I think that a lot of people are under the perception that the asteroid belt is all that remains from some large regular planet that broke up for some reason. Could we talk about how the moon might have been created when a Mars size object crashed into the Earth and so what you're saying is that more likely the planet never got formed in the first place. Jupiter was just around beating it up non-stop that it never got a chance to form anything like a planet.

Pamela: When we look at the chunks of the asteroids, now we haven't had a chance to do a lot of really detailed studies, we have sent the NEAR-Shoemaker Space Probe out to Eris and explored Eris in a lot of detail. We're sending the Dawn space probe out to look at Ceres and Vesta, two of the biggest asteroids. But we're still working on studying these things. We're still working to understand them.

From our present day understanding these things don't show the sign of being a large object that broke together. Instead, these thins appear to be leftover ingredients. It's like when you're mixing a pot of materials, and some of the stuff falls, half formed, out onto the counter and you end up with glops of flour and flour mixed with egg and other stuff all over your counter when you're doing a sloppy job cooking. Well, the asteroid belt is the stuff that got sloshed onto the counter. It's the leftover bits that's didn't get processed, that didn't get weathered, that didn't experience any of the reactions that you get when you do form a planet.

Fraser: Although it's a cluster of tiny objects, there's a few asteroids of note, so why don't we go through some of them?

Pamela: Well, the biggest four asteroids are Ceres, Pallas, Juno and Vesta, and these are the first four that were found. What's kind of cool is we went through thinking that Ceres was a planet, Ceres actually was called a planet for awhile. Until realizing, "wait, no, it's just part of the belt." And so we found these other objects, and then the more we studied the more we realized they were different from one another.

When we look at them where they formed effects how they appear to us. And so when we're looking out we find that Vesta is this big, hot, dry, baked world that formed to the degree that it formed very much like the inner planets did. Now, at the same time Ceres probably formed just enough further out that it actually has water. It wasn't blasted so much that all of its water got evaporated and sent to somewhere else.

Fraser: So are they on opposite sides of the snow line?

Pamela: We think they might have been on opposite sides of the snow line, what we know from data and looking at them, because we can't look back at where they formed, is that Vesta has def been blasted dry and Ceres shows signs of having moisture, so when we look at Ceres there's a thought that once dawn gets out there to explore it that maybe it will find ice caps, maybe it will find thin, water vapor atmosphere, and maybe there's even ices trapped beneath the surface of this not so little asteroid.

Fraser: I'm going to interrupt and provide an explainer here because you've talked about Dawn. For those of you who don't know, Dawn is the next mission that NASA is going to be launching. It's actually on the launch pad as we're recording, and it's due for launch September 25th, I believe. So it's going to be taking off almost at the time you're listening to this show. So, tune in to NASA TV. Dawn is going to fly out and it's going to orbit two separate asteroids. It's going to orbit Vesta and Ceres, one after the other, which is the first time that any spacecraft has ever orbited two separate objects in the solar system. It's got an ion engine, kind of like what smart1 had, to be able to get to high levels of velocity with very little fuel. So it's going to orbit one, gather a pile of data, and then it's going to move to the other one, orbit it as well, and so all the stuff that we're talking about is all we can know from our existing missions like the NEAR mission and ground based observations, but a few years from now it's going to be a whole different world with what Dawn is able to observe, so quite excited about Dawn's launch in the next couple of days.

Pamela: It's really cool. We can only see so much from the surface of the Earth and here we are looking at rather small objects, things that are way smaller than the moon, and we're trying to study them from a fairly significant distance and the only way to really get good data is to go out and visit. Ceres is about 1000KM across and the next largest are about 500KM across. These are little tiny things that, if you could gently land them on top of the US, without crashing into the planet, but just sort of set them there, they would cover some of the smaller states, but they'd be puny if you viewed them from outer space compared to Texas, so you're trying to look at something the width of Massachusetts.

Fraser: Wasn't there a movie about an asteroid the size of Texas coming to hit the Earth.

Pamela: That would be rather devastating.

Fraser: yeah

Pamela: That's one of the reasons we have so much good data on asteroids today. We're constantly trying to find the one that isn't politely staying out in the main belt.

Fraser: Right, but just to make a real distinction here, we're not talking about near Earth asteroids, we're talking about the asteroid belt, which these are safe, good, distant neighbors. Not the terrible, home wrecking neighbors, that we were talking about before.

Pamela: Exactly. Unfortunately, to try and sort out which ones are the home wrecking asteroids and which ones are being good neighbors at a polite distance we have to survey the entire region of the sky that you look through it, you see the near asteroids and you see the distant asteroids. So we're creating a pretty good map of both the safe stuff and the unsafe stuff.

Fraser: So I want to talk about the snow line again, and move further out. What do the objects look like as we get further away from Mars and closer to Jupiter.

Pamela: We have a mix of objects. There are both main belt comets which we think are objects that are responsible for creating the oceans on the planet Earth, so some of the objects that formed out closer to Jupiter were just little comet cores that got covered in dirt in some cases and are still hanging out, out there and in other cases different gravitational perturbations sent them our way and in the early parts of the solar system so many of them got sent our way that our planet got enough water to have all the oceans that we have.

What's neat is as we go further out we see these compositional differences where you start to see the water cropping in. You start to see differences such as do they have ices, do they not have ices, and we can sort all these things out just by looking at reflective light. That's what's cool is that these things aren't even generating their own light, we have to look at how the sunlight reflects off of them to try to sort out what we're looking at.

Fraser: But this is a source that many astronomers believe brought water to the Earth.

Pamela: Exactly.

Fraser: Well, thanks comets. There was some research that's really new talking about steam that's been detected in another solar system and so an alternative theory that I saw is that, in fact, the water can just fall directly as droplets, but this is new.

Pamela: It's new and a lot more data needs to be taken. That's the problem, we hear these really cool things hitting the pres and then the final results don't always make it to the mainstream media.

Fraser: Right. One of the things that's kind of different from all the planets is that we see the planets in the sky, but finding asteroids is rough. So can you talk a bit as an observational astronomer about what it takes to actually find an asteroid and how you know if we've got one of those home wreckers or a safe neighbor?

Pamela: This is actually a really well documented process and if you ever want to get into the business of looking for new asteroids, people are still finding these thing on a regular basis. The way you find them is, first of all, you go out and you look along what's called the ecliptic of the solar system. You go out and you look along that plane that pretty much all the planets are living in. The easiest way to find them is to take images of the sky that are long enough that you can see a object moving through your field of view. You can see it trail as it moves through your image.

Or, alternatively, you can take a whole bunch of different images and display them as a movie and look for objects that seem to move across this field. When you first find something in your image that's moving it may not be something new, and in fact it probably is something that is well known. Lots and lots of astronomers curse asteroids because they fly through fields all the time and you see this stripe of an object passing through your image.

If you want to find out what it is that passed through your image you have to do what's called astrometry. This is where you look up in a table of numbers where all of the different stars in your image are located and you put their coordinates in and then you do geometry and there's really good software called Astrometrica which will do all of this for you, and then it figures out where that moving object is located on the screen, where's that moving object located on the sky, and you write down what time you took your observation so once you have the time of your observation and the location on the sky of the object that was appearing to move you can go to the minor planet website and input all of this information and they have all sorts of how to manuals on exactly how to format your data, and it will spit back, "you were looking at…" and it will tell you the name of the object you were looking at, or it will say, "hmm, we don't' know about this."

You need more than one observation of the thing over a period of time to actually secure that you actually found something. You take observations one night, take observations the next night, and you see how it's moving across the sky. This allows orbits to be calculated. It could be one of two things happened. You either found a completely new object in which case you get to name it, or you found a lost object, because there are asteroids that were found decades ago, a century again, that we thought we understood what they were doing, but somewhere along the line their orbit got perturbed or our calculations went wrong and we've lost asteroids. So occasionally we even re-find them.

Fraser: I think that this is one of those fields of astronomy where amateurs can play a big part. I recently did an article about some astrophotographers and some of them assist in the search for near Earth asteroids and classifying asteroids in the asteroid belt. That's why most asteroids have those funny numbers; 2002NN49, right? They're discovered in 2002 and then there's a large number of numbers and letters used to help further classify them.

Pamela: what that could mean is each week of the year has its own letter code. So we're do the year that something was discovered, the letter code for the week that it was discovered, and then we'll do the number of the asteroid that was discovered. Now if it turns out that discovery is proven to be a brand new, never before know object, the person who finds it gets to name it. This is how we ended up with an asteroid named after David Levy, Mr. Rogers has an asteroid named after him.

Fraser: I think that Skepticality has an asteroid named after it. There's a guy who I correspond with who I call "asteroid Carl" because he's had an asteroid named after him. If you know an astronomer, you can have an asteroid named after you.

Pamela: It's very cool. One of the editors at Skytel it's just a hobby of his, takes just fabulous data and he's regularly chewing up asteroids that are his own discover, so those folks are not only doing great writing they're also doing great science on the side.

Fraser: So anyone who wants would be grateful if you wanted to name an asteroid after Astronomy Cast

Pamela: We certainly wouldn't turn you down

Fraser: Well, I think that covers the asteroid belt. We'll move on to the next target in the planet, which I think is going to be Jupiter.

Pamela: I'd be remiss if I didn't say that the asteroid belt is a number of little belts with the Kirkwood gaps in between.

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