Episode 12: Exiled Worlds on the Outskirts
Physicists: Sean Moran, Laura Hainline

Transcribed by Denny Henke

Ben: Over the course of my studies in theoretical physics I've traveled across the continent and around the world sampling new ideas and tasting different answers to the questions of how and why. And still I find there remains a deep hunger which lives within me, a burning desire to share these great ideas with the people around me. And so, I have assembled a team of some of the greatest, most lucid, most creative minds, I have encountered in my travels and I call them my Titanium Physicists. You're listening to the Titanium Physicists Podcast and I'm Ben Tippett. And now allez physique!

[1:30]

Ben: To preface this show, I want to tell you about two goddesses. There's Eris, the goddess of strife from Greek mythology and there's Sedna, the goddess of the sea animals from Inuit mythology. All of you, I'm sure, have heard of Eris, she was the goddess who was not invited to the wedding of Peleus and Thetis because she was a jerk. This got her nose out of joint and to spite everyone involved she showed up at the wedding feast and tossed an Apple made of gold onto the table. The Apple was inscribed with the words: "For the most beautiful one." And immediately the goddesses Hera, Athena, and Aphrodite started fighting over it. So, the net result was the Trojan war. You might not have heard of Sedna before though. She's the goddess who was responsible for seals and walruses and whales and stuff in Inuit mythology. There are many stories but they all have kind of similar plot point. One goes that she was an orphan and the villagers wanted to get rid of her so they took her out in a kayak and threw her overboard. The little girl held on to the side of the kayak to keep from drowning so they cut off her fingers. And each of her fingers became a type of sea life, they all became some type of seal and then she sank to the bottom of the ocean to rule of all sea life. And sometimes Sedna gets mad and doesn't release the seals for us to kill and we have to send someone to go wash her hair. She can't wash her own hair because she doesn't have fingers. But, if the villagers manage to appease Sedna's spite she'll send us some seals to eat and we won't starve. So, if memory serves it was about 2005 when I was a masters student in the astrophysics group at Queens University. Astronomy news had made the headlines so we were all called together for a meeting and that's where they broke the news to us that our solar system's family of planets was going to loose a member. You see, Pluto, the outer most planet in our solar system, it turns out that it wasn't a planet anymore. They'd discovered another planet thing further out, a couple of them, actually. There was one eventually named Eris, the goddess of discord and it was heavier than Pluto and then there was another object even farther out named Sedna after the lonely Inuit goddess of sea life. Now the discovery of these planet things meant that Pluto couldn't be in our family of planets anymore. They explained to us that Pluto had it's own family to belong in. The dwarf planets of the Kuiper Belt. It's not because of anything we did, it's just that as time goes on new information comes to light and sometimes things change. I guess it's ironic that celestial objects that broke up our family are named after goddesses known for being spiteful and lonely . Today, on the Titanium Physicists podcast we're going to talk about this massive family of objects, the dwarf planets of the Kuiper Belt. Our guests today are the incomparable Keith Hayward and Max Wellenstein. Keith is from the Henshin Justice Unlimited Podcast. The HJU Podcast is concerned with talking about Japanese Tokusatsu TV shows in English. So they talk about Kamen Rider, they talk about Ultraman, they talk about Super Sentai shows and Power Rangers and every other nerdy thing they can think of. Alright my guests, arise Keith Justice!! And Arise Max Overdrive!! Haaaahaaahaaa! Thank you for coming on today gentlemen.

Keith and Max: Thanks for having us.

Ben: I'm really excited. I'm so excited that I've gathered two of my most spectacular Titanium Physicists. Arise Dr. Sean Moran!

Sean: Waka, Waka, Waka.

Ben: Haha! Dr. Sean did his PhD in astrophysics at CalTech and is currently a postdoc at Johns Hopkins University in Baltimore, Maryland. He's an observational astronomer who looks at galaxy evolution. Now, arise Dr. Laura Hainline!

Laura: Mi, mi, mi, mi.

Ben: Hahahahaaaa! Dr. Laura did her PhD in astronomy at CalTech as well, and she's currently working as a postdoc at the United States Naval Academy. She studies accretion disks around black holes.

Alright everybody, let's talk about these dwarf planets. Okay, Laura, what constitutes a dwarf planet in the Kuiper Belt?

Laura: Well, a dwarf planet in the Kuiper Belt is going to be similar to a dwarf planet anywhere else in the solar system. It's smaller than what we call the major planets which would be Mercury, Venus, Earth, Mars, Jupiter... But they're smaller in size and smaller in diameter, there's less mass. And a dwarf planet is one which the International Astronomy Union has decided has not cleared out it's orbit around the Sun, of other objects.

Sean: So, there's sort of cruft around it still that hasn't been sucked up into, basically, aggregated onto the planet.

Laura: Right.

Max: So to be a real planet you don't have debris in your way?

Laura: Exactly. So, the Earth, we don't have much in the way of debris of significant size, in our orbit around the sun.

Sean: For example, everybody knows that there is an asteroid belt but there's one of these minor planets that's actually in the asteroid belt. The largest asteroid, I believe, Ceres, has been called under this new definition a minor planet. And it's because it's really quite large but it's not large enough to have cleared out the asteroid belt, it's still sort of in the asteroid belt and there's still all this other stuff around.

[6:26]

Keith: Can I ask how big these are, compared to say, our moon?

Laura: They're fairly similar in size, actually. So, I think the moon is about a quarter the size of the earth in radius.

Sean: Yeah, I think that's right. And many of these other minor planets out there are around the size of the moon.

Laura: Yeah.

Keith: Okay, so most of them are large enough for their own gravity has made them a sphere, you know, spherical, but not...

Sean: But they're not so big that they can clear everything else out around them.

Max: And Pluto has all sorts of debris in its orbit then, right?

Sean: Yes. In fact, Pluto is in the midst of this so called Kuiper Belt. There's a lot of debris out around Pluto and that was one of the arguments for making this new definition is because we have, it turns out, a lot of these things that are about the same size as Pluto but they tend to be in one of these belts where there's all sorts of stuff around them.

Laura: Hundreds of them, in fact, share an orbit with Pluto around the sun. They have, basically the same distance from the sun and the same orbital period. So, Pluto, definitely has not cleared out it's orbit.

Keith: So, I have always been fascinated by the different belts out there. It's interesting to me anyway that they haven't coalesced into a reasonably large sized planet yet. You know, they're just a bunch of debris knocking about in their, it's not gathering up, is the expectation that in a couple billion years from now these will accrue into something larger or is it just going to keep breaking down into ever smaller debris?

Laura: No, so, with the asteroid belt and the Kuiper belt, it's two slightly different scenarios. What we think happened in the case of the asteroid belt was that Jupiter is so massive that gravitationally it exerts an influence on all the objects in the asteroid belt and keeps them from coming together so they won't ever come together. And, the Kuiper Belt, I believe it's partly that they're so far away from the sun, based on the amount of sunlight that they receive, the temperature that they can have on their surfaces is so low that material can't condense into larger objects and they're not going to continue to grow but they might continue to get smaller because there are so many of these smaller bodies that they share an orbit with that they could collide with another object in the belt and loose a significant portion of their mass. So, that might happen, we don't know.

Sean: But that would be a very slow process.

Laura: Yes, over millions of years.

Sean: They're actually quite stable now. They do think though that in the past near the beginning of the solar system there was actually a lot more material out there and what we see now is just sort of the last remnants of what there was that either wasn't sucked in or blown out billions of years ago. So, just sort of the debris that's left, you add up all the mass out there and they think it adds up to much less than the size of the earth but once there might have been quite a bit more out there.

Keith: So, we're not, like, observing Pluto and Charon taking regular hits and loosing chunks.

Laura: No.

Keith: Okay.

Laura: No. The expectation is that something like Pluto would be in a collision with something else once in a billion years kind of deal. Maybe not a billion, it's actually probably a smaller time scale that but it's on order of millions or many millions of years.

Keith: Wow, cool. Thank you.

Max: Is it okay for like, normal people to still consider Pluto a planet, does that confuse anything or...

Keith: No, Pluto is a jerk.

Laughter:

Max: Well, it's always been there for us.

Sean: I understand why people might want to continue to call it a planet.

Laura: It's not a planet! There are so many other objects that are like it. It's not a planet.

Sean: It's not but in its defense and I'm not condoning this argument necessarily because the scientific consensus has been set. But if you want to argue that Pluto is still unique and say well, it was discovered 80 years before any of these other objects, it was the brightest and most prominent in the sky and it sort of holds a special place in its own way even though, by the numbers, it's not really any different from the other things that we've found out there more recently.

Keith: So, Pluto would be the first loser of the dwarf planets, would that be...

Sean: Yes.

Max: First winner of the dwarf planets because it was there first. I wasn't questioning why it got demoted until now. So, I guess the reason is because there are other planetary bodies out there like it so if we do say that it's still a planet then we have like 18 planets in our solar system?

Laura and Sean: Exactly.

Sean: If Pluto is still a planet then technically Eris should be a planet and Ceres the asteroid should be a planet and maybe a few others.

Laura: We'd end up with a lot of extra planets that we're not so sure it really works for them.

Max: Gotchya. Pluto's still cool by me though.

Laughter.

Ben: So, earlier we mentioned how Pluto was discovered. It's interesting how we observe these dwarf planets.

Sean: Yeah, it's really interesting because in a lot of ways we're still discovering these, sort of the old fashioned way. What we do to discover them is not so different from what was done to discover Pluto the first time. Back in the 30s what Clyde Tombaugh did was basically take a photographic image of the sky and another one a little bit later and he had this machinery that would blink the two back and forth so he could look at one quickly and then look at the other and he was just like, you know, searing his eyeballs out looking for things that moved from one image to the other. It would march across the sky a little bit at a time.

[11:29]

Laura: Look at hundreds and hundreds of these images.

Sean: Until he found something and it was a Eureka! moment. But it's taken a long time to find more things out there partly because that sort of thing is really time consuming. But, what's allowed us to find all these things much more recently, has been the fact that today, now we can take big digital images with lots of pixels with wide fields of view on the sky with our modern telescopes and modern digital cameras stuck to the back of them and then we can plug them into modern computers where we can say, okay, these two images and find me the things that are different between them so you can have the computer highlight everything that's changed from one image to the next and then you just have to go aha! That looks like, maybe an image artifact or this is a, something we already know exists or aha, this is something new then we can mark those and then we can go back and study them further.

Laura: And actually, some websites, Wikipedia even has one where they show you the sequence of images over time of a particular star field. So, the stars are so far away that they shouldn't move in between any of the different images but these dwarf planets, they're so much closer and moving so much faster that we can observe their motion over the time difference between the two images that are taken. This would also be true for asteroids. And there are little animations, they flash one image up against the next and you can see a little spot moving.

Keith: How much of that is automated now?

Sean: It's sort of semi-automated. I think somebody still has to look at the candidates that the computer identifies to make sure, for example that it's not just an image artifact. But then, so the tricky thing is that, you find these moving objects in your images and the computer can do all this stuff, but the trick is finding it again the next night or a week later or a month later. You have to be clever because you see these things that are moving a bit on your image, but if they are moving, if you just get, you know, two snapshots you might not know exactly where to look for it again if you come back later. So, these things have to be processed fairly fast and ah, you need to observe them again on a short time scale, you know, a day or a couple days later. Take a shot where you think it must be in the sky and if you see it again then you get a better idea of what the actual orbit of this thing is. Where it's moving, what direction it's moving across the sky and that sort of what you really need to figure out where these things are.

Keith: Do you need like three solid positions to nail these down or is it more than that?

Sean: It's at least three. I think they can do okay with predicting where they're going to see it next with three, or maybe four. But ideally you get a more and more accurate orbit as you observe them more and more times over the course of say, even a few months or a year.

Ben: Why don't we talk about the anatomy of the solar system. So we get a sense scale and also kind of what regions we're talking about, right?

Laura: Okay.

Ben: So, first there's the sun and then there are planets from the sun to Jupiter. And then there are the super big planets: Jupiter, Saturn, Uranus, Neptune. And then out past Neptune is the Kuiper belt and the Kuiper belt goes from about Pluto's orbit to about three times Pluto's orbit.

Sean: Yeah, that's about twice Pluto's orbit. And there's some tenuous stuff even further out.

Ben: And then past that is the Oort Cloud.

Laura: Yeah, the Oort Cloud is way out there.

Sean: Which is interesting because that's one of those things that we think exists because we see comets that look like they're coming from way out there but we've never actually detected anything that far out yet. So, the Oort Cloud is still theoretical in a sense.

Laura: There's a whole family of comets, they are called long period comets. They come near the sun...

Sean: But they come once and then disappear for a really long time.

Laura: ... In maybe a thousands of years kind of thing and the only way we can explain those is by having this hypothetical Oort Cloud of material that they come from. There are also short period comets like Halley's Comet, I think is a short period comet, of all the ones we know of.

Sean: And in fact the short period comets are thought to have been scattered inward toward the sun out of this Kuiper belt, out of this area where Pluto currently resides.

Max: So the Oort Cloud is ah just most likely but it could be like a crystalline entity that you see in Star Trek. Out there like...

Laughter

Max: Every so often just throwing snowballs and going ah, this is so boring.

Laura: Yeah, kind of.

Max: Awesome.

Sean: As far as we know.

Keith: So, what would be needed to confirm the existence of the Oort Cloud?

Laura: That's tough. I think that's part of the reason it hasn't been done yet.

Sean: In some sense, doing more of the same that they are doing with the Kuiper belt. They are doing deep surveys and surveys that cover more of the sky at once. Recently there's a survey called Pan-STARRS that just keeps going over the same several patches of sky every few nights and they've discovered tons of...

[16:17]

Laura: The problem is, I mean, too, is that comets are very small relative to the Kuiper Belt Objects. And they would be very hard to detect, they'd just be very faint.

Sean: Right, well I guess you'd hope that there'd be some larger objects out there like the Kuiper Belt which produces some short period comets and has these bigger things.

Laura: Yeah, but they're small and they're far away which would make them hard to detect, anyway.

Sean: Right.

Max: Is the Oort Cloud just a body orbiting our solar system or is it one of those things that encases the solar system.

Sean: You know, it's like the asteroid belt or the Kuiper Belt in that it's just a bunch of objects that are just somewhere out there. So there's no one thing called the Oort Cloud, I think it would just be this spray of debris that's just way out there that.

Laura: They are orbiting the sun though.

Sean: They are, yes

Keith: And is there any chance of Voyager might come across it.

Laura: Yeah.

Sean: But it's going to be actually, a very long time, because the Oort Cloud is, I think, probably...

Laura: A 100 AU I think.

Sean: Or, up to a 1,000 so I think it could be that Voyager, basically, could have 10 times further to go before it hits it.

Ben: The Pioneer Probes are out at 80 AU I think, right now.

Sean: Okay.

Ben: So, they're just past the edge of the Kuiper Belt and they're just kind of entering Oort Cloud territory. Um, so, there's two dwarf planets in my mind that are notable, one of which is the farthest out one, Sedna and the other which is the heaviest one, Eris. Because they're both interesting in their own right. Eris is the one they discovered that was heavier than Pluto that made everybody throw their hands up and say well I guess Pluto's not...

Laura: It's not just heavier than Pluto. They also thought it was larger than Pluto.

Sean: Diameter wise.

Laura: Diameter wise. But then, now, more recently they think it might be about the same size as Pluto. But it is more massive and we know that because it has a little moon. By observing the moon of Eris going around its parent then we can figure out the mass of Eris. So, that's how we know we are positive that it is more massive than Pluto.

Sean: But in fact that's the only way, ultimately, that we can figure out the masses of these things out there. By finding the ones that have little moons and measuring the orbit of the moon around it. It's very hard to figure out what these things out there are made of and how big they are, how massive they are. It's actually, it's quite tricky.

Max: Yeah, that's a question I have concerning these, this new club, of planets, the dwarf planets. Are they as varied in composition as are normal planets, are they all usually made of the same material.

Sean: Ah, there is some variation. It's hard to learn too much about them because unlike the big planets, where we can take an image, and we can see the atmosphere. The swirling clouds of Jupiter and the rings of Saturn. Ah, we really only seeing these things way out there as just sort of a point. Ah, so we can measure how bright they are, we can measure how bright they are at different colors and in the optical light and also in infrared light and we can find out some of the basic properties that way. But it's very hard to figure out the composition.

Laura; For those few Kuiper Belt Objects that had the moon where we could determine the mass, once we figure out what it's diameter is then we can calculate it's density. And that number can tell us a little bit about what it might be made out of. For example if it had a density similar to water or it was more like the density of rock or metal.

Sean: Yeah. So, it's basically how much of it is ice and how much of it is rock is basically how much we can tell. We know that from whatever density we measure but more detail than that is actually very tough.

Laura: And we can get an idea of what's on the surface. So, if it's bright enough we can use a spectrograph showing absorption lines from elements that are present on the surface of the dwarf planet. The problem is it's only the surface. We don't know what's underneath that immediate layer on the outside. So, on the earth, the earth's crust is a very thin layer relative to the interior of the earth which is, a lot of it is, there's molten rock, then at the very center there's this molten metal core. But we can find that out because we have ways of measuring that here on earth but we can't do that for something so far away. The only way we can get an idea is for the density but we can only get that for a few of them. So, it's pretty tough to know what they're made of. We can get an idea, like I said, from the spectra, we know they have a lot of ices. So, a lot of them have water ice and we see evidence for methane ices and ammonia and I think another one is ethane. We see a lot of ethane, also molecular nitrogen. So, all of these, which we think of usually in gas form, but here it's so cold that they are solid. So, we think that's a pretty common feature to the Kuiper Belt Objects. But that's honestly almost as much as we know.

Keith: Do most of these dwarf planets also have their own moon or, I was quite surprised to find out that Sedna has her own moon, that's, I thought that was kind of a more of a normal planet thing.

[21:21]

Sean: Well, most of these moons are very small, little rocks actually and when you are one of the largest things out in this Kuiper Belt then you have all this debris around you it's actually not too unlikely over the course of the last five billion years to have pulled in a companion.

Laura: Well, for example, Mars. Mars has two little moons that are very small and we think those are actually captured asteroids. So, some of these moons around the other dwarf planets in the Kuiper Belt are probably the equivalent of a captured asteroid. But also, the one difference is that Pluto's moon is quite large relative to the size of Pluto and that means Pluto's moon itself is pretty much a dwarf planet. They're like a binary planet as opposed to a planet and a moon.

Keith: So, what keeps some of the larger moons from being classified as dwarf planets like Titan or whatever. Is it because it's already under sway of another actual planet?

Laura: Yeah.

Sean: Yeah, that's just the technicality.

Laura: It's a technicality. In fact, I mean, we even think that one of Neptune's moons, Triton, may have been a Kuiper Belt Object and therefore would have been classified as a dwarf planet.

Sean: And in fact it is bigger than Pluto.

Laura: It's bigger than Pluto, yeah. It's a very odd moon because it orbits Neptune in the opposite direction from all of Neptune's other moons and that immediately...

Keith: That's weird.

Laura: It is really weird and we don't see that very often in the solar system. Almost never.

Sean: That was sort of a clue that it formed somewhere else and got hauled in as opposed to forming in place.

Laura: And because we sent, partly, I think, because we sent probes out there too we have some idea of what the density and surface composition of Triton. And I think it appears to be similar to the other Kuiper Belt Objects that we have information about. So, yeah, that's, it's a technicality, completely.

Keith: So if Triton had just, you know, stayed away from Neptune, Triton would have been the ninth planet, maybe Pluto would have been the tenth or it never would have been.

Laura: Yeah. But, yes, as you've pointed out, some of the classifications in our solar system are really just sort of semantics. I mean, they are historical too and it's hard to get away from history. And that was, even the case with Pluto, it was, a group of astronomers had to think for awhile to come up with criterion that defined a planet. Because it really was an incorrectly used term just as a moon is a sort of historically used term as well.

Sean: There was no technical definition of a planet until a couple years ago.

Laura: Yeah.

Sean: It was one those things, you know it when you see it.

Laura: Exactly.

Sean: Till we didn't anymore.

Keith: Alright, it seems like a pretty fine line now.

Laura: It is. Yeah, so Pluto's moon, I think, actually is, technically classified as a dwarf planet on it's own as opposed to the little teeny ones that go around Eris or Sedna.

Ben: Right, so, there's an interesting thing about Sedna which is that it actually doesn't have a moon. Eris has a moon and a few of the other ones I was reading about earlier have moons but there's mystery about Sedna which is that it doesn't have a moon but it's rotation, so, you know, planets rotate. They have day and night like the Earth does and most of them rotate fairly quickly like the Earth spins on it's axis every 24 hours, right? Generally, apparently, this is true with a lot of the planets in the solar system. But, Sedna rotates really slowly compared to everything else. And the only reason they can explain it rotating slowly is if it had a moon then the moon would steal some of that angular momentum and it would tidally lock Sedna's rotation. So, the moon would steal some of the rotational momentum of the dwarf planet and kind of move out in the orbit and this would slow Sedna down. And so, the only way to explain how slowly Sedna is rotating is if it has a moon. When they look for the moon there's no moon. So, that's a mystery.

Keith: So, could it's moon have been stolen? Like, yanked by some other passing body?

Sean: It's possible. Given that it's already in such a weird orbit, ah, we don't really know it's history, it's orbital history. Where it started from and how it got out to where it is now. But any sort of interaction that would have hauled the moon away, you would think that it would have also given it a kick to start spinning but I don't know enough about it to say whether it's impossible to have pulled the moon away without causing it to start rotating but...

Laura: One thing I was wondering is if it's tidally locked, I mean, it could be really close and we just haven't been able to separate it in an image, from Sedna. Because, as Sean said, we see these Kuiper Belt objects, as basically points of light, we don't see them as discs. We can't measure their size. In astronomy we call that unresolved. So, since it's unresolved it could also be mixed in with another smaller object that we simply just can't see. Maybe eventually when we can have a bigger telescope or one in space we could maybe get a clearer image and see if there's a small body near it.

Keith: Are there any thoughts or plans of maybe sending out another satellite to maybe take a closer look at these dwarf planets?

[26:25]

Laura: Yeah. It's on it's way, the New Horizon satellite is on it's way to Pluto as we speak. I think it's supposed to get out there in ah...

Sean: 2015 I think.

Laura: Yeah, 2015.

Sean: And they launched it in 2006 so it's a long trip but that's considered sort of an express trip as these things go.

Laura: But it's mission is to study the Kuiper Belt Objects, primarily Pluto.

Sean: But after it does Pluto it's going to try to rendezvous with one of these other smaller Kuiper Belt Objects out there so to hopefully learn a lot more about what these smaller things are made of out there.

Laura: This will hopefully fill in a lot of the gaps that we have.

Max: The New Horizon satellite, how do they pilot those things, is it some kind of remote control or is it... predetermined...

Laura: Yes, there's definitely, the Jet Propulsion Lab, they usually control a lot of these satellites by radio signals.

Sean: And they'll have small engines on board but really after it gets the initial launch out of Earth's orbit it's really small tweaks that they can do once they're out in space. It's almost a glide path where they send it out initially on the right trajectory, sort of slingshot around and get some gravitational boosts here and there and send it on it's way. But there's actually not that much...

Laura: Well, but they can communicate with it and activate the instruments...

Sean: Right and the engines to give it the right boost at the right amount of time but the actual amount of, like, fuel that they're using on the journey is quite low. Most of it is in the initial kick that they give it.

Keith: It's mostly like, just swing around, hey we want to look at this, turn left, turn right kind of thing rather than actually altering its trajectory much.

Laura: Yes. You can't alter it.

Sean: Because it's very hard, once it's going in a direction at a really high rate of speed it's pretty hard to...

Keith: There's no whoa, whoa, whoa turn around.

Laura: Well, the other thing is now it's also under the influence of the sun's gravity.

Keith: Sure.

Laura: Once it escapes from the Earth's gravity the sun is still there and they basically enter their own little orbit around the sun. And altering that orbit takes a lot of energy, more than usually the spacecraft has on board.

Max: It sounds quite amazing that, you're saying that, you know, once it does get out to Pluto and it does whatever it's going to do, observe this and that, do we have the technology to go, okay you're done there now we're going over here.

Sean: Yeah. I mean, it's going to have to be, you know, okay, what of these objects can we reach from where we are at Pluto? And you know, there's going to be some constraints, but they will be able to give it a nudge left or right to see if they can get it to rendezvous with one of these other things.

Max: Outstanding.

Keith: So, are we dependent on these long range satellites to take a peek at Kuiper Belt Objects and everything out there. Or, is it, you know, I'm always, like you see these amazing pictures come out of the Hubble and you hear a lot about Kepler and you know, eventually whenever the James Webb telescope is up, you know, is that something we can have pointed at in system objects or...

Sean: Actually, yeah.

Laura: Yeah.

Sean: I mean, we have with Hubble but it's still not really a substitute for going out there and taking a close-up shot of these things.

Laura: Yeah, the Hubble images of Pluto are very unimpressive. It just looks like, it well, it's more...

Sean: Little fuzzy disks.

Laura: Yeah, it looks like little fuzzy disks. So, really these long range satellites are going to be our best bet in the near term for getting a good picture of a Kuiper Belt Object. So one of the differences with the James Webb telescope is that it's going to have more of an infrared capability. So, Pluto is brighter in the infrared than it is in the optical. And the optical is the wavelength that Hubble operates in. So, Pluto will be brighter to James Webb but James Webb is...

Sean: But it's till going to be very small.

Laura: But it's till going to be very small so we may not be able to see much detail if any.

Keith: Okay. I've heard a comparison to if you're looking at an orange or a grapefruit from across the country.

Laura: Yeah, and at that level you probably can't even tell that it's orange.

Sean: Right.

Laura: At some point you loose color information. Hopefully the New Horizons probe will come back with some neat stuff. We just don't know what it's going to be yet.

Ben: So, this New Horizons, most of the energy that it gets on reaching the outer solar system, it will get by gravitationally slingshotting around the planets, right.

Sean: That's right.

Laura: Yeah.

Ben: So, in the procedure, essentially it's, they get really close to the planet and then they steal some of the planet's orbital momentum as it goes around the sun, it uses that momentum kick to project itself even further out into the solar system.

Sean: That's right.

Ben: And that's interesting because some of these Kuiper Belt Objects like ah Sedna specifically, there's no way the dwarf planet could form in terms of...

Laura: Yeah, it's too cold and...

Sean: Too far out.

Laura: Too far out.

Ben: And so it must have been flung out there by Neptune.

[30:58]

Sean: And in fact, it's really kind of a mess out there. The theory that people have come up with is actually pretty cool. The idea is that Neptune, in the early solar system, formed a little bit further in than it is now and it, for whatever reason, migrated outward and there was all this Kuiper Belt stuff out beyond it already including proto-Pluto and all this other stuff. What happened when Neptune migrated outward is that it started flinging some of these things outward onto these weird, longer, further out orbits that are maybe tilted at crazy angles. Ah, some of them got flung inward and some of those ended up becoming the comets that we see now and other populations of stuff in between the planets out there that were basically the result of Neptune flinging these things inward. And then, around where Pluto is, and in the main Kuiper Belt, that's the stuff that started out far enough out that it was relatively unaffected by Neptune. But there is this funny thing that Pluto was actually in what they call a resonate orbit with Neptune. It goes around the sun twice for every three orbits of Neptune. And that's kind of funny. What it is is that is an especially stable spot, it's almost a gravitational trap and there are a lot of other Kuiper Belt Objects that have fallen into this same trap. And the idea is that they maybe got swept up a little bit as Neptune was moving outward so you end up with sort of an over abundance of things in this nice little resonance with Neptune.

Laura: At the same time it's hard, because of this little trap, it's hard to kick them out of their trap as well.

Sean: Right. And the flip side is also true. There are some specific spots out in the Kuiper belt where there's gaps, there's, you don't see any objects at a particular distance and that's because that's a particularly unstable position because of the influence of Neptune. Neptune would kick anything out that occupied that spot.

Ben: So, the reason there are all these weird Kuiper Belt Objects, in essence, is because a long time ago, Neptune went and threw all these small dwarf planets way out into the Kuiper Belt.

Sean: Yes. Sedna included, maybe. Sedna is so far out there that it's not clear, I think, if Neptune could be responsible for kicking it out.

Ben: And there's only a few kind of orbits in the solar system that one of these dwarf planets can have, one of these resonate orbits. Where it will be safe from Neptune's influence.

Sean: Right.

Ben: And we see all of these dwarf planets piled in these few safe orbits.

Sean: There's less of a problem for the ones that are really far out that are not really affected by Neptune. They can be in any orbit. But as you get closer into Neptune you start to see it's imprint more and more in the orbits of these things that are close to it.

Ben: Well, that was a wonderful, interesting trip around the solar system. Hahaaaa! So, thank you Laura, thank you Sean, you've pleased me. Your efforts have born fruit and that fruit is sweet. Here's some fruit Sean. You get a jack fruit.

Sean: Mmmmmmmm. Nom nom.

Ben: Ahhhh. Good. And Laura, here is a peach.

Laura: Crazy sucking sound.

Ben: Gross! Cut it and chew it or something!?

Laughter.

Ben: Okay, so, Keith Justice, Max Overdrive, you've done very well. I hope you had a nice time on my show.

Keith: Aw, thanks very much. It's been fantastic.

Max: Most definitely, thanks for having us.

Ben: Ah, so, everybody, tune in to Keith's podcast, Henshin Justice Unlimited. Go to his website, HenshinJustice.com. Alright, so if you would like to email us you can do so at barn@titaniumphysics.com or you can follow us on Twitter at @titaniumphysics. You can visit our website at www.titaniumphysics.com or you can look for us on the Facebook.

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[36:38]

Laura: So, I want to say in *Star Wars*, you know how they have the, they go into the asteroid field, and I want to say this is the *Empire Strikes Back*.

Sean: Yeah. Han Solo is navigating them through.

Crosstalk.

Laura: Yeah. The real asteroid field and the Kuiper Belt, it's not nearly that dense. The bodies in the belt are really much further apart. So you could navigate through it probably with no problem if you were on a Millenium Falcon sized spaceship.

Max: The universe is a pretty big place so there's got to be some asteroids out there that are that close.

Laughter and cross talk.

Laura: Yeah, I, statistically, yes.

Laughter.

Sean: But they won't last that long because, as we saw in *Star Wars*, they were grinding into each other quite a bit and get pulverized pretty quickly.

Keith: So, you gotta take your small tramp freighter out to a very young system in order to do some asteroid dodging like that?

Laura: Yeah.

Ben: Or one that had a planet that just got destroyed by a planet-sized battle station.

Laughter.

Max: I guess one of the questions I had was ah, is it possible that we definitely do not have another Jupiter just hanging out in between the planets that nobody's seen yet because everybody's been looking someplace else. Do you guys know where the Jupiter-sized planet myth came from?

Sean: Yeah, well, so, that goes all the way back to the discovery of Pluto. And way back then it seemed to be that the orbit of Neptune which was known at the time, seemed to be not quite right. There was a little bit of deviation in its orbit and it was the sort of deviation you might expect if there was some other massive object even further out that was sort of tugging on Neptune. So, that's sort of what spurred people to look for this sort of Planet X way out there and it's what ended up driving this discovery of Pluto. Pluto turned out to be much, much too small to be causing this tug on Neptune. In fact, Neptune is much bigger than that and so it ends up Neptune has a big influence on Pluto, not the other way around. So, for all the decades since there's sort of still been this residual dream that keeps popping up that maybe there is still something further out there that we haven't seen yet. If we didn't catch it with Pluto maybe there's other stuff out there. But I think at this point it's been pretty much ruled out that there's anything bigger or nearer the size of Jupiter, that far out. All of the main planets of the solar system sort of orbit around the sun in sort of the same plane. So, it is true that a lot of these surveys have focused, looking for other unknown objects in the same plane that all the other, but there have now been a bunch of surveys that look above and below the plane and look all around the sky. And I think something the size of Jupiter would just be so bright, even if it were far out that it would have easily been detected, even accidentally, by now.

Max: Yeah, that's something I've been wondering about. Has our solar system evolved far enough that there wouldn't be other planets not on our celestial plane. Are we old enough that that's not possible or is that still possible that there's maybe a planet underneath the usual plane that we're used to looking at.

Keith: Like a wandering planet that's you know, ejected from another solar system, comes in on a different axis and get's captured in our system?

Sean: Ah, it's probably not to do with objects being in a different plane. It's possible that the sun could have captured some object in a different plane and in fact some of these smaller Kuiper Belt Objects do orbit in funny planes, even Pluto has a bit of tilt to it sort of. And Sedna that we mentioned, at the beginning is actually very far out there and it has a very funny orbit that isn't exactly fully explained yet. There doesn't seem to be all that many other things like Sedna way out as far as it is in such a funny orbit. So, that is a bit of a mystery. But, if there were something as big as Jupiter, even way out there, captured onto a funny orbit it, would still be pretty obvious to us at this point. There's no planet that's currently forming out of gas way out in the distant reaches of the solar system, we're much too old for that to have happened still.

Keith: Alright.

Laura: On the other hand, I mean, the odds of us capturing a planet from another star are still pretty low. Partly because stars are really far apart from each other, relative to their size. So, there are many orders of magnitude further apart than their radii. So, the planet around another star would have to come pretty close to our sun in order to get captured and none of the stars nearby are likely to come that close to the sun. It could have happened but it's just the odds of it happening are pretty low. It could happen and I mean it does.

[41:24]

Sean: Back in the good old days at the start of the solar system when, you know, the sun was born in a cloud of gas and there were other stars nearby, that sort of interaction might happen from time to time. But, as the sun ages it sort of drifts away from this area where it was born in close with other stars and we're now very far away from our nearest neighbor so these sorts of interactions are very unlikely now.

Keith: So, the two Voyager probes, one of them is on the cusp of the end of the solar system...

Laura: Yep.

Keith: Is that where we run out of all solar material, like all material from our system? And, there's no chance of running into objects until you get to the next area of Suns area influence? Is that kinda how it goes?

Laura: Sort of. I mean, so, there are, if you're talking about large objects, the answer is, perhaps, yes. In the, but there is still going to be gas and dust in between the stars. Maybe very, in the case of the solar neighborhood...

Sean: Very tenuous but it's there.

Laura: Yeah. In the case of the area around the sun there is not a lot of, it's very very low density hydrogen and helium that's in between the stars but there's still a little bit. So, it will, the probe will encounter that.

Keith: I was listening to your dark matter podcast and it mentioned, for the first time I've ever thought about that, dark matter might be actually just a whole bunch of non-ignited Jupiters out there. I mean, has that been...

Laura: That's one of the theories and the problem with the dark matter is that we can't detect it. We can't see it so if it's in between the stars, if it's in between stars we don't know.

Sean: But that theory has been mostly, it's at least disfavored now, it's been mostly ruled out, ah, by some other measurements, a lot of different measurements, in fact. But there was one, there was a survey that looked directly for that sort of thing, by just basically staring at fields of stars for awhile and counting how many times they might have seen one of these dark things pass in front of a star. So, you can get, actually, some pretty good limits if you just sort of stare out into space long enough and hope you might catch something passing in front of another star. Ah, and the amount of stuff, dark stuff out there that they calculated seemed to be not enough to explain dark matter.

Keith: Huh, okay.

Max: So, there more than likely aren't more millions of Jupiters, just rogue planets flying around, making their own planetary systems of Jupiters that we could possibly find?

Laura: As far as we know, that seems like no.

Sean: There's probably some stuff out there but it's not going to be stuff that we're likely to encounter. It's going to be pretty rare.

Laura: Space is pretty big. That's the thing to go with.

Laughter.

Laura: There's just a lot of room out there.