ROGUEMAKER: A Science Fiction Podcast

Behind the Science

ROGUEMAKER Theme Song plays.

ROOK: Hello and welcome to ROGUEMAKER: Behind the Science! That's right, no more of that bullshit science fiction, we're talking real-ass science today.

[Emma laughs]

ROOK: Um. You let me host. This is what I'm going to do. Anyway, so today we are going to talk to various members of cast and crew of ROGUEMAKER about the science that goes - that went into the actual writing of this. Um. And y'know, we're going to have a lot of fun while doing it. So uh, to start I will introduce Emma Johanna Puranen, uses she/her pronouns, who is the creator of ROGUEMAKER, who wrote the show, co-directs, co-produces, is the voice of Ship, and does all the sound editing.

SAM L: Really gotta carry your weight, Emma.

EMMA: Yeah you know just a little.

ROOK: Am I - am I missing anything?

EMMA: I think, I think, I think you know, that's it, that's all I do.

ROOK: That's it, that's everything, that's just barely anything. Anyway so Emma why don't you tell us what your astronomy history…your sci-, what's your sci-…how do you know about science, Emma?

EMMA: How do I know about science? Yeah, so um I am an astronomer? I'm adding a question mark there because I do interdisciplinary research, but one of the many things that I am is an astronomer. I have been doing astronomy since high school, which, I was very lucky to go to like a STEM magnet school that actually had opportunities to do astronomy in high school. Way back, since way back in high school I've been studying

exoplanets, which are planets outside our solar system, and in high school I tried to do an experiment to determine the wavelength-dependent transmittance of a hot Jupiter atmosphere by comparing radius measurements from light curves in different color bands.

(Clip from ROGUEMAKER of Woh́ saying "In layperson, maybe?" plays)

EMMA: I tried to figure out what uh a planet that we can't even see's atmosphere is made of. It didn't work. But I tried.

(*Laughter)*

SAM L: It's the thought that counts.

EMMA: Yeah that's all that should matter and therefore I accept no criticism.

ROOK: That's how science works, right? Does…science does, I dunno, I was a humanities major, science does partial credit right?

SAM L: Yeah, yeah, close enough, that's what's important here.

EMMA: Yeah, but yeah so as a result of that this episode will be astronomy-heavy because that's the science I know and that's the science that I was very excited to include in ROGUEMAKER. But I'm currently working on a PhD at the St Andrews Centre for Exoplanet Science um where I am still studying exoplanets but this time I'm comparing real ones to science fiction ones, which is super fun. So that's me.

ROOK: Alright. And next up, we have Sam Laporte, he/they, who you may recognize as the voice of our Racer, Jawn Batalha. Um but what you may not know is that Sam also does a bit of a science. Sam, tell us about your science.

SAM L: (silly voice) Uh I like to do a science.

ROOK: Thanks, Sam.

SAM L: Uh, yeah, I uh, not quite as prestigious as Emma, but I do have a Bachelor's degree in astronomy from the Pennsylvania

State University, um and currently I'm working at a NASA mission called Swift which is *not* an acronym, which may be the first time ever in astronomy that something has not been turned into an acronym.

EMMA: (gasps) I totally thought it was an acronym whoops.

SAM L: No, no it's just supposed to mean that it's fast. It just looks at things fast. Also it's a type of bird.

ROOK: Oh we love a bird.

SAM L: Yeah we love birds here. Mostly, well, the reason that Swift exists is to track down and localize gamma ray bursts which are products of some of the most energetic events in the universe, things like stars going supernova to black holes colliding to neutron stars colliding they're just spinning really really fast, um, because those will decay really quickly so we need something to tell everyone "hey! There's something going on up here! Turn all of your telescopes towards it!" and that's what Swift does. It does it automatically. Um so my job consists mainly of driving the space bus, just telling the satellite what to look at, and programming work. Um kinda looking to transition out of the field now but I still find it really really cool and I've got all this all this astronomy knowledge still living up in my brain. Uh…yeah.

ROOK: Alright, super cool Sam. And we also have Bonnie Calderwood Apinwall, pronouns they/them, uh who you would know as the voice of Pascal Almagest, uh the astronomer in-world. But Bonnie do you know anything about astronomy or science in the real life?

BONNIE: Oh, yeah yeah yeah, I'm a Libra sun Cancer moon Capricorn rising. Oh, wait, you said *astronomy*?

SAM L: Ughhhhhhh

EMMA: How dare.

BONNIE: Whoops! I know so so little and I am so excited to be here. Everything you guys are saying just sounds like the names of Muse songs and I'm just vibing.

SAM L: It's so painful.

EMMA: Bonnie is a really good actor.

SAM L: Yes.

ROOK: Bonnie is not an astronomer, but they play one on TV by which I mean podcast.

SAM L: And they do a fucking excellent job of it, I wanna say. You crush the jargon.

ROOK: Yes, for sure.

BONNIE: I can sometimes wrap my mouth around the words. But not my brain! Definitely never my brain.

ROOK: Alright. And last…but the opposite of least!

BONNIE: Last and most.

ROOK: Myself! I am Rook Mogavero, my pronouns are they/them. I am co-director, co-producer, voice of Chasma Jump Cannon, uh, I do transcripts, I occasionally remember to update the Instagram and that's I think it. Um and I was a theatre major but I did take Intro to Astronomy in my last semester of college but it was in the spring of 2020 so uh I'd be hard-pressed to retain anything from the second half of that semester but you know what I do remember some things. I'm not saying I'll be able to keep up, but I remember some things.

EMMA: I daresay you were bound by earthly concerns at that time.

ROOK: Yeah. That's definitely a lovely way of putting it. Alright, so let's let's dig into the actual science.

SAM L: Let's get into it, yeah.

ROOK: Let’s get into it. So let’s start at the uh very beginning of episode 1 uh we have that little scene where - are we doing spoilers? Are we cool? I mean are we assuming that people have listened to the entire show?

EMMA: Oh yeah.

SAM L: I feel like we have to.

BONNIE: Ya better!

EMMA: So this is your warning now, if you’re listening to this without having listened to the show somehow.

ROOK: Yeah, so yeah, contains spoilers for ROGUEMAKER.

SAM L: Go listen to it it’s really good.

ROOK: Listen to ROGUEMAKER! So in the very beginning of episode 1 we have Kuzha in the cockpit and you know Ship is saying all these different things in autopilot mode and they give some sort of coordinates-y thing?

(Clip plays, Ship says “Plutonic Flight 999 current position in Earth Celestial Reference System: right ascension 05 16 55.8. Declination minus 14 42 29.7. Distance from Earth 9.001 light years.”)

ROOK: What are those? I know you, Emma, well enough to know that you’re not just going to shove random numbers anywhere.

EMMA: (laughs) Yeah so that is a celestial coordinate system, that is right ascension and declination, which Sam probably uses a lot in figuring out where gamma ray bursts are coming from.

SAM L: Yeah.

EMMA: So actually do you wanna explain that one?

SAM L: Yeah, um essentially it is — stars move around - stars don’t move around on the sky so much as the Earth rotates around, but let’s ignore that for now. If you imagine that the sky is not three dimensional but is just a shell that is

surrounding the Earth then this particular method of setting coordinates for astronomical bodies uses the Earth's equator as sort of like a baseline. Um and just kind of projects that out into space and defines the zero point of the up and down axis as the Earth's equator. Right ascension is kind of your left to right coordinate system, its ordered in hours which is very convenient because that's also our unit of time that we can use to relate it to the Earth's rotation um and declination is in units of degrees um going from 0 to 90 and - well 0 to 90 and 0 to negative 90 at each of the poles. This is useful because it is essentially like location-agnostic, if I'm right, Emma, like it isn't dependent on where you are on the Earth, we can say this star exists at this coordinates, and just depending on where you are on the Earth and where you look up at the sky that just affects what range of coordinates you're able to see, not the coordinates of the objects themselves.

EMMA: Yeah the zero point is defined using the vernal equinox, which Bonnie might know from astrology.

BONNIE: I've heard those words.

EMMA: Um so there is like the Earth is moving around the sun and the axial tilt means the poles are tilted differently at different times of the year um relative to the sun but there is one defined zero point for it so yes it is location agnostic. Um but what Sam was saying about the shell is like, imagine, you're Lowkey Madigan and you're inside a zorb.

(Clip of Lowkey saying "The pods aren't clear like zorbs." plays)

EMMA: And you're inside one of these inflatable thingies, you're sort of like-

ROOK: Human hamster ball.

SAM L: Yeah.

EMMA: Yeah yeah you're like projecting this thing out from the Earth on the sky and you're making coordinates on that. However to figure out where the ship is, you need a third coordinate as

well, you also need a distance from Earth and so that's what the 9.001 light years is about.

SAM L: Mmm.

EMMA: Um this is based on a real thing called the International Celestial Reference System, the ICRS, but in the show I called it the Earth Celestial Reference System because it's probably not exactly the same, I'm sure they've changed it a bit. But those numbers are all real and they're all um, they're plausible for something that's on its way from Epsilon Eridani to Sirius, which are both real stars. All the stars that are mentioned in the show are real stars, and they're all real stars within about 20 light years of the Earth. So Epsilon Eridani, Sirius, Barnard's Star, the Luyten stars, Teegarden, Gliese 581, etcetera.

ROOK: Yeah no one of the things that really interests me about astronomy is like, how, you know you're studying everything outside of Earth and you know you're like, learning about how you know how - I don't wanna say small and insignificant because that's a bit too like I dunno cliche – but it's like you're learning there's like a bunch of other things out there and we're not special and the universe doesn't revolve around us and we're not the center of the universe. However we can only take you know observations and measurements from Earth, so we kind of have to be Earth-centric?

SAM L: Yeah.

ROOK: Or like near Earth. Which I don't know like y'know it's like okay y'know we've got stuff that's like orbiting around Earth. And that's sort of like y'know you're not you're not looking from a different viewpoint you're maybe just kind of tilting your head a bit I think is how it's…

EMMA: That's a great way of putting it. Astronomers are sort of very fancy photographers who have very low light conditions to work with, but we only have the one perspective. We can't go take a picture from a million light years away. We're only here.

SAM L: Yeah.

ROOK: Also I actually - this is nothing to do with ROGUEMAKER, can I ask a question that has nothing to do with ROGUEMAKER?

EMMA: Yeah.

SAM L: We love it.

ROOK: If - If, so y'know we've got some stuff on other planets in our solar system, not a lot, but some. But if we were to get like a big-ass telescope out to a different planet in our solar system would be able to gain anything particularly different or interesting than, y'know telescopes on our planet or in orbit around our planet, or is it too close to make much of a difference?

SAM L: My initial impression is that it would be too close to make much of a difference? I think that in order to get anything, like measurably different, you'd probably need to like at least get outside the solar system, or like meaningfully measurably different. Like there's fractions of like fractions of a percent like of course it's going to change as you get out there, but, I, unless I'm forgetting something significant which if I am please let me know. Um, on like astronomical scales something that I've always enjoyed is that once you get just super super gigantic huge like those sorts of - like distances that we on Earth would consider gigantic, like the distance between here and Neptune, is nothing compared to like the distance between us and the nearest like star or the nearest galaxy. So even like our perception of those things the way that they look to us the way that they're all sampled together would change minimally while moving on scales like that.

BONNIE: That's so cool.

ROOK: Alright, that's - that's messed up, man.

SAM L: Yeah! We're tiny. And I dunno, I find that fun.

EMMA: Me too.

BONNIE: Something about the way, I was just thinking about what you were saying before Emma – about how everything is, sort of –

I think we all touched on it a bit. Well, not me. I'm talking now, hello. Um what you guys were talking about is how everything um obviously has to be Earth-centric even though we're like using it to look outward. And then it's like when you come to science fiction it's that interesting thing of um especially what you've done Emma with ROGUEMAKER is base so much of it, well, like, everything you could, on the real science, to sort of be writing a possible future where we have outside um perspectives and have to sort of think, how much do we acknowledge that they would think about this totally differently without just making up new numbers and new calculations that you can't possibly do. Like, I think that's really interesting and um I like the way that you did it in ROGUEMAKER basically being like, well this is based on human and Earth-based stuff and so then you have these little nods like 'so humanocentric' and things like that. I thought that was a really cool way of sort of acknowledging that you're using real science to as much of - as much of a degree as you can, but you're talking about a world, a future where we have that outside perspective as well.

EMMA: Yeah, well otherwise you're asking the listener to like, learn a new language essentially as they're listening. Which, I think, sci-fi, sci-fi, people who consume sci-fi will accept a lot, but I think that's maybe a bit much.

(laughter)

ROOK: Yeah no I - that reminds me of a thought I had recently that I wanted to bring up at some point and it seems relevant enough now. That I was thinking about like, I dunno there's gotta be a word for this, alas we don't have one of our linguistics friends on board. That, like, linguistic redundancy like when two cultures interact and they have a name for a thing. And so like y'know like there's a culture that lives by a river and so they call that 'the river' because it's the only river they know or at least the only river that they knew when they were first developing language and so when someone speaking a different languages comes in and they say "oh what's that?" they say "oh it's the river" and so then they use the word for river to mean that specific river so then their name for it is like river river. Y'know see like Sahara desert, chai tea, naan

bread, et cetera. And I and I like realized recently that because like – and you know Emma you're very good about being an astronomer and calling our moon like Luna and our sun Sol, but that's still, that still just means moon and sun but in Latin! Um and so its like if we were to come into contact with other aliens and their language it'd just be moon moon?!

BONNIE: Moon moon!

SAM L: As it should be.

EMMA: Was that whole soliloquy just a leadup to a moon moon joke?

ROOK: I mean kind of? But that's I mean it's partially a moon moon joke but partially like I just find the linguistic redundancy thing interesting.

BONNIE: It's like um, there's a hill in Cumbria called Torpenhow Hill. Which is tor which is a word meaning hill, pen which is a word meaning hill, how which is a word meaning hill, and then hill. So it's just hill hill hill hill.

SAM L: Hill hill hill hill! Oh!

BONNIE: Yup, from all the different languages that came through Cumbria over the years. It's so good, it's so good.

SAM L: I love it.

ROOK: So, kind of, I feel, the main Big Science Thing in ROGUEMAKER is that… there's a rogue planet.

(Clip from ROGUEMAKER ep 5 plays –

Pascal: "A rogue planet is just any planet that doesn't have a sun. They're also called nomads, or orphans, or unbound planets… since they're not gravitationally bound to any star. They're found in interstellar space."

Lowkey: "Woah… so like, they're just floating around in the void? How does that HAPPEN?"

Pascal: Well, rogue planets form in star systems just like any other planet, but planet formation is messy – lots of times, planets kinda… fight, like siblings, jostling for positions, and some of them get kicked out in the gravitational game of musical chairs, so to speak?")

ROOK: What's– what is the deal with rogue planets, and how *do* you find them? Because one of the things I *do* remember from intro astro is a way of finding exoplanets, which – can I explain it? Can I explain it?

EMMA: Yeah! Do we wanna talk about exoplanets in general first?

ROOK: Ooh, maybe we could talk about exoplanets in general first, because I– one of the things that *I* know is the transit method!

EMMA: Mm-hmm.

ROOK: Which, again, it's another thing about, like, the limitation of only being able to look from Earth. Because, basically, the way you find – one of the ways you find exoplanets is that you look at a star and you look at the, the brightness of it, or whatever the term is for how much brightness we get from here on Earth, I don't remember the word–

EMMA: Flux.

ROOK: Flux! Yeah, so you look at the flux over time of how much brightness we get from that particular star, and if you put it on a graph, you see, oh, every, y'know, 349 days or every 57 days, the flux goes down a little bit. Um, which means that, y'know, if there– because there's a *planet* revolving around it, and so, when the planet is quote-unquote "in front of" the star, meaning between the star and Earth, the flux goes down a little bit, so we can tell that there's a planet there.

BONNIE: Right, because of the light.

ROOK: But of course that only works with planets that are a) revolving around a star, so you cannot find rogue planets this

way, and b) planets that have an orbit that just happens to be visible this way from Earth at the correct angle.

EMMA: A fortuitous alignment.

SAM L: Yeah.

ROOK: So yeah. So talk– I guess if we wanna talk about exoplanets, finding exoplanets, what's the deal with exoplanets, and then go into how we find rogue planets, if not by this way?

EMMA: Yeah. Yes I'm chomping at the bit-

ROOK: Gravitational micro-what-now, etc?

EMMA: Chomping at the bit for exoplanets. Ok, so, listener, I want you to think in your head right now, if you don't already know the answer. What is the year that we discovered the first planet around another star? Outside of our solar system. Have a year in mind? When do ya think it was? Alright. Cool. It was 1995. I dunno if that's way later or way earlier than you thought but for most people I've asked – Bonnie, did you have a year in your head?

BONNIE: Oh I had way earlier, I dunno, I guessed.

EMMA: What did you think?

BONNIE: I guessed…I guessed the year 1000.

(laughter)

SAM L: Hey who knows, someone might have seen something then!

BONNIE: I was just like I dunno, you're you're fooling me into thinking it's gonna be recent and it's gonna be long ago okay no I went the wrong way.

EMMA: That's very optimistic, though, I appreciate that. Look, most people-

BONNIE: Listen, look, they built pyramids, man, I don't even-

ROOK: Yeah, I only know it because of being friends with Emma and no other reason.

EMMA: Most people think it was a lot longer ago but as Rook alluded to these things are very hard to find. They're very dim compared to their stars that they're orbiting so usually the way we find exoplanets is through their effects on their star. So one of the methods is the transit method that Rook mentioned. The other one that works for a wider variety of alignments of the planetary system relative to Earth is called the radial velocity method. So that works because the star, it's not just the star exerting a gravitational pull on the planet, but it's a two body system, the planet is also tugging on the star a little bit. So the center of mass is not the center of the star, it's outside the center of the star. And therefore, the star is wobbling a little bit as this orbit is happening. A star that has a planet wobbles.

ROOK: Listener, I need to know that as Emma was talking about wobbling, both Emma [transcriber's note: they meant Bonnie] and Sam were just kind of uh y'know moving back and forth a little, doing a little wobble in their chairs.

BONNIE: Just doing a little shimmy. Little shimmy.

SAM L: It's instinctual. It's instinctual at this point.

EMMA: Their best quality? Their wobbles.

BONNIE: That's also what my brain was doing.

EMMA: So, if you find a star that's wobbling, it's got something tugging on it gravitationally, and you can measure this wobble by again looking at the light from the star, and when the star is moving away from us a little bit it's light is gonna be redshifted, and when it's moving towards us a little bit it's light is gonna be blueshifted.

BONNIE: WHAT.

EMMA: If you see it shifting, cuz the Doppler effect, um then you can tell it's got a planet around it. And you can do some

math, I almost said maths because I've been teaching in the UK for the past two years-

BONNIE: There's more than one number, Emma!

SAM L: No! Not in America!

ROOK: There's only one math though! It's only one math!

(laughter)

EMMA: And if I don't watch out I'm gonna start saying "nought point whatever" instead of "oh point whatever".

SAM L: Ack.

ROOK: Disgusting.

EMMA: Um anyway you can figure out the mass of the planet from this method. Um the transit method uh that Rook was talking about is nicer because it also gets you the radius. Um and if you have the mass and radius you can get the density and you can figure out what type of material it might be made out of. But since 1995 we've found over 5000 of these exoplanets. Every exoplanet scientist this year had to update all their Powerpoints to now say over 5000 instead of over 4000.

ROOK: Wow.

SAM L: That's huge.

BONNIE: That's so cool.

ROOK: Yeah I mean and I remember one of the things I learned in Astro 1, in my intro to astronomy class, uh is that there's like citizen science projects where it's like anyone can just like kind of look at a bunch of these graphs and see if they can find uh an exoplanet using the transit method. Although it's harder than you'd think because it's not y'know it's not like oh it's a straight line and then a dip and then a straight line and then a dip it's all y'know kind of noisy.

EMMA: Yeah astronomy has a lot more noise than signal.

SAM L: Oh that’s a really good line. That’s a very good line.

BONNIE: Much like podcasting.

SAM L: Emma I, I’m actually gonna ask you something because I’ve had this thought in my brain for a while which I’m not sure if its a misremembered thing from astronomy class but, how do you tell the difference between an orbiting like planet with an atmosphere and just an orbiting really big rock with no atmosphere? I think, I think I might have a thought but you’re you’re the exoplanet expert here.

EMMA: Yeah so you can pick out some stuff about the atmosphere um if it transits, because the shape of that curve, like-

SAM L: That’s what I thought it was! Haha, I know things!

EMMA: Yeah, (laughter), yeah like how how whether it’s really sharp or whether it’s at more of a gradual angle that it decreased to the lowest amount of flux before going back up because you’re getting some light passing through the edge of the atmosphere and then to us.

BONNIE: (gasps) Whoa, that’s so cool.

SAM L: Mhm. Mhm.

ROOK: Yeah.

EMMA: So if you can take a spectrum of that star’s light when there’s no planet passing in front of it and then at various points during the transit you can actually figure out some of the chemical species in the atmosphere.

SAM L: Yeah.

EMMA: Which again, we can - that’s what I tried to do in high school and failed. Um…(laughts)

ROOK: F.

EMMA: Hey, we still, we still we uh won regional science fair and we got to state science fair, so….

SAM L: Damn.

BONNIE: That’s so cool.

ROOK: Mazel tov.

EMMA: I peaked in high school.

ROOK: Mazel tov, high school Emma. And, and friends, I did you I assume you said we I assume you did that in a group?

EMMA: I had a I had a science partner, yeah, lab partner.

ROOK: Okay well let’s pivot from talking about exoplanets in general to tidally locked planets we a lot is talked about tidally locked planets because we have Tand, the homeworld for the ǵnonw. So what’s the deal with tidally locked planets and Tand?

(Clip from ROGUEMAKER plays of Woh́ saying “our cultural combination, how Night and Day are places on my world but to you night and day are times?)

(Clip from ROGUEMAKER plays of Kuzha saying “Tand takes the same amount of time to complete one rotation as it does to orbit our sun. So on Tand the sun never moves in the sky. It is in a fixed position. And if you stay in the same place, nothing changes.”)

EMMA: Yeah, so tidally locked planets are explained in the show I think fairly well, it’s uh-

BONNIE: I was gonna say, I know this one!

EMMA: Yeah, do you wanna take this one Bonnie, go for it!

SAM L: Yeah go for it.

BONNIE: Oh no pressure, yeah, screw it, why not. Ok so a tidally locked planet is a planet whose day rotation around its star is as long as the year rotation. Is that correct?

EMMA: Yeah.

BONNIE: So that means that it is always getting light from its star on only one side. Did I do it? Did I do an astronomy?

SAM L: Yeah. You did an astronomy.

EMMA: Yeah! Nice!

BONNIE: Yay! I took some stuff in!

EMMA: One of my big goals of the show is that frickin everybody who listens to it is gonna learn what a tidally locked planet is.

BONNIE: I'm so proud…of both of us.

ROOK: We're all very proud of you Bonnie.

BONNIE: Thank you.

EMMA: Um yeah the moon is tidally locked with the Earth as well, that's why we talk about the dark side of the moon, although that's a misnomer because it's getting sunlight, it's just we never see it, um but yeah tidal locking-

ROOK: I never thought of that.

BONNIE: Wait what?

SAM L: Yeah.

ROOK: I never thought about how the dark side of the moon isn't actually necessarily always dark, we can't see it.

SAM L: The fact that the moon isn't always full for us means the light has to be hitting it.

ROOK: Yeah I just never really I mean if I had thought about it for more than like five seconds which I really should have because again we did learn about the moon and phases of it in astro 1, I just never thought about that.

BONNIE: Yeah, of course…

SAM L: Emma this is my this is my favorite reaction to get from people when just talking about like astronomy factoids. Because you just don't think about it.

BONNIE: I still just I still can't like the fact that it took me until so recently to realize that we only saw the same bit of the moon every time and I'm like I was so mind-blown by that and I was like well yeah it always looks the same, dipstick!

(laughter)

EMMA: Aw be nice to yourself.

ROOK: I maintain that if you view the moon from a Wawa parking lot at 3 o'clock in the morning you do get to see a different moon.

(Laughter)

ROOK: Cuz the moon I I did that once and the moon definitely looked different. I have no proof of this but-

SAM L: A very specific position, you can do it.

BONNIE: Yes, absolutely.

ROOK: I think I think it's any Wawa parking lot.

BONNIE: That's fair.

EMMA: So tidal locking is more likely to happen when um an object, has is like very, when a planet is very close to it's star, cuz there's a much stronger gravitational pull when it's much closer to it's star, and Tand orbits a red dwarf star which is smaller than our sun, so in order to be in the habitable zone it's got to be orbiting much closer, therefore much more likely that that gravitational force is gonna slow its orbit and slow its orbit until a rotation of the planet is the same a revolution around the star.

BONNIE: (squeaking)

SAM L: That’s really smart. That’s really smart. I love how much you thought through all of this, it’s really impressive.

EMMA: It’s really frickin cool because a lot of like uh red dwarfs are the most common type of star in the universe so uf if we’ve we’ve found planets around them so if we can figure-

ROOK: I got that answer right that was an answer on Jeopardy the other night and I got it right! It was the it was the only one in the astronomy category that I got right and I did get that one right.

EMMA: Proud of you! (clears throat) I’ll give you a red star for that because it’s a red dwarf.

BONNIE: (squeaks)

ROOK: Yaaay.

EMMA: Um yeah so if if like if there’s a way that life could be viable around red dw - in like red dwarf systems, then it could be very common throughout the universe. Uh there are certain things you’d have to consider if you’re living on a tidally locked world um that some of which we explore in the show but I wanna talk for a second about Gliese 581. Because that is specifically the red dwarf star that Tand is it’s just it’s not called Gliese 581 in the show because why would the ǵnonw call it Gliese 581. Speaking of linguistics.

BONNIE: So humanocentric.

ROOK: Yeah they just call every they actually just call everything uh all of the stars and planets that we’ve discovered the same thing that we do it’s really convenient.

EMMA: I know, down to the number, right?

BONNIE: What a coinky-dink.

ROOK: That’s wild.

EMMA: My mom was looking at “Tand” and she’s like “tooth?” and I’m like “what” and she’s like “that means tooth in Dutch” I’m

like “ok I was unaware”, um, that’s not a terrible name. Anyway, Gliese 581 is a real red dwarf star like 20 light years away from Earth um it’s about a third the mass of our sun so it’s actually on the big end for red dwarfs. Um there’s not much stellar activity which is great so you don’t have to worry about flares, so that could be a good place to live. The reason I picked it is because when I first got into exoplanets around the 2009 2010 era, that was like, our candidate system for most, like it was the hot new discovery, everyone was like ah, we’ve got some planets here that might be in the habitable zone possibly, this is very exciting, so when I first got into it that was like the darling of the community. I want to talk a little bit about the chaos of it now because. (Sigh). Sam, are astronomers good at naming things?

SAM L: Absolutely not.

(laughter)

SAM L: Potentially the worst at naming things. Ever.

EMMA: The worst.

ROOK: They’re good at - uh, my understanding is they’re good at making acronyms?

SAM L: (really iffy noise)

EMMA: Yes, which is why I’m surprised Swift - uh, good in a certain sense - if you like puns, maybe?

ROOK: Yeah.

SAM L: Yeah good is a very strong word.

ROOK: Yeah I just you mentioned acronyms earlier and I’ve definitely heard a lot of things about…acronyms.

SAM L: Astronomers, astronomers are horrible at naming things but are perhaps masters of backronyms.

EMMA: So. Gliese 581 is the star. When exoplanets are discovered, they’ll go, ok, Gliese 581b, that is a planet

orbiting the star Gliese 581, because a is reserved for the star but no one actually says that. Um it assigns letters in order of discovery which is not necessarily the order that the planets are from the star.

SAM L: Mhm.

ROOK: Oh that sucks so bad.

BONNIE: Oh my god.

EMMA: I will share to you the Gliese 581 planetary system. The planets, in order from the star: Gliese 581e.

(laughter)

EMMA: Gliese 581b. Gliese 581c. Gliese 581g parentheses unconfirmed.

(louder laughter)

EMMA: Gliese 581d parentheses unconfirmed. And then a debris disk.

SAM L: Wait a minute wait a minute wait a minute.

EMMA: Yes.

SAM L: The closest one to the star is e?

EMMA: Yes.

SAM L: That’s after d, which is unconfirmed, but e is confirmed?

EMMA: Yes.

SAM L: That’s worse than I’ve ever seen!

ROOK: Yes I hate everything about this.

BONNIE: Tag yourself, I’m the debris disk.

(laughter)

ROOK: Oh no…

SAM L: Tag yourself I'm "unconfirmed d".

BONNIE: "Unconfirmed d" is my gender.

EMMA: So unconfirmed d is the one that actually I'm saying Tand is. If it, um, if it's if it's real. Um. Yeah. Oh I'm just realizing I was saying earlier Tand is what the planet is called there is a name um in the ROGUEMAKER universe for what the star is called that is actually never said in the show, but it is "Tva". T V A.

ROOK: Oh yeah I forgot about that.

BONNIE: I remember that from the the worldbuilding document.

EMMA: Yes. It's on the worldbuilding documents online. But yes they would not call the star Gliese 581. But they would not call the planet Gliese 581d they would call it Tand.

ROOK: No they call it uh they call it Gliese 581d unconfirmed, we're not really sure what we're living on right now!

(laughter)

BONNIE: Unconfirmed… Schrödinger's planet.

SAM L: Might or might not be there.

EMMA: See the thing is it's a radial velocity discovery, that's the one that I was talking about with the wobbles, um and due to stellar variability or lots of noise in the data trying to pick out different signals from each other, that's why - like, lots of people have analyzed this, some papers say it's there, some papers say it's not there, it's a hot mess, but it was very exciting when I was 14 and first getting into exoplanets.

SAM L: Yeah.

EMMA: So as an homage, Tand is Gliese 581.

SAM L: I love that.

EMMA: Yeah.

ROOK: Um so now that we have talked about Tand and we have talked about exoplanets, uh let's get into rogues, like the Tracer homeworld, y'know, the planet that they are on. Um uh what so obviously you can't find a rogue planet based on how y'know based on it's effects on the star if it's not orbiting a star, so what what is the deal with rogue planets? How do we find them? There was a mention of gravitational microlensing, of whatever that is, I'm-

BONNIE: Yeah I remember saying those words.

ROOK: You've explained it to me many times, and shhhhh I dunno, I don't understand it.

(Clip from ROGUEMAKER of Chasma saying "Gravitational micro-what-now?" and Alyss responding "Gravitational miçrolensing is a consequence of general relativity whereby-" and Woh́ interrupts with "Oh my stars we don't need another science lesson!")

EMMA: So have you seen the Hubble uh Deep Field and the new um JWST like update of, of, also, the one where they zoom into this tiny part of the sky and every dot is a galaxy and then your mind just like explodes when you look at it.

ROOK: Yeah. Yeah, that owns.

BONNIE: I didn't even look at it I just thought about it and my mind exploded.

EMMA: That image. Yeah, um so y'know how sometimes in there you'll see these blurry arcs of light.

ROOK: Mhm.

EMMA: Those are gravitationally lensed. So it's this thing where you've got, remember Rook talking about the transit method and there's a star and a planet passing between us and the star, but in this case you've got some massive object passing between us and a light source in the background, which could be a star or a

galaxy. The mass of that object that's passing between us is, like, it's gravity is warping that light into that weird shape. It also brightens it as it's warping it. Um, so, it's like-

ROOK: Why?

EMMA: Why? Ask Einstein.

(laughter)

ROOK: Alright lemme just get out my my necromancy kit for beginners.

SAM L: For beginners.

EMMA: Yeah, general, general relativity. Which is kinda funny, it's a bit of a misnomer-

SAM L: Yeah.

EMMA: -because um it follows from special relativity, which is actually the easier to understand of the two.

SAM L: It's called, it's, yeah, it's special relativity because it's – this is a little physics lesson - special relativity is called that because it is for a very special case. It's for, it's for when things aren't accelerating, right, Emma? Is that it? Or am I fully off?

EMMA: Uhhhh.

SAM L: Aha, I've stumped you! I think that's it. I'm gonna force myself not to google it and just commit.

ROOK: Oh I was about to google it. I've never taken a physics class.

SAM L: You can. I - I think special is when acceleration is not involved and general covers everything else. That's why it's general. And special's way easier.

EMMA: Yeah I will admit, yeah, special doesn't require calculus. You can do it without calculus.

SAM L: Damn.

EMMA: I will admit not being super familiar with either of them but I know that special relativity is the one that says that like the laws of physics are the same in all frames of reference and the speed of light is like also the same everywhere.

SAM L: Yeah.

EMMA: And then general relativity like adds gravity to that.

SAM L: Mmm.

ROOK: Uh-huh.

SAM L: And gravity is…such, such…

EMMA: Difficult.

SAM L: No, it's so easy. It's so easy bending the fabric of spacetime. It's fine. Yeah.

EMMA: Yeah, it's the one where you see those demos where like they put a bowling ball on a trampoline and they're like this is gravity warping the fabric of spacetime. Which y'know like all metaphors is is wrong in some ways I'm sure, but it's as good an illustration as you can get.

SAM L: Yeah.

EMMA: Yeah so that's what's warping the light. And so if you…like, gravitational mi – and then microlensing just means on a smaller scale, you can say gravitational lensing for like a galaxy's light getting warped, um microlensing would be like a star's light getting warped or or it can also be seen with smaller masses doing the warping like planet sized masses, which on an astronomical scale are small, which is ridiculous, but they are. Um so this is a weird one. Because you essentially have to be looking out everywhere for a flash of light. It's like looking for a firefly on like a summer night and like you'll just see them somewhere and you're like "ah! There was one, ah, there was one, I'm never gonna see it again". That's

what looking for rogues is like, you'll see like a flash of the event, of of like this planet randomly passing in front of a background object and we see this huge increase in the light um and then you may well never see that same object again or you'll never be able to prove that it was the same object again. Literally all you know is that there was a mass that was there that was not bound to a star.

SAM L: Yeah I was gonna ask about that.

ROOK: So wait, how do we know, so then how do we know that rogue planets are even a real thing?

EMMA: Because there was a mass that was there that was planetary mass. And you can um based on something about the the time frame of the brightening event um and how fast the object is going, you can rule out it being gravitationally bound to a star within a certain distance. So you can't - it could - it could actually be a planet on a very wide orbit, but we've found enough of them that some are probably not. Some are probably rogues.

ROOK: Mhm.

SAM L: Yeah. Yeah. That makes sense. I was gonna ask if there's like any consistent way to like do science on individual rogue planets if you're like just kind of hoping that you see one at some point.

EMMA: Nope.

SAM L: There - there's a really fascinating amount of astronomy, especially, like, uh, especially, cuz even going back years and years to like when it was still being initially developed, that just kind of relies on luck. For you to catch the thing as it's happening or as the light is finally getting to us.

EMMA: Yeah. And we put some data from gravitational microlensing in the show, we, like, we sonified it, and it's um the textbook bit at the end of episode 2. Um because this one actually like the graph is fairly simple like with a transit um you've got time on the x-axis and then you've got how bright is the thing on the y-axis. So you can hear um if you put the note the

brightness to like uh like lower brightness is a lower note higher brightness is a higher note,

(The sonified microlensing data plays in the background.)

and then over time, and you put that to music, you can hear like the low and then like this this quick peak to like a um higher notes and then the decrease. So that's in the end of episode 2.

BONNIE: (whispering) That's so cool.

SAM L: That's really cool.

ROOK: Uh in the in the show they talk about like y'know how there's probably not any life on this planet how do like what is the deal with life on rogues? And also, this isn't in here, but like, I mean, Pascal gives a little um explanation of how rogue planets work about like jostling each other out of the…the…what was…there was like the planetary game of musical chairs or whatever?

SAM L: Yeah.

BONNIE: Mhm. Musical chairs.

ROOK: Yeah, like, I, I assume…is that yknow, accurate, is that, I mean is that just a guess of how we figure they're - they become a thing?

EMMA: So how solar systems and - how planetary systems form is very much an active area of research. Uh, there's a lot of various theories, particularly about um how Hot Jupiters happen, and I promise this will relate. So, a Hot Jupiter is-

ROOK: Hot Jupiter is such a good phrase.

(laughter)

BONNIE: It's the name of my band.

EMMA: Again, great at naming things. Yeah, it would be a good band name, someone should get on that. Um, so that is just the concept of a gas giant orbiting very close to it's star. So it

is like Jupiter but it is hot. Cuz in our solar system all the gas giants are far away. So that doesn't make sense, they can't have formed that close to their star or else their atmospheres would've gotten stripped away. So they had to have formed farther out and then migrated in.

SAM L: -and then moved in. Mm.

EMMA: So that could be one mechanism for the formation of rogue planets, where you've got this, like, imagine if Jupiter started scooching in, like we're, we're gonna be, yeeted out of the system.

SAM L: Terrifying.

ROOK: Ah, so that's, so that's why the roguemaker is a gas giant.

EMMA: Mhm. Yeah.

SAM L: Ohhh is that like you, is that just a cheeky little reference by you, or is that like actual like fundamentals of the science of it?

EMMA: I was probably thinking a little bit of this concept of of like Jupiters scooching in and kicking out all the little baby terrestrial planets farther in. Um,

ROOK: Rude of them.

SAM L: Those big bullies.

EMMA: Yeah we have a nicely behaved one, we should be grateful to it.

SAM L: Yeah.

BONNIE: For now.

EMMA: It's staying out there at 5 AU, beyond the asteroid belt, we're all, we're all good.

ROOK: Yes sir we are literally under siege by planet fucking Jupiter.

(laughter)

EMMA: That’s - that’s why it’s the king.

ROOK: That was a Homestuck reference I’m very sorry.

SAM L: Nooo I didn’t catch it. (groans)

EMMA: (vaguely in Ship’s voice?) I have not read Homestuck.

SAM L: Continue not reading Homestuck.

EMMA: I dunno why I sounded like halfway into the Ship voice there. Anyway.

(laughter)

BONNIE: You did!

ROOK: Yeah.

EMMA: But yeah. That’s, that’s probably how rogues happen, or um, you might get some other interstellar interloper coming into a system and messing with it gravitationally.

SAM L: Was gonna say, if a, I assume if like a rogue planet was big enough, it itself could fly through a solar system and it’s gravity could pull a different planet out of it’s orbit and make another one.

EMMA: Yeah.

SAM L: That’s fun.

EMMA: When rogue planets show up in science fiction they most are doomsday events, they mostly are-

SAM L: Bleghhhhh

EMMA: There’s this rogue planet coming to destroy the Earth! Ahh!

BONNIE: What I’m hearing is that’s it’s Starlord’s dad, right?

SAM L: Mmmmm.

EMMA: I….saw that movie once and have forgotten the details.

BONNIE: Too niche MCU?

SAM L: No I got it he’s a big face. Big face and a planet. If I’m not mistaken.

BONNIE: He’s a planet!

ROOK: I I haven’t watched a Marvel movie in a very long time I’m sorry.

BONNIE: This is the only reference I have for so many of the words you guys are using.

[laughter]

SAM L: Oh no!

EMMA: One other, one other just tidbit while we’re on rogue planets is that I’ll say that rogue is one of the terms you’ll see for them in astronomical literature but you’ll also see “free-floating planet”. We’re still kind of figuring out the terminology cuz rogue as a word has some baggage, which is exactly why I wanted to use it.

SAM L: Yeah.

BONNIE: It’s so cool.

ROOK: Yeah it’s the coolest - it’s the coolest word to use so obviously you gotta use it.

BONNIE: I imagine it wearing like a little Zorro mask, it’s so cool. And sexy.

EMMA: It’s mysterious.

SAM L: (snorts) The sexy planet, yeah.

ROOK: And also this is where we reveal that the LARP that uh ROGUEMAKER is based on was originally called R O G U E but we changed it to ROGUEMAKER because it’s easier to search.

(Clip from ROGUEMAKER plays of Pascal saying “The ice layer might keep the subsurface warm down here on the Tracer world, too. Lots of people theorise about life on rogues, but, well…” and Trip replying “Funding.” and Pascal agreeing “Funding. We never get to go check.”)

EMMA: But as for the actual environment of the rogue, um, it would be frickin cold. The temperature of space is like 2 or 3 Kelvin. Uh, 0 Celsius is 273 Kelvin, for comparison.

SAM L: Yup.

BONNIE: Oh…okay.

EMMA: Yeah, so if there were to be, like, say you had a planet that had some life on it and then it got kicked out of it’s system somehow, probably the life would die off, but like, you can’t even rule out life on a rogue planet. Life would need an energy source and some warmth, so if it was still geologically active somehow, or say it had like, a giant ice layer and then an ocean under it, um or if it was in a two-body system and there were tidal forces keeping it warm, there, there are ways that, y’know, I wouldn’t discount life on a rogue planet.

SAM L: Yeah.

ROOK: Yeah. Oh also a thing you talk about in the, uh, the thing that’s talked about in the show is the like the atmosphere freezing, and that you’ve just got ice on the planet that is from the atmosphere?

BONNIE: Yeah, the atmosphere that froze and condensed and fell?

EMMA: Yeah.

BONNIE: Ahhh!

SAM L: Yup.

(Rook laughs)

SAM L: Atmosphere rain.

EMMA: The atmosphere - the atmosphere has fallen as uh, ice and snow probably. Um.

(Clip from ROGUEMAKER of Trip saying "It's slow going climbing over things, but, hey, at least at this temperature the ice is too cold to be slippery." Pascal replies "I think this ice used to be the atmosphere." Trip says "We're walking on top of an atmosphere?!?")

EMMA: Yeah! And it's too cold for ice to be slippery. Cuz ice gets slippery from like friction from your boots or whatever uh melting the top part of it.

SAM L: Oh, that's right yeah!

ROOK: Oh, and so you can't, it's too cold for you to melt the ice.

EMMA: Mhm.

SAM L: Yeah it's a very thin water layer.

BONNIE: What - nope, don't ask that question.

ROOK: Aw man.

SAM L: I'm learning things!

ROOK: Wait no Bonnie, ask, what were you gonna ask, what were you gonna say?

BONNIE: (laughs) No you're in a spacesuit! What happens if you pee when it's that cold?

(pause)

SAM L: You’re doomed. Just don’t do it.

BONNIE: Does the ice go up inside of you?!?

(laughter)

SAM L: (groan of pain)

ROOK: Oh my god…

EMMA: Uhhh….

BONNIE: I told you I shouldn’t ask!

EMMA: Then you should probably clean the spacesuit before someone else uses it.

BONNIE: Ok fair enough.

SAM L: Yeah I mean the space-

ROOK: I mean generally speaking I hope so. No matter what the temperature is outside.

EMMA: This is a fun new version of how do you go to the bathroom in space.

SAM L: Yeah. The realistic answer is that the spacesuit would have to be insulated so, uh, you’d just be standing ankle deep in pee.

BONNIE: Yeah.

SAM L: But the fun answer is that someone, somewhere, thousands of years in the future will just find a piss icicle floating through space.

BONNIE: Just gently curved.

(laughter)

EMMA: You heard it here first, folks.

(laughter)

ROOK: Um…but in ROGUEMAKER, there's a bit where, uh they're talking about y'know the Tracer being a rogue planet and uh…T-and, bleh, bleh bleh, I can talk, they're talking about uh uh the Tracer homeworld being a rogue planet and Pascal has this sort of throwaway line-ish that they're like oh, it's a rogue moon actually.

BONNIE: It's a moon.

ROOK: Because it's y'know, um, it's orbiting around the, um, the gas giant, the roguemaker. And so which made me think what, where do you draw the line between a planet and a moon and what's….what…what exactly is a planet? (laughs)

EMMA: If you-

SAM L: It's – oh go ahead, Emma, I was about to jump to the end.

ROOK: Are planets a real thing even? I've, there was a Vlogbrothers video about this recently which also had me thinking about it.

SAM L: No…no it's all arbitrary, that's why we can just say Pluto isn't one anymore. We can just decide what isn't real.

BONNIE: But why would you…if it's arbitrary why would you kick him out of the group?

EMMA: Mwahahahahaha.

SAM L: Spite!

(laughter)

EMMA: I was…I was going to say if you want to break any academic ask them a question of definitions,

SAM L: Yes.

EMMA: Because they'll just spin for hours.

SAM L: Um, it's, like, legit, I, I don't wanna say it's just vibes? But it's kind of vibes. Like with certain things you can

tell the difference between the chemical composition obviously a star isn't a planet, but between like particularly large asteroids that could be caught in an orbit and a planet, it's like…is it? I guess? Not? Maybe? We can just say it's not later. Like, it's…it's very, it's surprisingly arbitrary, to be fully honest.

ROOK: I mean, you say, like, the difference between planets and stars is really, like, obvious. But like, I dunno, when I was like learning about astronomy it's like you've got some like really small and relatively cooler y'know pl- uh stars and then planets that are y'know bigger and more gaseous and I feel like there's a spectrum there.

EMMA: It's fusing hydrogen into helium in the core. That's the difference.

SAM L: Yeah. The chemical - the chemical composition. Yeah.

ROOK: Ah. You just got - that has a, has a pretty clear definition.

BONNIE: Okay. Nice and concrete. Okay, sweet.

ROOK: But they're closer, but they're closer than I thought they were.

SAM L: Definitely.

EMMA: What's fuzzier is the difference between a really big, like, Jupiter-style planet versus a brown dwarf,

SAM L: Yeah.

EMMA: Which is the thing below a star which fuses deuterium rather than um hydrogen. But! Planet definition time.

(giggles)

EMMA: The International Astronomical Union famously - infamously - uh decided in 2006 on this definition for a planet. Uh it is only applicable in our own solar system so you'll notice it excludes all (laughing) exoplanets.

(laughter)

BONNIE: What?

EMMA: As well as, it applies to gravitationally bound objects so it excludes all rogues. Um (clears throat). “A “planet” is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium”

(Clip from ROGUEMAKER of Wóh saying “In layperson, maybe?” plays)

EMMA: Meaning it’s nearly round, “and (c)"

(Rook laughs)

BONNIE: Ohh.

EMMA: “has cleared the neighbourhood around its orbit.” So c) is the one that Pluto failed on. It’s not big enough to have kicked everything else gravitationally out of it’s orbit, there’s tons of other stuff there, but-

BONNIE: There’s some joke to be had about that last one, just, y’know I can do that at a party.

(laughter)

SAM L: Oh no!

EMMA: “Sufficient mass to”-

BONNIE: Sorry, carry on!

SAM L: Are you - are you a planet, Bonnie? Is that what you’re saying?

ROOK: Also that second one it’s like that’s a lot of words to say it’s basically a circle. It’s kind of a circle.

BONNIE: It’s kinda round. Yeah.

EMMA: It’s a sphere. Um.

SAM L: It’s - it’s like it’s not getting pulled, or like molded like play-doh, anymore, that’s how I interpet it anyway.

EMMA: Mhm. But in that specific line I was imagining that Pascal was guessing that these planets had been a planet-moon system that got kicked out of a system together. And of course later we find out that they’re not like from the same system or or whatever, like, yeah.

SAM L: Wait, ha - I’m curious about that actually. Are - cuz I was gonna ask, is the rogue moon in orbit around the gas giant or are they just kinda hanging out together on the same trajectory?

EMMA: Uhh they’re definitely in orbit around each other. As rogues.

SAM L: Gotcha.

EMMA: Yeah. But they weren’t originally. Like it it was a planet around a star.

SAM L: Mhm.

EMMA: The Tracer world.

SAM L: (whispers) The Tracer world.

ROOK: (whispers) The Tracer world.

BONNIE: (whispers) The Tracer world.

ROOK: Yeah (laughs) Uh let’s see so we’ve talked kind of about the way the roguemaker works or would work, um-

EMMA: Yeah it’s just a gravity bully.

SAM L: Huh. Jerk.

ROOK: Yeah. Meanie. Yeah. So let’s talk about, um, Pascal’s research. Y’know, they’re, they’re, um, at EE station, they talk about Aegir, or whatever, which, I, I did a, had to do a google,

I’m like, does that, is that the s-, it’s, it’s, Aegir is one of the planets that is orbiting EE?

EMMA: Yeah, it is a real exoplanet orbiting Epsilon Eridani.

ROOK: Is my understanding? I did a goog- I did a googling, it was confusing because that’s also the name of like, uh a moon, I don’t remember which one, something, a moon of a planet in our solar system I just forgot which.

EMMA: That makes sense, Jupiter and Saturn have so darn many.

(laughter)

BONNIE: Put some moons back, honey, you don’t need them all.

(laughter)

ROOK: We have moons at home.

SAM L: I was about to say that, yeah.

(Clip from ROGUEMAKER of Pascal saying “I study atmospheric dynamics on gas giants. My last paper was on the longevity of the storm systems on Aegir, which is just past the first asteroid belt around EE, I forget if you've been?”)

EMMA: But yeah, Pascal’s research is, uh, is, I have, I have several colleagues who work on atmospheres of gas giants. So I was like alright, let’s make Pascal research atmospheres of gas giants. But the cool thing is that because they’re so far in the future, we can do that much more practically. We’re not Earthbound anymore. So Pascal can be in like a space station just above this gas giant, which is frickin cool, and be like studying environmental effects on the gas giant, environmental effects that uh humans and ǵnonw are having on this gas giant, with like um all the all the comet and meteor impacts that are having because of the mining activity, we get that in the bonus episode. That’s based on something that happened in the 90s where this comet slammed into Jupiter. And if you look up images of it you can see like it literally looks like it’s bruised. Like you can see the impacts um affecting the atmosphere from

this planet and then if you imagine that this happened a whole bunch, that would be people altering a gas giant, which is nuts. So it's also sort of environmental science, Pascal's astronomy in the future.

SAM L: Yeah.

ROOK: Wow.

BONNIE: So cool.

ROOK: Yeah it's weird to think about environmental science on something that isn't Earth.

SAM L: Yeah.

ROOK: Because we're - cuz - that's where we live!

(laughter)

ROOK: That's the environment we've got!

BONNIE: Yeah. Yeah.

ROOK: But if you've got people living in other environments you've got other environmental sciences.

BONNIE: Now that we've spoken about…Jupiters…of being these potential bullies and that our one's nice, I'm now just thinking of it as like our bodyguard and it got a black eye for us.

SAM L: It very much is. It very much is. Um, Emma-

BONNIE: It's a bouncer.

SAM L: You can, you can back me up or corroborate this but I'm pretty sure Jupiter's responsible for like diverting the course of numerous asteroids that would've been hassling Earth and like the internal planets-

BONNIE: (gasp) It's our protector!

SAM L: Yeah. Jupiter - it’s, it’s hugeness, the gravity, has been like handing stuff for us for years.

BONNIE: Oh my god.

EMMA: And it keeps the asteroids corralled in their belt.

BONNIE: That’s kinda beautiful cuz it’s kinda like the opposite of Tand’s relationship with asteroid strikes, cuz like on Tand they need the asteroid strikes to bring them, the, all of the things that help them to sustain themselves. And then we’ve got our, our big bruiser planet that keeps us from getting beat up.

EMMA: Yeah.

SAM L: Yeah!

BONNIE: That’s really sweet!

EMMA: We see asteroids hitting us as like, death and destruction, and culturally on Tand the ǵnonw see that as life-bringing.

SAM L: They’re like hell yeah.

ROOK: And now I’m just imagining someone on Tand like watching an Earth disaster movie about a meteor coming and just being like “what the fuck? Like, what is going on?”

SAM L: Why are you blowing it up?

BONNIE: No one is relating to you right now.

ROOK: Your experiences are not universal.

(laughter)

BONNIE: Oh my god.

ROOK: Let’s see, are there uh, any other places in, uh uh in, ROGUEMAKER that like, unexpectedly have, uh, accurate science that you’ve just kind of shoved in there. This is a leading question, I know the answer to this.

EMMA: So yeah, a leading question perhaps, but I bet most people didn't think too hard about the lyrics of Super-casa-nova. Um which it turns out do actually include some real science about supernovae, um which are explosions of massive stars at the end of their lifetime that are just ridiculously violent and expel several suns worth of material into the interstellar medium. Um but as they're doing that they briefly are bright enough to uh just be like as luminous as an entire galaxy.

(Bonnie laughs)

EMMA: When I say brief I mean like a couple months, which astronomically speaking is very brief.

ROOK: Oh yeah that is very brief if you're talking astronomy.

SAM L: Yeah, that's all you get to look at it. We, at Swift we get requests for like this supernova just went off, like, all the time, so I'm a little bit desensitized to it but like when you really think about it it's a very short window.

EMMA: Yeah. And do you know how often they - cuz, so all these supernovae that you're looking at, Sam, would be in other galaxies, yeah?

SAM L: Yeah.

EMMA: Do you know how often they happen in the Milky Way?

SAM L: (sighs) You're asking me for definitions and specifics. Basically never, basically never.

EMMA: Yeah.

SAM L: Like if we, if we get a galactic s- like, all the supernova that we do get we look at them like "eh, another supernova, eh", if a galactic supernova went off, that would be probably the only things we're looking at or talking about for a very long time.

EMMA: Mhm. I think we'd all hear about it, yeah.

SAM L: Yeah.

EMMA: I didn’t know this stat either, I looked it up earlier today. About three times per century.

ROOK: (whistles)

SAM L: Mhm.

BONNIE: Oh wow.

EMMA: Mhm. So it’s probably like your once-in-your-adult-lifetime experience.

SAM L: Yeah.

EMMA: That there might be a supernova going off in the Milky Way.

SAM L: It’s the sorta thing where you hear about like people way back when being able to see one with their naked eye.

BONNIE: Yeah, that was what I was gonna ask, like what would that look like to the naked eye?

SAM L: It’s a star. I believe. Like that’s how I envision it.

BONNIE: But - but - just a really bright one?

SAM L: Yeah like - just uh - well, like, I think, for some reason, I feel like one happened in the 80s?

EMMA: Uhh-

SAM L: That was like bright enough to see during the day.

BONNIE: Woah!

EMMA: Was that the one that made the Crab?

ROOK: Crab? Crab? Crab?

SAM L: That may have been the Crab, yeah.

EMMA: Crab -

SAM L: Yeah. Time - time for crab, yeah.

EMMA: Crab Nebula?

BONNIE: What?

EMMA: I think so. I could be, I could be misremembering, that might be-

SAM L: Yeah I could be as well, there's a ton of history here, but-

EMMA: It might be fake news.

BONNIE: I felt like astrology was coming through for a second.

(laughter)

BONNIE: My Cancer moon? It's relevant?

EMMA: So-

BONNIE: Carry on.

EMMA: A lot of people talk about uh Betelgeuse, which is one of the stars in the constellation Orion, which we think uh is probably gonna go supernova at some point. Y'know, that could be in 1000 years, who frickin knows, but it's 'only' 500 light years away, so when that thing blows, we'll see it like during the day, like it's be, it'll be really frickin bright. It'll be really cool.

BONNIE: For like two months, we'll have a star-

EMMA: Yeah.

BONNIE: Just visible all the time.

EMMA: And that, the crazy thing too is because of like light travel time and I said it's 500 light years away, we're seeing light from it 500 years ago, so it might have already gone off and we don't know yet cuz that light hasn't reached us.

BONNIE: Ugh. UGHHHH.

EMMA: Bonnie, Bonnie is clasping their, is like running their hands through their hair like tearing their hair out -

(laughter)

BONNIE: I know this on paper and then you say it and I actually think about it and it's just, it's just like, I, I know it, I know it, but on my god.

SAM L: I I actually just looked up the supernova thing. Uh. Was kind of right. Apparently the last one went off sometime between 1890 and 1910,

EMMA: Mhm.

SAM L: But by the time that the light got to us and we were able to see the remnant it was 1985.

ROOK: Mm. Okay.

EMMA: Okay.

BONNIE: Oh. Oh oh oh okay.

SAM L: Yeah.

BONNIE: That makes sense. Ugh.

EMMA: Nice. I found another statistic, which is that um if you had a supernova that's like 10 parsecs away, so that's like 32 light years away, it would be, let's see, so you know Sirius, the brightest star in the night sky?

ROOK: Mhm.

BONNIE: Mhm.

SAM L: Mhm, Sirius Revel Six, yeah.

EMMA: Yeah, and home - famously, home of the Sirius Revel series of battle-of-the-bands competitions.

(laughter)

EMMA: We never did make it there. Anyway, um -

ROOK: We'll go - we'll be at Sirius Revel Seven sometime.

SAM L: Yeah.

BONNIE: Yeah.

EMMA: Yeah. If a supernova went off 32 light years away from us, it would be 1.5*10^7 times brighter than Sirius.

SAM L: Christ.

EMMA: That's like 15 million if I'm doing that correctly?

SAM L: Ten to the seven? Yeah.

EMMA: Fifteen million times brighter than Sirius.

(laughter)

ROOK: Yeah so you could see it in the city.

BONNIE: I don't know how to compute that.

EMMA: I don't either, honestly.

SAM L: Let's not talk about the magnitude scale here, Emma, I'd love to go on about the magnitude scale, but (grumble)

BONNIE: Ok..ok…ugh…huh….

EMMA: Yeah let's not talk about the magnitude scale, it's a, it's a shit show.

SAM L: It is.

ROOK: Things are too big! Our brains are not meant to think about things that are too big.

(laughter)

SAM L: No we're meant to stand in a field and eat apples. That's, that's it, not think about this stuff.

BONNIE: Yeah I can't even cope with the size of buildings in Manhattan, I have to pretend they're painted on or I start to panic.

(laughter)

BONNIE: You, you laugh but I'm serious!

SAM L: Oh no!

EMMA: Most people, if you like, told them to like pick a starting spot and then go stand I dunno a hundred feet a hundred meters whatever some smallish distance away from it, they would be way off. I think everybody's concept of even these closer ones that we deal with is way off.

SAM L: Yeah.

ROOK: Humans aren't meant to measure things, we're messing with the natural order of things, by… (laughs)

BONNIE: Burn all the rulers!

(laughter)

(Clip of Super-casa-nova plays, with Woh and Lowkey singing "super-casa-nova" back and forth and finally "Just this once we outshine the galaxy/Outshine the galaxy")

ROOK: Anyway, uh, speaking of things humans aren't meant to do, what's up with faster than light travel, cuz you've got lightflight - we've got lightflight -

(laughter)

SAM L: Excellent, excellent segue.

BONNIE: That was so smooth. That was good.

ROOK: We've got iridium. What's going on with iridium and lightflight in ROGUEMAKER?

EMMA: (shrug noise)

(laughter)

ROOK: Alright next question!

EMMA: Everybody gets - everybody gets one handwave. Iridium was chosen because the way that people figured out that um an asteroid impact killed the dinosaurs is that iridium is more plentiful in asteroids than in Earth's crust. There's this layer of iridium on the Earth from the geological era of the asteroid impact which meant it must have been an asteroid impact. I picked iridium because it's more plentiful in space than on Earth.

ROOK: Mm.

SAM L: That's really good.

EMMA: That's the only thought that went into that. The rest is just I dunno they can go faster than light and they're fine.

(laughter)

BONNIE: It's fine. It's fine don't worry about it!

SAM L: That's a whole, it's, like, thinking about, actually, the way, just, as a small detour, the way that I originally got into physics and thus astro was all those books that you'll see around that's like theoreticians being like here's how we can go faster than light, like here's how we can time travel, here's all like the quantum tunneling and teleportation stuff, which is like, at best 50% real science, but like that's enough to really get your brain going.

ROOK: Mhm.

SAM L: Um - and -

BONNIE: It's enough to really get my brain to shut down.

(laughter)

SAM L: Mm. I - I've seen - like there's a bunch of things just like oh here's how we can go faster than light, but I feel like the only one that people were like, was physically possible, because light is the speed limit of the universe, or the speed of light is, uh, was people were talking about some way, that if you kind of cheated, and found a loophole in physics, where instead of making you move through space faster than light, you could compress the space behind you and uh expand the space - or compress the space in front of you and uh expand the space behind you and then you'd be able to cheat because you're not technically moving faster than light-

ROOK: Ah, you're just, you're just moving through less space somehow.

SAM L: Yes! Exactly.

BONNIE: That's what it looks like they're doing in Star Trek as well.

SAM L: It is, the visual effect, yeah.

ROOK: Oh yeah isn't that like, I mean, is that what warp is, they're warping space? Is that what Star Trek - have we solved how Star Trek works?

SAM L: (shrug noise)

ROOK: Y'know, ROGUEMAKER: Behind the Science…of Star Trek.

SAM L: I'm using, I'm using my handwave on that.

(laughter)

ROOK: Um, anyway, uh, now that we've gone extremely in-depth on faster-than-light travel and how it's definitely possible and Emma knows everything about it, um-

[Sam laughs]

EMMA: You mean Sam?

ROOK: Sam also.

SAM: [noises of disagreement]

[Rook laughs]

BONNIE: I was here!

[All laugh]

ROOK: And Bonnie was here too, as was Rook! Um… how ‘bout them aliens? Um, I don’t really have a concrete question about aliens, but I know that Emma wants to talk about aliens so hows- hows- howsabout aliens?

SAM: It’s cool. This is cool.

EMMA: Yeah! So I bet everyone’s expecting me to talk about the ǵnonw here. I’m actually not going to because most of what I thought about them was um, more social? Than like-

SAM: Mm.

EMMA: …Was more societal stuff. I wanna talk about the Tracers a little bit. Um [laughs] our other aliens that we never really see except for one of their robots. Because I wanna talk about this thing called the Kardashev scale, which, um-

BONNIE: [quietly] Oh yeah…

EMMA: …is also very mind blowing. So, uh, this Soviet astronomer named Nikolai Kardashev came up with it and it’s this scale for how powerful a civilisation is in space. So it’s- if you have a Kardashev level of 1 you are able to use all the energy from a planet. Like, the entire planet. If you have a Kardashev level of 2 your civilization is able to harness all the energy of an entire star, which is way, way, way more than a planet. If you are a Kardischev 3 civilization you are able to harness all the energy of a galaxy.

[stunned silence]

ROOK: Woah…

EMMA: Where would you guess humanity is on the Kardashev scale?

[Sam laughs]

ROOK: I mean you talked to me about this so I'm not gonna answer.

EMMA: Yeah.

SAM L: It's gonna have to go to you, Bonnie, cuz I know the answer.

BONNIE: No, I was there for this conversation!

SAM L: Oh no!

EMMA: Ah frick, I talked to too many people!

ROOK: God, stop being so social, Emma!

SAM L: We're like a zero, or a 0.5 right?

BONNIE: God Emma, stop talking about the cool things you know…

[Sam laughs]

SAM L: Like obviously we're not even at a 1 yet.

EMMA: No we're not at a 1.

SAM L: Yeah.

BONNIE: Yeah I would have- even before you said I would have guessed that we weren't at a 1 yet.

EMMA: Yeah we're at a .73 is what-

BONNIE: Ok!

ROOK: That's not too bad.

EMMA: -is what the people who have done the math on that apparently say.

BONNIE: That is troublingly close actually…

EMMA: Yeah I shudder to think actually when we hit 1, um…

SAM L: MMM.

EMMA: If we survive to that.

BONNIE: Let's go back a little bit, let's back it up, guys.

EMMA: The Tracers I think would only be about a 1.7. They're beyond the planet level but they're not actually quite at the star level, but they can create this scary thing like the Roguemaker. Because that thing is not as massive as a star, it's still planetary-scale.

[noises of agreement]

EMMA: I just- They're not even… They're not even at the star level and they're that scary? I just- I cannot even wrap my head around-

BONNIE: Yeah…

EMMA: …what a Kardashev 3 civilisation would be.

SAM L: Yeah. You can do plenty of crazy shit before you can even har- like, build a Dyson sphere, which is a theoretical construction around the surface of a star which harnesses all of its energy.

EMMA: Yeah.

SAM L: You can do all sorts of stuff before you've reached that level.

EMMA: Yeah, like it's just extra to go beyond that.

SAM L: [laughs] Yeah.

BONNIE: I mean so many of the things that humans have already done are like, amazing and/or terrifying, so…

[noises of agreement]

BONNIE: So to think- and that's stuff that's- I- we already done that. That's scary. Scale, again. Scale is breaking my brain.

SAM L: This whole like- even in science fiction, it kind of puts everything else into like a really weird, interesting perspective.

BONNIE: Mmm.

SAM L: Yeah. It's like these- these unknowable hyper-beings that made whatever that AI was…

BONNIE: Makes you realize why they call it "cosmic horror" doesn't it?

SAM L: Yeah!

[Sam and Bonnie laugh]

EMMA: Yup!

BONNIE: You're like "Oh, ok! We're talking about stuff that we can't even talk about cuz we don't even know cuz it's so big it'll break the brain."

EMMA and SAM L: Mhm!

EMMA: Just breakin' the brain, everyday, that's what I'm doin'!

[*clip of Lowkey singing "Did you build a giant death machine / take yourselves off of the scene? Portal to a new dimension / stars, I just can't take the tension! / Did your empire collapse and fall / did you shrink yourselves down really small? / Or take off to Andromeda / can't explain these phenomena" plays*]

ROOK: So now we're going into some stuff that uh, isn't, um astronomy-based, but other- other sciences that we've got. There's the ǵnonw double-chambered larynx has got a lot of people very curious, and I dunno, Emily was saying some things about birds. What- What's up with double-chambered larynxes and the ǵnonw?

EMMA: Yeah, so that was not my idea. That came about very last minute because of what Emily wanted to do with the song, so I'm gonna let Emily explain that one to us.

EMILY: Hi! My name's Emily, I'm the composer with Roguemaker. I also happen to be a biologist. So when Emma started writing Wanderer's Lament, which is sung by the amazing Alex DeAngelis who plays Woh́ in the show, I thought it would be really cool to add some harmonies. I really, really love folk songs that have these deep intricate harmonies, and I wanted that for our show. The only problem is, to my knowledge humans can't really harmonise with themselves with the exception of things like whistle tones and throat singing, which is not exactly something you can just pick up in a day. So I started thinking about other animals that sing in nature, and I got on the idea of birds. Birds can sing two melodies simultaneously because of a specialized vocal organ called the syrinx. Unlike the vocal production organ in humans called the larynx, which is essentially one cavity or chamber, the syrinx in birds splits into two chambers leading eventually to the lungs. Each chamber can be operated independently of one another by vibrating an internal membrane, AKA the walls of the syrinx, to produce a sound. In this way not only can birds vocalize two melodies simultaneously, but they can also take a breath in the middle of a song without disrupting the flow. In Roguemaker I had the idea to give the ǵnonw a double-chambered larynx, which would work similarly to the vocal organ in birds, functionally giving them the ability to harmonize with themselves, as well as double their laughing and breathing. This is all loosely-based though, since I'm not a linguist, and this definitely isn't my area of expertise, but that's pretty much it!

[*clip of Woh́ singing in harmony with themself "So where are you going / and where do you sleep? Through my bones wind is blowing / but who is there to weep?" plays*]

ROOK: And now for my character's great scientific contribution to Roguemaker, um, THE BENDS! Uh… THE BENDS!

BONNIE: THE BENDS!

EMMA: THE BENDS!

ROOK: Uh yeah, I know it’s a thing with scuba divers, but- But uh… Whassup with the bends… man?

[laughter]

SAM L: It’s just pressure. It’s just pressure on gasses in your human body.

EMMA: Yeah!

SAM L: We all got gasses in us sometimes!

BONNIE: I hate thinking about the gasses in my human body…

EMMA: Yeah.

SAM L: Yeah, it’s the worst.

BONNIE: There’s- there’s like some I know about, but then there’s all these ones in places that I- I don’t like that they’re there.

[laughter]

SAM L: No? Well they’re there anyway…

EMMA: Yeah.

BONNIE: Why are they in my joints? Why are they in my joints, Emma?

[laughter]

EMMA: Yeah, they’re - [laughs] I can’t answer that question. Yeah it’s a problem with pressure changes, and it’s the opposite with space than it is with the ocean because space is a much more low-pressure environment than what we’re used to whereas the ocean is a higher-pressure environment than what we’re used to, but a rapid pressure change from a high pressure environment to a low-pressure environment can cause those gas bubbles to expand in a Bad Way.

BONNIE: Eesh…

EMMA: So Trip experiences one of those on the surface of the Rogue um and then like, is still hurt- like, he's been returned to the correct pressure environment but like, in order to help flush out that nitrogen from his blood stream he needs to breathe pure oxygen, which is a real thing that they do to divers who get the bends. My diving instructor the day that I got certified got the bends, so that was an omen.

ROOK: OH NO.

SAM L: Damn!

EMMA: She was fine, it was minor, but-

ROOK: The thing that we kind of hand-wave of like, Chasma saying that on Doctor Sang they saw, uh, Doctor Sung doing some snappy procedure to the joints, is that a real thing or is that a thing they made up on Doctor Sang?

SAM L: Mm.

EMMA: I- That definitely came about from me doing some sort of research while writing the script but I cannot remember the details.

[laughter]

ROOK: Amazing.

SAM L: Valid.

BONNIE: [laughs] Absolutely fair.

SAM L: But the uh, the temperature difference thing I think is why in so many science fiction shows, like when people get off of a spaceship or go onto the spaceship, they'll always have this little interstitial room that does some kind of process with like hissing and like steam and like [fshhssst shhhh kkhhhkhkhh] and that to me is like, we're equalizing the pressure now so that you don't like, explode once you get into this differently pressured environment.

EMMA: Yee.

BONNIE: Was that- I was- this can be an aside but I remember watching a film as a kid with people going down to a deep sea… research lab and they're in the like, the elevator going down, and the air they- they're breathing like a mixture of… oxygen and helium?

EMMA: Mhm!

BONNIE: And I'm guessing it's probably something similar.

EMMA: Yeah.

BONNIE: Also if anyone can remember what that movie is I wanna watch it again cuz it scared the shit out of me.

[Transcriber's note: The movie is The Abyss (James Cameron, 1989)]

[laughter]

BONNIE: And I LIKE BEING SCARED.

EMMA: One of the things where humans actually can like, withstand a greater range of stuff than you would think is breathing various atmospheres. Like oxygen's the important bit.

SAM L: Mhm.

EMMA: We need a certain amount of oxygen, but you can s- a lot of the other stuff in atmosphere isn't really doing anything for us and you can substitute. You can substitute helium for that- some of that nitrogen, because nitrogen is the problem.

ROOK: Then you just talk like a chipmunk.

EMMA: They do, yeah. [laughs]

SAM L: Mmmhmm!

EMMA: It's true.

BONNIE: And there's one you can breathe that makes you talk super low as well.

ROOK: Oh yeah!

SAM L: Mmm!

EMMA: Oh really, what's that?

ROOK: I think I've heard- I mean it's a heavier, it's a heavier gas instead of a lighter gas.

SAM L: Yeah, it's like boron or something?

BONNIE: Adam Savage did it on uh, Mythbusters.

ROOK: Oh I think I saw that as well!

[Transcriber's note: Adam Savage demonstrates with helium and sulfur hexafluoride: https://www.youtube.com/watch?v=d-XbjFn3aqE]

EMMA: As a voice actor that'd be kind of fun to try out!

[Rook giggles]

BONNIE: And we just- we just assume this is normal pitch just cause of the air that we're breathing-

ROOK: Yeah who needs voice modulation programs when you've got- when you've got gasses! Various gasses!

BONNIE: Exactly!

EMMA: You know what, I wanna see that- I wanna see that in a sci-fi, is everybody goes to a planet that has like a helium-oxygen atmosphere and they're all sounding like chipmunks!

BONNIE: YEAH!

ROOK: YEAH! That won't be annoying to listen to AT ALL!

[Sam laughs]

BONNIE: Everyone laughs about it for like three minutes and then the rest of it is just played straight.

EMMA: Yep!

SAM L: MMMM.

EMMA: That’s what would happen!

BONNIE: That would be spectacular.

SAM L: I agree, yeah.

EMMA: Sound would conduct differently through like, different uh, air densities as well.

ROOK: Ooh!

SAM L: MMM!

BONNIE: Yeah! Oh that’s really cool.

ROOK: Speaking of sound being conducted, that leads so perfectly to my next question!

[laughter]

SAM L: Nice.

ROOK: Which is something that I was talking about at a bar last night, bragging about how cool my friend was for designing this, so as we all know in space no one can hear you scream.

[laughter]

ROOK: So Emma talk to us about sound designing in a vacuum!

EMMA: Yeah! Um, the answer is low-pass filter.

[Rook laughs]

EMMA: That'll make sense to the sound design geeks out there, um-

[laughter]

EMMA: I did- I did some research and I was like, looking at what, uh, people who've done spacewalks say that they can like, hear during spacewalks, um, and you can pretty much just hear the stuff inside your suit, so there'd be like, a gas hiss, you might hear like, the rustling of the fabric as you're moving your arm around, um, or if like, something thunks against the suit you could hear like, the vibration of that travel through the suit to you, um, or there's like-

ROOK: Or if you're an astr- Sorry, I was just thinking about, so when I was talking about this at the bar last night someone was talking to me it was like "Oh, astronauts if their comms- if their comms don't work they just kind of thunk their helmets together and they can hear each other through the- through the helmets." And I'm like "WE DID THAT ON THE SHOW, EXCEPT WITH PODS!" [laughs]

SAM L: Ohh!

EMMA: Exactly!

BONNIE: SO COOL.

SAM L: That's great!

EMMA: I got that from The Expanse, there's a bit where their comms go out-

SAM L: Mmm!

EMMA: -and there's two of them like, like, like, hugging each other and like, like, the glass, or whatever, plates of their spacesuit masks are touching and the vibrations are what's carrying their-

BONNIE: That's sort of adorable!

EMMA: And the ǵnonw do- I guess I will talk about the ǵnonw a little bit. They definitely do some- Like, they're much more sensitive to vibrations than humans are, so that's why Tarsul is like "Alice, you don't need to yell. What are you doing?"

[*clip of Alyss muffled, shouting, "You can't ignore me forever!" and Tarsul groaning and responding, "Argh, stop yelling!" Alyss: "What?!" Tarsul: "Ah! I said STOP YELLING."*]

SAM L: OOHHH that makes so much sense!

BONNIE: [laughs] Nice!

EMMA: Yeah! So- but yeah, low-pass filter is what gives you that nice, nice muffled sound. You also hear it when Woh́'s pod closes and Lowkey finishes his line about how it's gonna be ok.

[*clip of Woh́ and Lowkey from episode 1, alarms and Ship's emergency announcement in the background, Woh́: "It's gonna be ok." Lowkey: "I've got the best bandmate in the galaxy, so of course-" (sound of the pod door closing) Lowkey (muffled): "It's gonna be ok." Ship (distant and muffled): "This is not a drill."*]

BONNIE: Even thinking about that gives me chills. I love that sound design so much.

EMMA: Yeeeeah. So that's how you do that. It's tougher than it sounds to sound design for a vacuum.

ROOK: Yeah, sound design for a place where sound can't travel. Have fun!

SAM L: Yeah, exactly!

EMMA: Cause you've gotta make it make sense to the listener too, it can't just be a weird series of noises that they're not gonna be able to interpret, so I probably was like…

BONNIE: Yeah, or just silence.

SAM L: Yeah, if you- if you can get it to a spot-

BONNIE: "WE'RE ALL WATCHING AN EXPLOSION RIGHT NOW!"

[laughter]

[*clip of Kuzha: "(sigh) Space explosions are so boring. Where's a good atmosphere to conduct sound when you need one?"*]

ROOK: Yeah, no, I was- I was going- if no one else had I was going to bring up the thing of like, you know, space explosions are just being- just being boring and anticlimactic when, you know, in so much of science fiction it's like "oh, bbsshh, big explosion in space" or it's like, [sigh] yeah it just sort of happens. It's just sort of a little thing.

SAM L: Yeah.

ROOK: And um, I know you've- you've spoken about this a lot before, but uh, talk to me about Ship, Emma, and writing AI. Cuz I think-

EMMA: Yeah.

SAM L: I'm really interested in this.

ROOK: One of the things- that's one of the things that really interested me in the way you wrote Roguemaker, cuz like I've, you know, been seeing a lot of things with AIs pop up, like, I dunno, I read the Murderbot Diary series, and I like, listened to The Mistholme Museum of Mystery, Morbidity, and Mortality, which is another audio drama which I highly recommend. But it's like- I feel like in a lot of ways people write AIs is they sort of use it as they have them act basically human, or human with a little bit of difference, and it is- you know, you see humanity in them but you like- they sort of projects a sort of difference, like a lot of AIs just sort of seem like, neurodivergent and you know, see a lot of autistic people, uh, projecting onto Data from Star Trek. I've never watched Star Trek, I just have heard a lot of autistic people projecting onto him.

[Bonnie gasps in neurodivergent who projects onto Data]

ROOK: Um, and while I really love these depictions of AI I feel like you take a very different approach to AI sentience, or

sapience I guess is the correct word technically that I don't really hear anyone else use.

EMMA: [laughs] Yes, but it's my hill to die on, so we're using sapience and sapient instead of sentience in Roguemaker. The difference is if you're sapient you can think, like "I think therefore I am." If you're sentient you're just like, sensory experiencing the world around you. So like, a snail is sentient, but it's not sapient.

SAM L: Yeah.

BONNIE: Is- IS Ship sentient? Does Ship has- have- I mean, some senses, or sensors…

SAM L: Oooh! Sapient but not sentient.

EMMA: Sapient, instead of sentient, you mean?

BONNIE: No, I mean, is Ship ALSO sentient?

EMMA: Ah I- Hmm… I dunno- I- I-

BONNIE: Sorry, I've derailed…

EMMA: Yyyes?

SAM L: That's the question!

EMMA: But like, for a different- I guess for a different definition of senses?

[noises of agreement]

EMMA: Like, Ship definitely senses its environment and reacts to it and responds to its environment. Uh, there are a lot of machines that do that.

BONNIE: Yeah.

SAM L: So Ship could FEEL all the viruses in the Titan's system!

[Rook laughs]

BONNIE: [mimics noises of panic/anxiety]

SAM L: Just like, scurrying around!

EMMA: Yeah!

BONNIE: “ITCHY! IT’S ITCHY”

[Rook laughs]

EMMA: But also, like, Ship can tell when like, Malachi walks across the room. Like-

ROOK: Mhm.

SAM L: Aww…

BONNIE: Right, yeah.

EMMA: Umm…

BONNIE: Awwwwwww…

[Emma laughs]

BONNIE: [joke sobbing] …Just thinks it’s neat…

[laughter]

EMMA: We know how you feel, Bonnie.

BONNIE: I feel so many things… Ok, sorry-

EMMA: But yeah, I did purposely try to write Ship differently than a bunch of AIs I’ve come across, and like the- I refuse to answer whether or not it is sapient, but I will definitely say that I’ve- Like, there are a lot of AIs that are definitely, definitely sapient, and the fact that I refuse to answer that means I am… more towards the other end of, you know, “Could go either way, can’t really tell!” But people will personify and attach onto ANYTHING, and that is absolutely- I am TRYING to do that with Ship, that is the goal, I want people to like, latch

onto it, sympathise with it, whatever. Um, it's like the same way-

SAM L: You do a really, REALLY good job.

ROOK: Yeah it's very sad that like, kind of nobody really likes- nobody really appreciates Ship except for Malachi in the-

EMMA: Mmhmm!

ROOK: …in the- in the podcast which I found was such an interesting choice because I feel like in the- in the- um… in the LARP a lot of people did. I mean there were definitely people who were like, "Shut up, you stupid robot who can't do anything good!" But it's like, I feel like more of the characters did, you know, decide to pack bond with the AI, um…

EMMA: Mhm.

[Bonnie and Sam laugh]

EMMA: Well it's like the difference between like- I dunno, people make fun of Siri all the time, and that's sort of what I was going for, or they'll just make like, an "Alexa, play Despacito" joke or whatever. Um-

[Bonnie giggles]

ROOK: "SHIP, PLAY DESPACITO!"

EMMA: Yeah!

ROOK: "This is so sad-"

SAM L: OHHH!

BONNIE: Like you plug in your destination and then you tell your sat-nav to shut up.

EMMA: Yeah!

[Sam laughs]

EMMA: But on the other hand-

BONNIE: Everyone I know does that.

EMMA: On the other hand you've got stuff like, um, the- the Mars Rovers, which I have shed real tears-

SAM L: Mmmmmm!

EMMA: -over some comics people have made about the "It's getting dark and I'm running out of battery" uh, thing.

BONNIE: [fake sobbing] My heart!

EMMA: And like, NASA absolutely plays into that on their social media, they're like, "Hi, my name's Percy! I'm the Perseverance Rover. Today I've been to Jezero Crater and I've done blah blah blah." Um… Like, they're personifying their -their robots and it's- it's a ploy and it works and I fully buy into it!

[laughter]

SAM L: Yeah! Humans are- humans are social animals, and there's something inherently like, sad and relatable about just this little machine that's just doing its best on the surface of a faraway world!

ROOK: Yeah, I mean people will treat their Roombas like a pet, you know? Like… [laughs]

SAM L: Yeah!

EMMA: Exactly.

SAM L: "It's my friend!" "I just wanna be ok!"

EMMA: Like, what's the difference? The difference is Siri and Alexa talk, maybe?

SAM L: Mhm, mhm.

ROOK: I mean also they're stealing your data or whatever, but you know…

EMMA: Yeah, but Ship is too! Ship is a corporate robot. Ship is a corporate AI.

BONNIE: Yeah…

SAM L: Get it the f- get it the fuck off the- off the Titan! Get it off my fuckin' ship!

[laughter]

ROOK: We can't let Ship know about all of the drugs we're doing!

SAM L: Goddamnit!

[laughter]

BONNIE: All of the piracy we're committing!

ROOK: Is Ship a required reporter?

SAM L: Oh my god…

[Bonnie gasps]

EMMA: Well Ship doesn't work for Plutonic anymore I guess, um… But to bring it back for a little bit-

[laughter]

EMMA: The things that I think about when writing a Ship line, and this does relate to actual artificial intelligence, is- and like, coding in general, is what has been the computer's input, and then what is its purpose? What is its goal, what is it trying to do? It's like a combination of those two things: what input has it received from its customers, and then what is its goal, which is customer satisfaction. So what is it going to say that will best attempt to further that goal based on the input. Which, honestly, you can think about your own conversations that way if you want to, like, break your brain a little bit.

[laughter]

EMMA: But that is how I wrote Ship.

BONNIE: It's that- it's kind of the question of- of, uh, is there any such thing as true altruism? It's like am I just doing it because that make me feel good?

EMMA: Mhm!

SAM L: Yeah…

EMMA: Yeah.

BONNIE: Is it- my purpose is customer service, oh no…

EMMA: There's also this principle in, um, machine learning particularly, that's like, garbage in, garbage out. If you feed the thing bad data you're gonna get bad stuff out of it. So like, an artificial intelligence does have some amount of intelligence and will like, learn as it goes from the data you give it. So Ship also has been influenced by um, its environment and who has been around it, namely Malachi. So any differences that this installation has from other installations of the same software would be because of its experiences and because of what Malachi has been feeding it.

SAM L: I was actually gonna ask you about that, which you've already kind of answered, whether or not your vision of Ship's intelligence was just like, a very complex decision tree? Like, if you get this input then you do this designated output, or if it's machine learning where it kind of designs itself over time. That's really interesting.

EMMA: Yeah I think it's the latter, otherwise I don't think it would really be an AI.

SAM L: Yeah. Yeah! And it- it's also terrifying to think what if our Ship met like, a Ship install fresh off the assembly line?

EMMA: Mmhm!

BONNIE: Mmm…

SAM L: Like, what would that interaction be like? How much more alien would-

ROOK: Oh my god, new bonus episode idea! Ship just- it just- It's just Emma talking to herself!

[laughter]

BONNIE: Just Emma!

SAM L: Yeah! Just back and forth!

EMMA: It would be very fun to voice act, I'll say that!

SAM L: Yeah!

[Bonnie laughs]

SAM L: We c- we could have it do like, uh… I don't wanna say we. You could have it do like a GPS thing, where each Ship install has potential different voices. So maybe it's not just you talking to yourself if you don't wanna!

[Emma chuckles]

BONNIE: It's also- and going back to the input-output kind of thing as well, I was just thinking, like… For a split second I was like, "Oh well there's not much of Tarsul in Ship," and then I remembered the bonus episode and it's like, so well-explained that Tarsul just has Ship off and doesn't interact with Ship…

EMMA: Tarsul just does not talk to Ship!

[Rook and Sam laugh]

BONNIE: …for anything but the bare necessities. So like, every sort of, like, personality-style bit of learning that has come, it's all been from Malachi, not- not at all from Tarsul.

SAM L: Yeah…

EMMA: Mmhm!

BONNIE: I- although I suppose things that maybe Malachi has reported about Tarsul-

SAM L: [skeptical noise]

BONNIE: …but again through Malachi's lens.

SAM L: It makes a lotta sense why Malachi gets along so well with Ship then, because they probably think very similarly at this point.

EMMA: Mhm!

BONNIE: Yeah…

ROOK: Yeah.

EMMA: Yeah.

BONNIE: And they like the same books.

SAM L: Yeah!

ROOK: And would, like, would a different install of Ship ever give inspiring quotes, or is that like, purely Malachi-influenced, because they've read all these things?

SAM L: [gasps] Ohhhh!

EMMA: I saw that as coming from the reading list.

[laughter]

EMMA: But the stuff like, um, like the reminder to stay hydrated, etcetera, etcetera, that was probably more corporate programming.

ROOK: I love Ship so much.

EMMA: Me too.

[Bonnie laughs softly]

SAM L: It's really, really good, I- I was also curious about one thing because it was like, bandied around a little bit in like,

the production server, uh, of like, Ship being like, potentially like, the secret villain…

BONNIE: Mmmm.

SAM L: …Like, “Oh the hostile evil AI doesn’t have feelings!” Like- And I feel like you tried to maybe play into that a little bit? Uh, or at least you were talking like you were, and like- Or at least you got a kick out of the idea that Ship could be evil secretly!

[Bonnie laughs]

EMMA: Mhm!

SAM L: Um… How- how much of like, that uncanny like, this-is-not-a-human like, vibe were you giving- like, looking to kick off of Ship?

EMMA: Hmm.

SAM L: …In order to set the- set the atmosphere?

EMMA: That’s a good question. I mean the evil AI is such a trope, right? Like that pops up all the time. I just decided I didn’t want to do that, but I didn’t mind if people thought that? And again, Ship has been programmed by a corporation! [laughs] Like it’s- [laughs] it- it is meant to be…

SAM L: So it’s inherently evil, is what you’re saying?

ROOK: Exactly.

BONNIE: Yeah!

EMMA: It is meant to be uncanny, that is like, a terrible grating customer service voice, it’s like- [laughs] Yeah, I don’t mind if people really don’t like it.

ROOK: It’s just me at my retail job!

[Bonnie laughs]

EMMA: Yeah!

[laughter]

BONNIE: Yeah! Me and my phone voice.

EMMA: Exactly.

SAM L: Ughhh…

BONNIE: And then it's- it's interesting as well, like, I mean I guess we've already talked about it, but that sort of- the self-awareness of like, "Oh, this isn't in my programming but it seems to distress you. We should- we should discuss upgrading that." And it's like…

EMMA: Yeah!

BONNIE: It's not about keeping people happy beyond, that's the, uh, that's the protocol.

EMMA: Yeah! It doesn't have emotional range so it can't sound sensitive when people are distressed! You think that's maybe a problem, Ylem Interstellar? Maybe?

[laughter]

SAM L: Noooo, it's fine! It's fine! [laughs]

ROOK: And so aside from- I mean earlier we talked about the "outshine the galaxy" line in, uh, Supercasanova, but I know you've got other little easter eggs planted in there that are scientific stuff, um… Do you want to maybe talk about those? And when I say "do you want to" I mean "I know you want to because you put it on this document".

[laughter]

EMMA: Thank you for bearing with me, Rook! Um, Sam can probably attest, and I've heard from a lot of my office-mates that they've been enjoying the astronomy jokes that are just sprinkled into the show, cuz there are several.

SAM L: It’s great. I get a kick out of the “magnetic fields” one every time.

[*clip of Pascal saying “Never could get the hang of magnetic fields…”*]

[Bonnie laughs]

EMMA: And that’s HILARIOUS if you’re an astronomer. It’s HILARIOUS.

SAM L: Yeah!

EMMA: Because-

SAM L: Because-

BONNIE: And why is that?

EMMA: Go for it!

SAM L: No one- no one’s gotten the hang of magnetic fields. It is a well-known fear that like, you’ll be giving a- uh, like, presentation at a conference or something up in, like- It’s all structured and it’s all great and you’ve got all your stuff figured out, and ONE JERK in the audience will just be like, “Have- have you considered how magnetic fields will affect these?” And you just have to go, “MM. [silence] Yes YOU over THERE, what was YOUR question instead?”

EMMA: “But have you considered magnetic fields?” is a bit of a meme in the astronomy community.

ROOK: I mean it’s like what ICP says: “Water, fire, air, dirt / fucking magnets, how do they work?”

[Bonnie laughs]

SAM L: EXACTLY. EXACTLY. WISDOM.

EMMA: We don’t know!

SAM L: [laughs] We just don’t fucking know.

EMMA: Yeah, god, the other- Oh and then also the astrology joke.

[*clip of Lowkey saying, "Oh yeah! You're like, a* real astrologer, *right? I only dabble in that, I'm- I'm mostly into mindfulness myself," and Pascal replying, tersely, "I'm an* astronomer.*"*]

SAM L: [angry noises]

EMMA: Sam, have you been called an astrologer?

SAM L: I think maybe at like, a… a family get-together at one point? So I no longer talk-

ROOK: Oh no!

SAM L: I don't talk to that person anymore.

[Bonnie laughs]

ROOK: For this reason?!

SAM L: Uhh yeah.

[laughter]

BONNIE: Spectacular.

SAM L: But luckily it hasn't been like, a very common thing, uh, because most of the times when I'm like, being very astronomy is around other astronomers. But it is a very common misnomer, it's just deeply, deeply upsetting.

EMMA: Most astronomers have a story of the time that someone called them an astrologer.

SAM L: Yeah…

ROOK: There was at least one person who auditioned for Pascal and because the names weren't settled in when we put out the casting call, um, the- uh, instead of the names of the character people auditioned with like, a title like "The Racer" or "The Stowaway" or "The Astronomer". And there was at LEAST one person who when they slated- when they stated their name and the

character they were auditioning for, uh, there was at LEAST one person who said “astrologer”.

[Bonnie laughs]

SAM L: [angry noises]

ROOK: I don’t remember if there was more than that, but there was definitely at least one, and there was also an “astroNOmer”.

SAM L: That’s good!

EMMA: It was great. We were like “well we definitely can’t cast THAT person” and then we got an astrologer anyway!

BONNIE: Eyyyyy!

[laughter]

BONNIE: But luckily I can hide it!

ROOK: It’s important to know that the astrology line was put in there far before we cast Bonnie and far before we knew that Bonnie was into astrology!

[Sam laughs]

BONNIE: Yeeeeaahhh!

SAM L: Method acting!

EMMA: It’s ok, it’s ok, I know my signs as well. Sagittarius sun, Virgo moon, Cancer rising. If anyone wants to know.

BONNIE: And OOH it shows! [laughs]

[Sam groans]

ROOK: I’m a Sag sun and I have a- I have a Co-Star, so…

[Emma laughs]

BONNIE: Yeah you do, I see you on my- my dailies! I see you!

ROOK: Uhh yeah, Capricorn rising, Gemini moon!

BONNIE: Cap rising! Yoooo!

SAM L: I figured mine out-

ROOK: This means NOTHING to me.

BONNIE: It means we're good at bullshitting, Rook!

EMMA: [laughing] Yeah.

ROOK: Ah! Yeah…

EMMA: Other than all of that, just basically I just want people to know that every time there's a-

ROOK: Bonnie, Co-Star says that we should design tattoos for each other.

BONNIE: Aw hell yeah!

SAM L: Just- just before we get- Libra sun, Virgo moon, Capricorn rising, that was mine. I don't know what the hell that means.

EMMA: Alright-

BONNIE: LIBRAAAAAA!!!

[Sam laughs]

EMMA: Somebody out there- somebody out there is hastily taking notes.

SAM L: OH NO! [laughs]

BONNIE: Oh no, my bank details!

SAM L: My social security number!

EMMA: Oh god…

BONNIE: Happy recent birthday or soon birthday, Sam!

SAM L: Oh, thank you! It was a couple weeks ago. That means a lot!

BONNIE: Yay! [quiet chanting] Libra, Libra, Libra…

[Emma laughs]

EMMA: So it meant something!

Rook: And Emma's birthday is the day after mine.

EMMA: Yes.

SAM L: Oooh!

BONNIE: Yep.

EMMA: Hence the both Sagittarius sun. Um, the only other thing that is really an easter egg is that every time a random number shows up it's an astronomical constant, or some number that is important in astronomy. Um, 206265, which is the code for that safe that Alyss mentions, is the number of arcseconds in a radian.

SAM L: Ohhh! [sound of mind exploding]

[laughter]

EMMA: Yeah!

[*clip of Alyss from episode 2 saying "Locker J13 at Middleman Storage in Dededo, code 206265." plays*]

EMMA: Someone gets it, woo!

SAM L: I KNEW I recognised that!

[laughter]

SAM L: Oh that's so good! Ah!

EMMA: 567108 is really 5.67×10^{-8}, but that's the number that Kuzha calls at one point, and that's the Stefan–Boltzmann constant.

[*clip of Kuzha saying "Calling 567108, this is Kuzha Tvask."*]

SAM L: Ahhhhh! [laughs] That's so clever.

ROOK: I have a couple numbers that come up in the Chasma bonus episode that I'm writing and one of them is vaguely a reference- is a reference to Wolf 359.

[Bonnie gasps]

EMMA: I will say I did feel like when I was using all these close-to-Earth stars I felt like I could not use Wolf 359 cuz that's been done!

[laughter]

EMMA: I can't make that be anything in Roguemaker, Gabriel Urbina already did everything he could possibly do with Wolf 359.

BONNIE: [laughs] You can't touch it!

ROOK: So I think that just about wraps up the episode, sooo, um, I think… Any… takeaways that anyone wants to- any- any last thoughts anyone wants to share, any takeaways that they've gathered, any future endeavours/social medias they want to plug, um, before I go into that? I don't have anything really to say, but hey I'm- I'm CorvidCastle12 on- on Twitter and, oh, also I'm CorvidCastle on Twitch if you wanna watch me read Homestuck! [laughs]

[Emma laughs]

SAM L: Yesss!

BONNIE: You should.

ROOK: Now you have to keep in all the Homestuck references that I do, so that it- so that it all comes back around to I'm rereading Homestuck currently and YOU CAN JOIN ME.

[laughter]

BONNIE: Join them on the journey.

ROOK: Join me on the journey through Homestuck. So anyway, Bonnie, do you have any last thoughts you wanna share?

BONNIE: Um, I really enjoyed being here and being the designated, um, head-empty-just-vibes. Uh, it was great, thank you for having me. [laughs] Um, you can find me on Twitter @BonnieAspinwall, on Instagram and Twitch @bonthemightybon and I'm currently reading Carmilla on Twitch on Friday evenings 8pm BST… or… well, BST for a couple more weeks, and then it'll be GMT. [laughs] And that is partially in honour of spooky season and partially in honour of a show I'm gonna be in, a lil show called Re: Dracula, @redraculapod on, uh, Twitter which is currently crowdfunding so check that out!

[Transcriber's note, Re: Dracula's crowdfunding has now ended and Bonnie is now streaming Fridays 8pm GMT]

[various "ooh" noises]

SAM L: Hell yeah!

ROOK: Yeah, and that's going really well from my understanding so, you know, congrats on that!

EMMA: OH yeah.

BONNIE: It's so exciting, oh my god! I feel normal about it!

[Sam laughs]

ROOK: Anyway, Sam, uh, any- any parting thoughts and anywhere that people can find you? Or maybe you don't want them to find you and you want to run away into the woods?

SAM L: [laughs] I would love both of those things to be true. This has been an absolute blast honestly. I caught a few of the astronomical references in the show, but not all of them, and it's been a lot of fun to kind of engage that part of my brain, be like, "oh yeah this is really cool and weird and there's stuff in it!" Also just like talking about AIs and like interesting science fiction and cosmic horror, that always gets my brain wound up in good directions. So applause to everybody involved in this, all three of you, as well as the entire rest of the cast. If anyone's interested you can find me @MelodiousGunk on Twitter, um, at inconsistent intervals I tweet things that are inscrutable and that I find delightful and at some point in the future I'm intending to put a little bit of a homebrew supplement on, uh, Dungeons & Dragons…

[Bonnie gasps]

ROOK: Oooh!

SAM L: …or other tabletop RPG things, uh, so you can tune into the feed for that, um… And any other voice roles that I may audition for and get, cuz that's also something that I'm interested in doing more of, uh, but yeah!

BONNIE: Woo!

ROOK: Cuz you do a lovely job of it, I must say.

SAM L: Thank you!

ROOK: Anyway, Emma? Last thoughts?

EMMA: Yeah!

ROOK: Speak now or forever hold your peace.

[laughter]

EMMA: So I guess I just wanna emphasise that science is not something that's holding you back in your science fiction world-building, it's something that you're drawing your inspiration from and very often truth can be stranger than

fiction, so you should look to truth. That said, you know, FTL, screw that. Just hand-wave it.

[laughter]

EMMA: It's fine. It's fine. Thank you all for this wonderful-.

BONNIE: It just works!

EMMA: It just works!

SAM L: It just works!

ROOK: And where can we find you on the interwebs, Emma?

EMMA: Yes! I do exist online, possibly too much. I am on Twitter @spacesword13, um, and from there you can mostly find me elsewhere.

ROOK: Alright, well thank you all so much, this has been a lovely conversation and my voice is going and I wanna eat dinner so it is time for me to go, so, um-

[Bonnie laughs]

SAM L: Absolutely.

ROOK: Have a lovely-

EMMA: Science: we've been blinded with it!

ROOK: Have a lovely day/evening/whatever time it is wherever you are whenever you're listening!

[Bonnie laughs]

ROOK: BYEE!

BONNIE: Happy timezone!

EMMA: Buh-bye!

SAM L: BYE!

BONNIE: BYE!

[roll credits]