Episode 5: The Dunes of Titan
Physicists: Charlie Barnhart, Catherine Neish

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!

[1:49]

So, Titan is cool. It's Saturn's largest moon. It's 97° Kelvin, that's about -200° Celsius. It's essentially a big ball of ice floating around a giant planet in the middle of the solar system. But it's got lakes of liquid hydrocarbon and it's got an atmosphere and it's got dry river beds and it's got dunes and lakes and robots. And hey you know what else has these things? Earth. And you know what else has these things? Mars. So, today we're going to explore how such dissimilar planetary bodies can have such similar features. Okay, today my guest is Mr. Ryan North. He's a professional web comic artist, writer and duke of the Internet. He writes dinosaur comics at quantz.com. Hello master North, welcome back to the show.

Ryan: Thank you very much for having me me back.

Ben: This is Ryan's second appearance and he's got a newish book out, *Dinosaur Comics: Everybody Knows Failure is Just Success Rounded Down.* He also just wrote the *Adventure Time* comic book. How'd that go?

Ryan: Ah, good. I mean, the first issue comes out in February so we'll see then if I managed to do a good job.

Ben: Fantastic! So Ryan, because your comics and writing are out of this world I have assembled today a panel of two of my favorite planetary Titanium Physicists. Arise Dr. Catherine Neish!

Catherine: I have arisen.

Ben: Fantastic. Dr. Catherine did her undergraduate at UBC with me and her PhD at the University of Arizona in planetary science. She's currently at the John's Hopkins University Applied Physics Laboratory. And now, arise Dr. Charlie Barnhart!

Charlie: zzzzzzwwwwwwwwhhhhhhhiiiiiit! Hello world.

Ben: Dr. Charlie did his undergraduate at the University of Washington in Seattle in physics and astronomy and his PhD at the University of Santa Cruz. He's currently a postdoc at Stanford working for the Global Climate and Energy Project. Charlie's also on the hit science podcast, Science Sort of with me.

Charlie: Hear, Hear.

Ben: Awesome, Charlie. So, today's topic is Titan and Mars and why they look like Earth. So, let's start talking about Titan because nobody talks about Titan enough.

Catherine: Titan is one of the most interesting places in the solar system and I would argue that it is the most Earth-like planet in the solar system. Other than the Earth itself of course. Titan is the largest satellite of Saturn, actually it's the second largest moon in the solar system. It's bigger than Mercury. If it didn't happen to orbit Saturn it would probably be called a planet in it's own right. It has a huge atmosphere. It's the only moon with a substantial atmosphere. It's atmosphere is actually larger than the Earth's with 50% higher pressure at it's surface than we have on the Earth. And what makes it like the Earth, well, it's got this large atmosphere made of nitrogen, just like the Earth does. It has lakes filled with liquid. It has streams and sand dunes and mountains and volcanoes, maybe. All these things that we see on Earth. But it's, it's like a bizzaro Earth. Where, instead of having rock made of silicates, the rock is ice. It appears to be a large ice ball and instead of having water flowing over the surface it's liquid methane and liquid ethane. So, oil, oil is flowing over ice and making all these features that we see on the Earth. So, we really didn't know a whole ton about Titan until actually pretty recently. We've never seen the surface of Titan until 2004. That was only seven years ago when the Cassini orbiter arrived at Saturn and started taking pictures. And what Cassini had that no other spacecraft had had before it is a radar. And so what this can do is it can peer through Titan's big hazy atmosphere to see the surface which had never been seen before because Titan actually has a whole bunch of organic gunk in its atmosphere. Along with that nitrogen is methane and that methane reacts with sunlight and with other charged particles to create this gunk that sits in the atmosphere obscuring the surface and eventually rains down onto the surface to make the streams and the lakes that I was telling you about earlier. And, in addition to Cassini which is still orbiting Saturn, knock on wood it's doing quite well, there's also a robot that landed on Titan in 2005 called Huygens after the guy who discovered Titan so many years ago. And Huygens is the farthest planetary probe that humans have ever placed on another object. And it descended through Titan's atmosphere, took a bunch of readings and then eventually landed. And staid on the surface of Titan for several hours before it eventually froze to death. But, we learned a lot about Titan from those few hours that we're still analyzing today. We're hoping to send another spacecraft to Titan. It's called the Titan Mare Explorer. It's currently in the running for NASA's next Discovery mission and the idea of this mission would be to send a boat to Titan. It's the first extraterrestrial boat which would land in one of Titan's polar lakes and take measurements of the lake composition, how deep the lakes are, what the weather is like on Titan, whether we should build our next beach resort there. So, that's Titan in a nutshell.

Ryan: Can I, can I ask some questions?

Catherine: Yeah, please, I was hoping somebody would break in there.

Ryan: Okay. So, this is going to make me sound really dumb but you said there was oil on the surface but I was under the impression that oil came from dinosaurs.

[6:46]

Catherine: Yeah, it's ah, it's a different type of oil. It's ah, I guess a more pure form of oil, it's made of methane and ethane. So, methane is carbon with four hydrogens and ethane is two carbons with six hydrogens. And we think that Titan just formed with these elements and when it formed 4.5 billion years ago it condensed with these molecules that at earth are really, really volatile. They'll evaporate really quickly. And so, since it's so cold out at Saturn you can condense with these more volatile elements.

Ryan: Right, so there's been the two space craft that have gone around and visited this moon. Only two, right?

Catherine: Well, there were the Voyager spacecraft.

Ryan: Right, but they sort of wiz by and said hi.

Catherine: Yes, they did wiz by.

Ryan: So, isn't it possible that the oil could be from dinosaurs and we don't have evidence for that yet.

Catherine: It's true that we have, we don't know that there weren't dinosaurs on Titan.

Laughter.

Ryan: And you say you have a PhD?

Laughter.

Catherine: Um, it's sort of, it's one of those unknowables, right, whether or not there were dinosaurs on Titan is not really a testable hypothesis...

Ryan: Sure it is.

Catherine: ... and I would argue it's not science. Okay, okay.

Ryan: It's testable. I mean, I don't want to go around saying, like putting a quote to your name that says "Oil on Titan came from dinosaurs." But it sounds like that's what you're saying. At least it's possible.

Catherine: Sure. Anything's possible, right? We just, the thing about science is we have to find a way to test that, so.

Ryan: Right, well, I mean, I was listening to our introductions and it was like here are these great people who have accomplished so much in their life and have all these degrees and here's Ryan who's written some comics. And so, what I'm trying to do is ruin these two careers...

Laughter.

Ryan: by dragging you down to my level and...

Catherine: Well, actually

Ryan: Making you seriously argue that there were dinosaurs on or not on Titan.

Catherine: People do argue that there was life on Titan. It would have to be a very different life from the life we have on earth.

Ryan: Life, but not as we know it?

Catherine: Life, but not as we know it. Yeah, and so one of the things that this new spacecraft is entrusted in looking for are strange...

Ryan: The boat?

Catherine: The boat, yeah. Are strange organic molecules we can't explain by inorganic processes alone.

Ryan: Right. That would be amazing.

Catherine: Yeah, it would be really hard to detect. Detecting life in the solar system, even if it exists, is going to be really hard to do. Because we're really good at looking for things that are like us and we're really bad at looking for things that aren't like us. So, if we do find something it might just be us. You know? And if we don't find it, it doesn't to mean it's not there, it just means we don't know how to look for it.

Ryan: Ahh, so, this boat. You say a boat and I worry that it's just the dumbing it down language where it's not going to be a boat coming in on a parachute but something that is analogous to a boat but not actually, you know, a motor out back.

Catherine: It's, I like to compare it to Huygens which is the spacecraft that landed on Titan in 2005. But, now we know where to put Huygens, we know where the lakes are now. When Huygens landed we had no idea where it was landing. We thought Titan might be entirely covered in liquid. There was a huge, planet wide ocean of ethane. We know now that's not the case. Now we know where the lakes are and so now we know where to put the boat. If we were to do Huygens with the information we have now we would put it in the lake. So, it's like Huygens in a lake.

Ryan: So, we just got lucky that Huygens didn't hit the lake and sink.

Catherine: Actually, it was designed to land in liquid.

Ryan: Really?

Catherine: So, I guess it depends on what you think is luck. Maybe it was unlucky in that we didn't land in the lake.

Ryan: Could it have done different things if it had been water born.

Catherine: Well, the liquid is not water, it's hydrocarbons.

Ryan: Well, yeah, I meant metaphorically water.

Catherine: Sure, sure. Yeah, actually...

Ryan: You need to change your language for this.

Laughter.

Ryan: Had it been ethane born...

Catherine: Ethane born, yeah. It did have the, it had a sonar on it that could have detected the lake bottom. So, it had a couple of instruments on board that were meant to be submersed in water that just never got used because...

Charlie: Didn't it have an accelerometer so it could test wave periodicity and ascertain wind speed and things of that nature.

Catherine: Every spacecraft has an accelerometer so and yeah, you can back out that information.

Ryan: Did you say every spacecraft has an accelerometer?

Catherine: Well, yeah, most of them do. Landers usually do.

Ryan: That's awesome. I just love that, please, every spacecraft has an accelerometer.

Laughter.

Charlie: Yeah, I was like, oh I'll shut up now.

Laughter.

Ryan: Obviously. A Wii remote has an accelerometer.

Catherine: You need to know when you've landed right, you want to know when you've hit the surface so you need an accelerometer.

Charlie: Obviously.

Ryan: Alright. So, I'm with you so far.

Catherine: People like to call Titan, you know, it's very earth like but we were talking earlier and um Charlie was arguing that, what was it, that Mars was the most earth-like planet in the solar system.

Charlie: No, I said Earth was the most Mars like planet.

Catherine: There ya go.

Ryan: Ooooh. What do you mean by that?

Charlie: Because Mars has many features that Earth has but Earth has many features that Mars does not have. So, it's the comparison from Earth to Mars is more direct than comparing Mars to Earth. What I'm trying to say is they're both silicate bodies with evidence of geomorphic activity, water carved features, dry lake beds, mountains, volcanoes, all sorts of things in common. But then Earth has other things like cats and YouTube that Mars does not have.
[11:42]

Ryan: Cats and Youtube being the two distinguishing features of the two planets.

Charlie: Exactly.

Ryan: So far, I'm more inclined to go with your side, Charlie. Because Catherine's direction was you know, talking about how planets are similar using language in this really, ah, subtle way, like, oh yeah they both have lakes full of liquid.

Catherine: Well yeah but it's the only place with liquid.

Charlie: What's interesting about Titan...

Cross talk and laughter.

Ryan: Is it the only place in the solar system with liquid?

Catherine: Other than Earth. Unless you count liquid hydrogen and then Jupiter has that.

Ryan: Isn't there some frozen ice found on the polar...

Catherine: It's frozen.

Ryan: Well, that's a form of liquid. The solid form.

Laughter. Crosstalk.

Charlie: And Mars has liquid deep underground.

Catherine: But not on the surface.

Charlie: So, I think a more precise way to say it is they have an active cycle in which a compound exhibits itself in three different phases: solid, liquid and gas.

Catherine: Although it might not actually be solid on Titan - it might not get cold enough for there to be solid methane or ethane. Right now. But it is close to the triple point.

Charlie: Sure it get's cold enough up in the atmosphere.

Ben: So, does it snow methane?

Catherine: Oh, so, you're saying in higher up in the atmosphere it's frozen out. Yeah, I'm not sure if that's where the methane precipitates though. I think it's lower down in the atmosphere where it would be liquid.

Charlie: So, on Earth it's interesting because we fill wine bottles up with hydrocarbons to make Molotov cocktails. On Titan you would fill a bottle up with oxygen and then chuck it's at the hydrocarbons.

Catherine: Right. So, actually there was this really funny letter to *Nature* a while back. This guy was really, really concerned about sending Huygens to land on Titan because there's tons of acetylene there and acetylene is really explosive on Earth. And he was like if you land this spacecraft on Titan the whole moon is going to blow up. Of course, that's not the case because plenty of things are impacting Titan all the time and there's also no oxygen there so...

Charlie: So, for the combustion reaction to occur you need a hydrocarbon plus oxygen equals CO_2 and water and plus oxygen is missing.

Catherine: Totally missing, yeah, there's very little oxygen on Titan except in the form of frozen water ice.

Ryan: So, if you have a canister full of oxygen on Titan you've got a bomb if you just chuck it?

Charlie: Exactly.

Ryan: So, if you had a base on Titan there'd always be danger of getting a leak and a spark and the whole base explodes.

Catherine: Well, that's why you add nitrogen, right.

Ryan: Well, I mean, we'd want to learn that lesson the hard way.

Catherine: I think we already did. It was called Apollo 1.

Ben: Oh, no.

Catherine: Ohh. Sad face. Sorry, I just brought the mood down.

Ryan: You brought actual death into this, instead of just cartoon explosions. Let's continue.

Laughter.

Ben: So, Catherine, why does Titan have, why are there so many hydrocarbons there? As opposed to, you know, here?

Catherine: So, I mean, it probably has something to do with the fact of where Titan originated in the solar system. Out where things like methane can condense and are stable and are not going to evaporate or sublimate away like they do in the inner solar system. But why Titan in particular has a huge atmosphere with methane in it, is sort of not well known. One idea is that the methane is, was trapped on the inside of Titan and is slowly leaking out over time. Because Titan actually shouldn't have as much methane as it does. The methane in Titan's atmosphere get's destroyed on the timescale of about 10 million years. So either we're just ridiculously lucky and happened to see Titan after it burped a bunch of methane or there is some process that's bringing methane out from the inside of Titan to the atmosphere. One of the early ideas for why Titan had so much methane in it's atmosphere, one way you could supply that methane would be from a huge ocean. That you had an ocean of ethane and methane and the methane would just sort of evaporate from this ocean, and, ah, supplement the atmosphere. But now we know the ocean doesn't exist so that's why people are now looking for new ways to explain how methane can stay in the atmosphere without disappearing over time. Because, when it reacts with the sunlight and with the other particles in space it turns into ethane and it turns into other heavier hydrocarbons that will turn into liquids and solids and fall onto the surface and just sit there. And since it loose the hydrogen to space there's no way to go back once you've made these higher order hydrocarbons. So, it's a current area of research, actually.

Ryan: Just to clarify a small point, is it the current consensus that Titan coalesced from the same accretion disk that the rest of the planets came from?

Catherine and Charlie: Yeah.

Ryan: So, why does it end up in orbit around this other planet instead of being a planet in it's own right?

Catherine: So, I think the idea is that each of the giant planets have their own sub-nebula, it's called. So, the sun had it's own planetary nebula when it was forming. But, one idea is that Jupiter and Saturn also had little nebulae and that's where they formed their moons.

Ryan: So, it's own mini-solar system.

Catherine: Mini-solar systems.

Charlie: Yeah, these nebulae were accreting from their own paths as they swept through the accretion disk of the solar system. And then there was an inner spiral where they were forming their own moons, turtles all the way down.

[16:43]

Ryan: Yeah, I didn't know that.

Ben: Okay, so, let's bring it back to the overall topic which is why the Earth and this weird moon around a gas giant and Mars all have similar features in their geomorphology. Yeah, why similar surface features? Okay, yeah, Why? So what are they? The common ones talked about are dunes. So, what's with the dunes on Titan?

Catherine: Dunes on Titan are not the dunes you might have seen on Earth. So, when I say sand dunes I mean something made out of micron-sized particles. Now, the composition of those particles can be anything you want. They could be made out of dinosaurs.

Laughter.

Catherine: For example. All that matters is their size. So, on Titan we have these sand sized particles made out of, presumably organic crud, that fell out of the sky whereas on Earth the sand sized particles are made out rocks that were churned up in oceans and rivers to make smaller particles. But the important part is how big they are.

Charlie: And their density.

Catherine: So they can be picked up and formed into sand dunes. If they are too heavy, they won't get picked up, if they are too light they won't induce other sand particles to hop and move forward to form these characteristic dune forms. So, there's this sort of sweet spot that you want to get at in terms of size. And there are tons of them on Titan. They form this belt, basically, around the equator. There's more organic crud in these sand dunes on Titan than there is the coal reserves on Earth. So, that's Titan. But on Mars, I guess, they are more similar to the dunes we have on the Earth except it's weird, right, because the atmosphere is so much smaller.

Charlie: Yeah, there's the idea that the particles are smaller as well. And the combination of higher wind speeds, reduced atmospheric viscosity, and lower gravity allow dunes to still form because there is a slightly different sweet spot. But, clearly they do form because we see pictures of them. And Mars actually forms these really cool dunes called barchan dunes which are these curved shield shaped dunes that actually self replicate because the tails of the dunes create wind conditions that make other barchan dunes behind them. There's great examples of them in the north polar regions of Mars and I think in Colorado and various parts of South America.

Ryan: Does Titan form barchan dunes?

Catherine: No. The only thing we've really seen on Titan, for sure, are lots and lots of linear dunes. Um which are actually relatively unusual on the earth. And they're formed by wind that goes in two alternating directions. So, if something's coming from the south and something's coming from the north and they alternate you'll get something going east/west and that's what we see on Titan. And you also see them, for example, there's huge, um, sand see in Namibia on the Atlantic coast that looks very similar to the dunes we see on Titan.

Charlie: What's interesting on Earth is the dunes are these very active features that change daily. If you watch dunes in the desert you can just see them forming and rolling over each other. Where, on Mars, we think they form really, really slowly and some of these dunes might just be petrified relics of past climate regimes. Do you know if they are actively forming on Titan?

Catherine: Again, not that we've seen. They might also be petrified relics, that would be a great discovery to see a moving dune on Titan. But we haven't seen that yet.

Ben: So, what other geomorphological features are there? Okay, so, ah, rivers. Why are there rivers? Well, there are rivers on earth because there is liquid water on Earth, right?

Charlie: Yeah, so it's potential energy if you have a mass of something higher than it could potentially fall then it has gravitational potential energy and it's going to move downhill unless something blocks it. Now, liquids occupy the shape of their containers so they are very good at moving downhill because they can zip around whatever things are blocking it. When they start moving downhill gravitational potential energy turns into kinetic energy and now it has momentum and so it can push things, it can carve things. It can move sand on Earth and Mars or ice on Titan and begin to carve channels. And once a channel is carved subsequent water or liquids will naturally flow towards that channel and the channel will carve deeper and deeper and these begin to form networks and so you get networks of channels and when they get deep enough they become streams and deeper yet they become rivers and eventually they may hit a very big, low lying area and form a lake.

Ben: So, are there rivers on Mars?

Charlie: There were. There were about 3.8, 3.6, 4 billion years ago, however you want to say it. There may have been several episodes of river formation in Mars' past. But yeah, there are huge, huge river networks. You know, rivers that are as long as the Nile.

Ryan: So, what happened to the rivers?

[21:29]

Charlie: Mars is a small planet, alas, so it has a lower gravitational field, it has less of a thing called a geo-dynamo, so it has less radioactive elements because it's smaller and so it can't keep a molten core which allows a magnetic field which prevents hydrodynamic escape and hydrogen loss from the top of the atmosphere. And the hydrogen loss leads to the separation of hydrogen from oxygen, which is water, and then the planet eventually drys up. And all the water is either lost or frozen.

Ben: So, does the earth's magnetic field help to retain the water?

Charlie: It does help. But two things help with Earth. It's higher gravitational field, so it's harder for things to escape from the earth. It's location in the solar system helps because water will not freeze out because we live in a place where temperature equilibrium allows water to be liquid And then three, the magnetic field that protects high energy gamma rays from entering the atmosphere and splitting hydrogen off of oxygen.

Ryan: So, Mars lost it's water and atmosphere you said, what, 4 billion years ago?

Charlie: It's not entirely known, but based on dating of the surface, and we date planetary surfaces by looking at how many impact craters are on them. Which is not the most elegant method but it's what we use and from that it appears that it's rare to find these very large fluvial water related, geomorphic features later than about 3.8, 3.6 billion years ago. There are other examples of simple channels being carved near volcanic features and gullies that are present in the very near past but these are very small and they're usually related to some subterranean phenomena, not something that was happening actively at the surface or in the atmosphere. They're not rain related, I guess is what I'm saying.

Ryan: So, how old is the planet itself?

Charlie: Ah, roughly the same age as the Earth which is 4.56 billion years, give or take based on radiometric dating of asteroids, meteors...

Ryan: So, the atmosphere didn't last very long.

Charlie: No, it didn't. And this is largely due to the fact that it's small so it didn't have a geo-dynamo to protect the atmosphere and less gravity to hug the atmosphere close.

Ryan: Right. Doesn't that make the chances of actually finding even microbial life on Mars pretty slim because this very small window to show up and do things in?

Charlie: Yeah, I mean, no one knows how long it takes for life to get started or form. So, maybe it was plenty of time. There's evidence of life on Earth going, roughly 3.9 billion year ago.

Catherine: Yeah, perhaps of water even before that. So life might start really quick and then if it can adapt and perhaps, you know, move to subterranean habitats. Perhaps there's still life on Mars in these underground reservoirs that it's moved into now that the surface is no longer habitable.

Charlie: There's some crazy ideas that because of Mars' smaller size it would have cooled more quickly than Earth and then thus been more conducive to life earlier than Earth would have been and so life could have taken root on Mars before it did on Earth.

Ryan: Hmmm. Well, should probably send some robots over and check it out.

Charlie: Yeah, we do, we keep on...

Catherine: Well, actually one its way as we speak.

Ryan: Are you serious? Right now?

Catherine: Yeah, Mars...

Charlie: About a week ago we shot one off.

Ben: So, earlier you were talking about how there's a difference between how the lakes form on Titan as how they form on Earth.

Catherine: Well, not a difference. We're just not sure how they form on Titan. The one idea is, using the Earth, actually, as an analog, we do this all the time. We look at things on the Earth and we look at other planets and we say hey, this thing looks a lot like this thing we see on earth. So, we're going to see if the same process happens on different planetary bodies. So, one process that happens on the Earth is called karstic lake formation. So, um, limestone is really soluble in water. So, if you take a big limestone formation and water is able to percolate through it, it will dissolve and form big caves underground. And then these caves tend to collapse forming big pits. And then water can fill in these pits to create karstic lakes. And so one idea is that perhaps the lakes we're seeing on Titan are formed through this process. Because they look an awful lot like karstic lakes on earth. But the question is, how is this happening on Titan? Because water ice does not seem to be soluble in ethane or methane. So you have to be dissolving something else. Ah, so, perhaps Titan has this huge layer of organic crud on the surface that is soluble in methane or ethane. So, maybe that's why we're seeing these features that look like karstic lakes on the Earth. So, it's not limestone and water, but maybe it's solid acetylene and methane that are forming karstic lakes on Titan. Same process, just different materials.

Ryan: Crazy.

Catherine: I know. I know.

Ben: So, at this point in time, yeah, do we, are there any other questions or topics you guys want to cover?

[26:33]

Charlie: Did you want to touch Lorenz's maximum entropy production? Well, one of my favorite planetary scientists is this guy named Ralph Lorenz. He produces very bold ideas that are very interesting. They may be right, they may be wrong but at any rate they are incredibly interesting. And so, he wrote this paper, I forget the exact title but it's something like Maximum Entropy Production on Earth, Mars, and Titan? And so he looked at the temperature gradients as a function of latitude. So, what's the temperature at the equator, what's the temperature half way to the
North Pole, what's the temperature at the North Pole, of these three bodies? And then looked at these gradients as if the atmosphere was an engine. So, an engine operates with a cold temperature reservoir and a hot temperature reservoir and then it does work by moving material from hot to cold.

Ryan: Right.

Charlie: And the efficiency of the engine is based on the temperature of these reservoirs. And the amount of work produced is a also based on these, the amount of material moved and the temperatures. And another way of looking at work is how much entropy is produced because when energy changes hands entropy is produced. If it is a non-reversible process which hemispheric heat redistribution is. And so, he looked at these three different bodies and then noticed that there's a fairly large temperature gradient between the equator and the poles, such that the amount of entropy produced is maximized. So if there was no temperature gradient then the entropy would be zero. And if there was a temperature gradient such that it perfectly matched the re-radiation back to outer space, a temperature gradient that matched the radiation that it was receiving from the sun, then there would be no heat transfer, and so then the entropy production would be zero. But on all three of these bodies, it's somewhere in between such that it maximizes entropy production. And so using this entropy production model he was able to predict the behavior of the there atmospheres and match it with the actual temperature gradients that we see on these three different atmospheres. So, there's this cute, clever idea that is definitely on the cusp of thermodynamics, sort of, but I found it quite intriguing.

Ryan: I'm, so this ah, model, has a predictive element to it. That could be used on other planets if we had an idea of what their temperatures were like at the poles and equator?

Charlie: Right.

Ryan: Interesting. Well, we don't have anything that, fine enough measurement to measure that, generally speaking. On other planets?

Charlie: I don't think we do yet. It may be coming with Kepler but I'm not sure. It's a new idea, this maximum entropy production theory and some people accuse it of being a psuedoscience because it's difficult to test...

Ryan: Right.

Charlie: And it's difficult to find...

Catherine: Like dinosaurs on Titan.

Charlie: Yeah, I wouldn't damn it that far but, um, people can start to make bold claims with maximum entropy production like it can govern the evolution of the entire universe. But whether that's testable or not remains to be seen. It's a relatively new idea that came out of information theory during the 70s. Schrödinger even talked about it when he tried to define life back in the 40s. And he said that life feeds on negative entropy, it's an open system that feeds on negative entropy. But it hasn't been entirely accepted and I don't know why. I'm smart enough to find it very attractive but not smart enough to know why people are scared of it.

Ben: Okay, We've covered everything. Time to do the wrap up. Okay, so, thank you Charlie, thank you Catherine. You have pleased me, your efforts have born fruit and that fruit is sweet. So, to thank him for his efforts, Charlie gets a rambutan. Good. Enjoy that rambutan.

Charlie: I capped it into my mouth.

Ben: Catherine gets a durian.

Catherine: Peeeyyyeeew.

Ben: Oh no, she doesn't like it. Okay. So, I'd like to thank my guest, Ryan North. Thank you for coming on.

Ryan: My pleasure.

Ben: Yeah, this was really good. You asked great questions and now we know more about Titan and lakes.

Ryan: And the dinosaurs that live underneath them.

Ben: And the dinosaurs that live...

Ryan: I mean, according to Dr. Catherine.

Ben: That's right.

Laughter.

[30:56]

Ben: Um, so, you can you can email us 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 Facebook. If you have a question you would like my Titanium Physicists to address email your questions to tiphyter@titatiumphysics.com and if you are a physicist and would like to become one of my Titanium Physicists email physics@titaniumphysics.com we're always recruiting. The Titanium Physicist podcast is a member of the BrachioMedia. If you've enjoyed our show you might also enjoy Science Sort Of or the Weekly Weinersmith, please check them out! The intro music is by Ted Leo and the Pharmacists and the end music is by John Vanderslice. Good day my friends and remember to keep science in your hearts.

[32:37]

Ryan: Well, we should probably send some robots over and check it out

Charlie: Yeah, we do, we keep on...

Catherine: Well, actually one its way as we speak.

Ryan: Are you serious? Right now?

Catherine: Yeah, Mars...

Charlie: About a week ago we shot one off.

Ryan: Man, I love that you guys can say "we" for this. Like I don't get to do that.

Laughter.

Caroline: Not that I was involved at all.

Charlie: I wasn't involved either. I very liberally used the term we. I think I'd like to say I helped dissuade them from choosing one landing spot but that's all I did.

Catherine: That's pretty good.

Ryan: How'd you do that?

Charlie: Ah, I did this redistribution of subsurface materials to impacts calculation. To say that maybe the clays, these hydrated minerals we see in one location might not have actually formed on the surface, they have formed underground and a big impact crater just dug them up like a steam shovel and threw them on top of the ground.

Ryan: Sounds plausible to me.

Charlie: Yup. I guess it's not the most exciting thing but I thought it was cool.

Catherine: So, where is it going now, Charlie? Which site did they decide on.

Charlie: It's going to a very safe site on the equator which is Gale crater. It's still an interesting place because there are gullies on the side of Gale's walls. There's a small valley network and there is an alluvial fan. An alluvial fan is something that forms from a stream that's carrying material downslope over a long period of time such that it deposits material and then the stream becomes rerouted because there's this pile of material now and so it will deposit material somewhere else and then it swings back and forth trying to find the place where it's deposited the least amount of material until, after many iterations of this a large fan shaped structure develops. And so, these are sexy for planetary geomorphologists because that means that stream was flowing for a prolonged period of time so it's going to land on that thing and drive around.

Ryan: When does this happen?

Charlie: I don't know. How long does it take to get to Mars? About six months?

Catherine: About six months. So, next summer.

Ryan: Something to look forward to.

Catherine: Yeah. Well, if it lands. Cross your fingers. Safely.

Charlie: Yeah, it's got this crazy landing scheme.

Laughter.

Ryan: So, what's the landing scheme?

Charlie: It has, first it enters the atmosphere with a big heat shield and there's this behavior called aero braking where the heat shield just slams into the air and that slows it down. Then, once that gets hot enough and once it has descended to enough altitude that heat shield will pop off and the it will light like four jet packs.

Ryan: What?!

Charlie: On all sides of it. And then the jet packs will continue to slow it's decent. And then the jet packs will continue to burn as a, there's like cables begin to lower...

Catherine: Yeah, the sky crane.

Charlie: Yeah, the sky crane canes, four cables start to lower the robot, the rover and then it softly drops the rover onto the surface of Mars and then the jetpack carries the sky crane off and it crashes somewhere.

Catherine: You need to Google this, it is the craziest video I've ever seen of a spacecraft landing on the surface of Mars.
But then again...

Charlie: It's absolutely insane.

Catherine: But then again we threw airbags on the surface of Mars seven years ago and that worked like gang busters so, who knows.

Charlie: It's just the ah, there's an engineering concept that the failure rate goes with the square of moving parts. And there are a lot of moving parts to this scheme.

Catherine: Yeah.

Ryan: But, it's got four jet packs involved which seems like, you know.

Catherine: And four cables too. But this thing is huge.

Charlie: But there is a possibility for awesome stuff.

Catherine: Oh yeah. Of course, of course. So, keep your fingers crossed.

Charlie: Why don't we have jet packs here? Why can't I buy a jet pack?

Ryan: You can buy those water jet packs. I was looking at this gift site for millionaires the other day and they have this ah, you put it in the water and it sends a stream of water into your backpack that shoots out jets and you get to fly, hover above the water with your water jetpack. That's what I'd um...

Catherine: Do you have a lot of millionaires on your Christmas list.

Ryan: No, you know I just thought they'd want to buy for me and
I could give them ideas. They also had a, you know, people like, water skiing will need someone to go in the boat for you. This is like a little sea dude that you control from the handlebar on the water ski from behind. And so it's a one person water ski mobile.

Catherine: Wow.

Charlie: Lonely. That's very cool.

Ryan: Yeah, you don't need friends when you've got that. And maybe this could be adapted, to bring it back on subject, to landing on Mars somehow.

Catherine: Or water skiing on Titan's lakes, you know. Like I sad, next beach resort.

Ryan: We, would die instantly even if we had...

Catherine: You would not die instantly. It would take several minutes to suffocate.

Charlie: So, on Titan you wouldn't want to wax your skis right? because the wax would stick to the hydrocarbons. What would you do?

Catherine : Oh yeah. Um. Let's see. Huh. That's a good question. They're mostly non-polar. I don't even know if it would matter. I'm not sure if you could do anything. I have to think about that.

Ryan: Maybe there's a paper.

Charlie: What's slippery on gasoline? I'll have to figure that out.

Ryan: Banana peels?

Laughter.