Episode 32: Sailors take warning
Physicists: Amanda Bauer, Ken Clark

Transcribed by Denny Henke

Ben: Oh. Hello old friend, it's good to see you. Let's talk about this word fascination. It describes an unquenchable urge which compels our hearts to quest and be captivated. As long as there are elegant explanations to complicated phenomena science will never lose its romance. Over the years I've traveled the world indulging in my fascination with physics and now I find that a new hunger has woken within me a fiery need to share these great ideas with the people around me so I have assembled a team of some of the greatest most lucid most creative minds I have encountered in my travels and I call them my Titanium Physicists. You're listening to the Titanium Physicists Podcast and I'm Ben Tippett, and now allez physique!

[2:06]

Ben: Why is the sky blue? I can't think of a more fundamental question and in my life I've heard lots of different explanations and most of them are wrong. So, it's not dust in the atmosphere and it's not blue for the same reason my shirt is blue or that water is blue and it's not blue because it's reflecting the color of the ocean down on us and it doesn't really have anything to do with the chemical composition of the atmosphere at all. It's something else, something wonderful. So, today we're going to answer the question, why is the sky blue? So, obviously this question is the type of question would ask a parent along with why is expensive peanut butter really oily or why does the water in fire hydrants not freeze in the winter? These are all good questions but why is the sky blue is the one we're talking about today and recently I received an email from a guy by the name of Steve van Breda. "Recently my ten year old son asked me the common question, why is the sky blue and I found myself struggling to explain it in a way that he might understand. Would you be able to explain this to him with your usual awesomeness and if you feel so inclined you be able to do it orally on some site like Sound Cloud. My son would think that you were just the coolest guy if I could get a response of that magnitude from you." So, in response to his letter, no Steve, I don't know how to work Sound Cloud. Do you expect me to learn how to use some crazy new website just to answer your kid's question? Obviously not. So, allow me to introduce today's guests, it's Steve van Breda and his son Reuben. Hey Steve.

Steve: Hey Ben!

Ben: Hey Reuben.

Reuben: Hey

Ben: So, Steve has five kids and Reuben is the oldest. He's a ten year old and he's pretty much the coolest person we've ever met. He's into Pokemon and when he grows up he's going to be a cartoonist. So, Steve, Reuben, for you today I've assembled two of my most powerful Titanium Physicists. Arise, Dr. Ken Clark. It's a bird, it's a plane, no wait, it's Dr. Ken. Dr. Ken did his undergraduate at the University of Toronto and then his Masters and Phd at Queens University and now he's at Penn State working on Ice Cube. Now, arise Dr. Amanda Bauer. Dr. Amanda is a super science fellow at the Australian Astronomical Observatory. She's an expert on how galaxies form and change and she is one of the world's leading astronomy bloggers. Her blog is at AmandaBauer.blogspot.com and there will be a link to it in the show notes or you can just google Astro Pixie to read about what's new in astronomy and what's fantastic to know about. Alright guys, so why is the sky blue?

Amanda: We know that we've got daytime when the sun shines on Earth and sunlight is, actually, a combination of all the colors in the rainbow. When you add all those colors up then sunlight is actually white but things happen to that white light as it travels. If light just travels on it's own and doesn't hit anything then it just travels right in a straight line. The light from our sun actually hits our atmosphere as it shines down on us and things happen to it as it hits the atmosphere.

Steve: Now I've heard that it hits dust or molecules in the atmosphere and something happens to it.

[5:22]

Amanda: Exactly right. There's gases in the atmosphere and particles, mostly this is nitrogen and oxygen in Earth's atmosphere but it doesn't actually matter what it is. It's the interaction between that light. So light has energy, it's got an electromagnetic field and these particles in our atmosphere also have electromagnetic fields so it's this complicated reaction between all of these electromagnetics that causes the light to change its path. Now, these, particles cause the light that comes in to change its direction, that's the main effect that it has. And different kinds of light, so the different colors of the light change their direction in different ways because they have different because they have different wavelengths. So, you can think of light as it travels as a wave as you would see a wave on top of water. You've got the crest, the peak at the top and then you've got a dip and then that pattern goes back and forth and the distance between a crest and the next crest, those two peaks, that is what we call a wavelength, the length of the wave. So, when you have white light you get all combinations of all kinds of wavelengths added together and when you see that white light split into a rainbow you've seen light shine through a prism and you can see it split up into its rainbow, those colors, that blue, that green, that red, those represent different lengths of the wavelength.

Reuben: I've heard that red is the one that goes the farthest.

Amanda: Red is definitely the longest wavelength.

Reuben: So why isn't the sky red?

Amanda: Exactly. We're getting there…

Steve: So that's the question.

Amanda: That's an excellent question. So, blue light has the shortest wavelength and because the particles in the atmosphere are the size they are they happen to bump the blue light, they scatter the blue light, they change the direction of the blue light more than the red light. So, it's more likely that this blue light that comes through our atmosphere gets shaken up a bit more and gets scattered off in all directions more than the red light. And so you're exactly right, more often, gets through the atmosphere and travels to us and that blue light get's scattered and bounced off in all directions and since all the particles in the atmosphere are all bouncing all the blue light around we see the sky as that blue scattered light.

Reuben: So is that kind of why the sky is kind of red when the Sun is setting or the sun is rising?

Amanda: Yeah, so as the Sun starts to set it goes off towards the horizon and as you're looking at the horizon you're actually looking through more and more and more atmosphere. When the Sun's straight up you've only got a couple miles worth of atmosphere there but as you start going over to the side you look through more and more and more atmosphere, up to ten times more so ten miles of atmosphere so you've got more particles there that are able to scatter the light from the sun. So, the blue light get's scattered away then it starts scattering some of the green light and you scatter all of those colors so the only thing that's really left is the orange and the red. So at the sunset all that gets through is the orange and red and that's why we see red at sunsets.

Steve: Okay, I have a question that maybe you're going to address later on, but what I learned about the rainbow and colors splitting, in grade school, you learn about ROYGBIV, aren't those the ones that, the colors indigo and violet, aren't they at the end of the color spectrum and wouldn't they have a shorter wavelength than blue.

Amanda: Excellent question, that's absolutely right. What you've described in the rainbow is the visible spectrum, so, that's what our eyes are sensitive to seeing, human eyes. Other animals can see other kinds of light. If you go to much shorter wavelength it's called the ultraviolet so ROYGBIV ends in violet and then the ultraviolet is a little bit shorter. That actually starts to get absorbed by the atmosphere and our eyes are not sensitive to that so then you start to get into the violet and indigo and blue and it turns out that, you're right, the violet and indigo do get scattered, even more than the blue light, but, our eyes are not very sensitive to that violet and that indigo light, not as sensitive as we are to blue light. And also, the sun produces a certain amount of blue and red and ultraviolet light and it produces a lot more blue light than it does indigo and violet.

Steve: Really?!

Amanda: So, there's a lot less of that light to get scattered and our eyes are not as sensitive to that light.

Ben: Alright, Reuben, how much did you get of that?

Steve: See if you can explain it back in your own words.

Ben: Yeah, yeah, do your best.

[10:00]

Reuben: So, the sun like hits the atmosphere and it's kind of like, it just scatters but the blue light scatters the most so that's kind of why the sky is blue. Right?

Amanda: Exactly.

Ben: I've got a bad metaphor. Would you like to hear it?

Reuben: Sure

Ben: Ok. So, you know how if you mix colors, you get different colors right? If you mix yellow and blue you get green or if you mix all the different colors together in the right way you get white, ah, so I like to think of it in terms of like, a stream. So, have you ever watched those nature documentaries where there's like a bear that's batting salmon out of the water?

Reuben: Yeah

Ben: Yeah, ok, so it's like that. So, there's a whole bunch of different colored salmon. So there's some purple salmon and some blue salmon and some red salmon and some orange salmon, right? And the bear's really like the salmon that are bluish and purplish colored, so, at the very bottom of the stream, when the salmon first entered the stream, the bears along the stream start whacking, knocking out and eating the salmon. But they try to pick out and knock off the salmon that are bluer and purpler, so the purple ones go first, then they knock out a whole bunch of blue ones until all that's left are crappy yellow and red salmon and so, in essence, an, you know, if we're standing next to the steam all we end up seeing is a whole bunch of blue salmons because those are the ones that the bears are knocking out of the stream at us, so in the evening when you can look directly at the sunish, [pause] never look at the sun…

Laughter from multiple…

Ben: In the evening

Laughter from multiple…

Ben: …anyway

Steve: What are you saying to my son?!

Ben: All the salmons that are left in the stream after the bears have had their go are just these orangey, yellow salmon and that's why the sky is orange and yellow at night.

Reuben: I think it's a really good metaphor.

Ben: Thank you. Incidentally, we've been saying this world scatter and scatter is an interesting word. All it means is, there is some structure and the organization goes away, right? So, when you go into your room and you take all your toys and you can scatter around the room…

Reuben: Kind of means, kind of like going in all different directions.

Ben: Yeah, that's right and the deal is that there's a whole bunch of different ways, a whole bunch of different mechanisms to scatter the light. So, for instance, the reason the reason that my shirt is blue is because the light that comes and hits it only blue light gets scattered off my shirt. So, whenever we talk about colors we're going to use the word scatter but what happens in the upper atmosphere is a really special type of scattering. It's called Rayleigh scattering. It's named after an old British guy.

Reuben: Rayleigh

Ben: And the deal is, that all light is a type of wave. You've played with magnets before, right? Have you ever played with static electricity.

Reuben: Uh huh, with my hair.

Ben: Yeah yeah. right.

Steve: I've got a mini Van de Graaff generator wand.

Ben: Oh man!

Steve: Dude, I've got so many fun science toys, it's awesome.

Ben: That's fun! So, the deal is, there's a connection between magnets and the static electricity and it's fairly complicated but the deal is that if you move static charges around really fast or if you move magnets around really fast you end up making these waves, these electromagnetic waves they're called and we have another word for electromagnetic waves and that's light. So, somewhere in the sun, you have charged particles that are moving around really fast and those waves are what we perceive as light. Okay? So, it's kind of like a wave on the ocean. You guys live in Ontario, right?

Steve, Reuben: Yup.

Ben: It's kind of like a wave on Lake Ontario.

Steve: Ah, Lake Huron dude.

Ben: It's kind of like a wave on Lake Huron

Reuben: Huron.

Ben: Huron. It's kind of like a wave on Lake Huron. So, I want you to imagine, like, a boat, okay, so imagine this really calm day and you have a boat sitting out on Lake Huron. Now, imagine that you had, a really big hand, so, like you were the Hulk or something, and you could reach out and grab the boat and push it down and shake it. It makes waves, right? So as you move the boat up and down waves will get radiated out and now I want you to imagine Lake Huron on a pretty windy day okay, so there's already big waves in the lake, really big waves, waves that are, you know, big enough to move the boat.

Reuben: You said really calm.

Ben: No, tomorrow. So, today it's calm, and I move the boat up and down and I make waves, right?

[Laughter]

Reuben: Yeah.

Ben: So, tomorrow I come back and it's a windy day.

Reuben: Okay.

Ben: And it's so windy that there are big waves. So now the waves are moving the boat up and down so a big waves comes in, as it lifts up the boat the boat goes up in the air and as the trough of the wave moves in the boat goes down. So as the boat is bobbing up and down it's still going to be making waves, you dig it?

Reuben: Yeah

[14:52]

Ben: So that's kind of at the heart of Rayleigh scattering. What's happening is these electromagnetic waves are coming in and moving through the atmosphere and as they move through the atmosphere they move near particles in the upper atmosphere and they cause the particles to jiggle. We can talk about this a little bit more, in more detail a little bit later, but they cause the particles to jiggle and when the particles jiggle they end up emitting light, their own light, and the shorter the wavelength the waves are that hit, the faster it will make these particles jiggle and the faster the particles jiggle the more light they're going to emit.

Steve: Has the light already broken into separate parts at this point?

Ben: It's kind of like the stream full of Salmon. So the bears in this case are the jiggling particles when a purple salmon moves past the bear it will swat the salmon out of the stream, so this is, the particles jiggling in response to the wave moving past it, is, in effect, the sorting mechanism. It's how all of the different colors end up being sorted by the particles in the sky.

Steve: You're saying though that the sky itself becomes a bit of a source of light.

Ben: That's right.

Steve: That's awesome.

Ben: Well, you think about it, so if the Sun is over on the horizon, it's morning so over in the eastern horizon, there's still light coming from straight up in the sky, even though there's no star that you're looking at. And the light that we see from the atmosphere in the middle of the day is all just light that has been sorted and knocked aside by particles in the upper atmosphere. So that light wasn't, it wasn't moving straight from the Sun to us, it was glancing through the atmosphere but then the atmosphere did this sorting thing and knocked some blue light, blue colored light down our way.

Steve: Okay. So, this actually, is really interesting to me, because I've always thought and I think a lot of people are with me, is that the Sun goes through and it breaks up into colors and for some reason or other, the blue part of that spectrum gets bounced around and gets diffused through the dust or gasses of the atmosphere and that's what kinda, that's where we see the blueness of the sky. But what you're saying is the sky itself is emitting light and this blue light is kind of like an incidental part of this, of the Sun shining on the atmosphere.

Amanda: Yeah, that's pretty much it. So, the Sun comes in and it's got these energy waves and they react with the gasses in the atmosphere, so it can be any kind of gasses up there, anything that that star light would interact with would cause this Rayleigh scattering. So it excites, or it bumps around these particles and because the size of these particles, relative to the wave that's coming in, also determines the fact that it scatters the blue light more. So if those particles get bigger and bigger then it stops scattering the blue preferentially and it starts scattering all the light just the same. Because these particles in these gasses happen to be the size that they are that they cause this sensitivity in their scattering the blue light more. Now, I want to ask if you have noticed what color the clouds are?

Reuben: White

Amanda: White. Do you have any idea why they might be white?

Reuben: Because like, water and kinda like, sorta like the Sun's going on it and turning it, kind of like boiling, so it evaporates.

Amanda: Interesting

Reuben: So when it comes up, kinda like the light, but um, just turns all white instead of the green or blue in the water, just purifies kind of.

Amanda: So, you're exactly right about these particles in clouds being mostly water and water particles are bigger than just the nitrogen or hydrogen gases that are in our air and so because those particles are bigger they don't scatter blue light more sensitively than they scatter their red red light so they just scatter all the light and when we add up all that scattered light it looks white. So, it's because of the clouds are made of water and that those big particles scatter all the light the same so we see all that as white light, that's why the clouds are white.

[19:08]

Amanda: So, there's another interesting thing that happens in our sky and I don't know if you've noticed it before but if you look straight up during the day you notice that the sky is actually much bluer than when you look down toward the horizon.

Reuben: Yeah

Amanda: The closer and closer you get to the horizon it actually gets lighter and almost close to white, have you ever noticed that?

Reuben: Yeah, a little bit. Yeah.

Amanda: So, do you have any guesses as to why that might be?

Reuben: Probably because aren't there more particles, something like that?

Amanda: When the sun is kind of overhead that light that goes towards the horizon has to go through more and more of the atmosphere so more and more light is getting scattered so the blue is scattering out and then the green and then oranges and reds even start to get scattered. So the sky's not completely blue because you do have this mixture of lots of different scattered light and the light coming from the Sun that's white that doesn't happen to get scattered. So, as you go down toward the horizon more and more and more light gets scattered so in addition to the blue you start adding in also the green and the yellow and some of the orange and so when you start adding more and more light together you get closer and closer to white. So, it's just the blue that gets scattered straight above because you're going through thinner atmosphere and and you go through more and more atmosphere everything starts to gets scattered so that adds up to be white.

Steve: Instead of getting lighter and lighter blue, why wouldn't it change to different colors until it got to white?

Amanda: Because you still have all of that blue, it's just, in addition to the blue you start to get some yellow and some orange and some green as well.

Steve: Okay. Oh yeah, of course, because the blue is not being subtracted, so, it's therefore a shade of that blue.

Amanda: Yep. It's the blue plus, plus more stuff.

Ben: Okay, so, Reuben, do you want to know about the colors of sky on other planets?

Reuben: I've kinda really been wondering the colors of sky from different planets.

Amanda: So, I've read some science fiction books where they describe the sky as being green which would be kind of an interesting thing to see but as far as I can tell, there's not an easy way to make that really happen. So, have you seen some of the images that the Curiosity Rover or the Pathfinder Rover or some of the other Mars Rovers have sent back?

Reuben: No

Steve: Yes. Yes!

Laughter

Steve: Aw, yes you have! Pictures of Mars from the Rovers.

Reuben: Oh, yeah!

Ben: Yes, ok.

Amanda: Aw, sorry I asked my question in a confusing way I guess.

Steve: It's okay. I swear I'm not a bad dad.

Laughter

Ben: You're going to dad jail!

Steve: I know!

Laughter

Amanda: So, they call Mars the Red Planet and it looks to me in some of those images, like the sky there is kind of, maybe yellow or butterscotch or orange or red. Do you see some of those colors in those photos?

Reuben: Yeah

Amanda: And I think what happens anytime there's an atmosphere there are gases in the atmosphere and the star light comes through that you're going to get Rayleigh scattering as we described before which is going to make the sky blue so that will happen no matter what as long as there's an atmosphere.

Steve: So, you're saying that no matter what is in that atmosphere there will be some sort of a blue sky.

Amanda: Yeah, as long as it's got…

Amanda: Yup. It's going to tend to scatter that light towards blue.

Steve: Can we sense, like a blue wavelength coming from a planet?

Amanda: So, yes and no. I'll give you a couple answers. So, the other issue is that if you've got anything else in the atmosphere in addition to those gasses then that will start to change the color away from blue.

Steve: Okay.

Amanda: So, fundamentally you might have this blue sky but if you've also got dust, which Mars is pretty famous for its dust storms, and you've got other things like aerosols and that starts to absorb light and it also starts to give different colors to the sky so what we think from these photos from the rovers is that the Martian atmosphere is a bit thinner than ours and it starts to look very pink because of the high dust content. Now, a big challenge with knowing what the color of the sky on a distant planet is, is actually the limitation of what our cameras are on the rover. So, the camera on the rover has certain filters, when it sends its photos back to Earth we can add them together to get our color images but it's very, very difficult to know whether or not those images are actually what our eyes would be sensitive to. So, this is one complication in fine tuning exactly what the color of the Martian sky is. I've seen some images they've taken of the sun set, so as the sun set gets down towards the horizon most of the sky looks pink because of this dust that's in the atmosphere but the actual sunset on Mars looks a little bit blue and that's because the dust starts to absorb all the blue light, it doesn't actually scatter it in the same way that our atmosphere does. It absorbs the blue light which takes it away which makes the sky generally look pink but then when you go through all of that atmosphere, when the Sun gets way down in the horizon it does start to scatter some of the blue light again and so the

Martian sunset looks kinda blue, or it looks a lot lighter than what ours does. It's almost the opposite of what Earth's sunset is.

[24:35]

Steve: You know, I remember seeing pictures of it, it looks almost silvery. Especially, maybe thats the red surrounding it. But, hazy, silvery, and maybe a touch of blue too.

Amanda: Now, can you imagine what the sky would look like on a planet that had absolutely no atmosphere?

Reuben: Black

Amanda: Exactly. So, that sunlight is just going to keep on traveling as it is until something gets in its way and if there's no atmosphere to get in its way then we'll just see that pinpoint of the sun and the rest of the sky will look completely black. So, Mercury is an example of a planet in our Solar System that doesn't have an atmosphere so its sky looks black.

Reuben: Cool.

Ben: Okay, so, Reuben, it doesn't sound it's very possible to get a sky that isn't blue.

Reuben: Hmm hmm.

Ben: Now, here's the question, what if we had a planet that was around a different star? So, did you know that stars are different colors?

Reuben: Yes

Ben: Good. So, some stars are red, some stars are bluer, the color of the star kind of depends on how big and heavy it is and also how young it is.

Amanda: It depends on its temperature.

Ben: Yeah

Amanda: And that's because of all those other things

Ben: Yeah, that's right! Okay, so, we were saying before that the color white is made up of all the different colors combined, right?

Reuben: Yeah

Ben: But, it's made up of all those different colors combined in a really specific ration. So, you've played with paints before, right? You ever mix red paint with white?

Reuben: Yeah, it turns pink.

Ben: Yeah! That's right. If you change the ratios, you end up with a different color that's not white. So, if you have light coming from a different star, where that star isn't white colored, maybe it's blue, maybe it's red and it hits the atmosphere of a planet, the Rayleigh scattering will cause the sky to maybe be a different color. Maybe it will be a reddish color or a more violet color.

Reuben: Okay.

Ben: Does that make sense?

Reuben: Yes it does.

Ben: Awesome.

Steve: Is there a limit as to what colors that a sky could be then?

Amanda: Well really it depends on what eyes you're looking with. So, your human eyes can see the rainbow, the ROYGBIV that you described before, the red to violet. So, we would be able to see any of those. We're most sensitive to blue so if there's blue sky than that's most likely what we'll see.

Steve: Would there be a sun that could hit an atmosphere that we could conceivably stand on in whatever sort of space that would give us a green sky?

Amanda: No, green is interesting. If you looked at the stars and you've noticed red and blue and white and yellow stars, you don't actually see green stars and that doesn't have to do with the temperatures of the stars it has to do with the fact that our eyes are the least sensitive in that space. There's three little response curves for our eyes and the one that peaks at the blue side is really sensitive and then there's like the green one and the red one but I think there's a spot between the blue and the green where we're not really that sensitive.

Steve: Okay.

Amanda: Which is why we don't see green stars.

Ben: Do green stars exist?

Amanda: Temperature wise, they do. There's a whole range of temperatures of stars that in principle include green. It's our eyes that are interpreting it and we're not sensitive to be able to see it.

Steve: So we interpret it as a different color?

Amanda: Yeah, we would be sensitive to the other colors that the star gives off it's jut that green that we're not receiving.

Steve: Ok.

Amanda: Well, we're not interpreting I guess. It hits our eyes but eye isn't as sensitive to it.

Steve: Interesting! Ok.

Amanda: Yeah. It was really an interesting thing when I first realized that there aren't any green stars. My guess is that it would be very hard with our human eyes to be able to see a green sky just because the way our eyes receive light. We don't have a high sensitivity to green. We very easily see a blue sky obviously and we would start to see more orange or red.

Reuben: So do you think it's like possible that say somehow we manage to get an animal on a planet and it would see a different sky than we do?

Amanda: Yeah, I think that's absolutely right and I think if we were creatures that evolved on a different planet with a different sun then its likely that our eyes would evolve to have a different kind of sensitivity. So, maybe our eyes, for some reason, would be more sensitive to green than they to blue like our human eyes.

[29:14]

Steve: And that's what that first interstellar war, was an argument over what color the sky was.

Laughter.

Amanda: It's amazing how difficult it is to quantify colors.

Steve: Yeah, I imagine so.

Steve: It's a very, because it's subjective how I see the world versus anyone else.

Amanda: Well, I think there's two different sides. There's the physicist which what produces the light and how is the light changed and then the physiological side, how do we interpret that, how do our eyes receive it? And of course 10% of the male population doesn't have that red receptor, or is color blind so they would see things in shades of gray and not as distinct colors.

Ben: We could talk more about the craziness of Rayleigh scattering because there's an additional detail that we haven't told you about. How would you like to go about it.

Steve: Well, Reuben, do you want to hear more about this?

Reuben: Yeah, sure, I think it's really interesting.

Ben: Alright. Okay.

Steve: Well, there you go guys.

Ben: So, what I'm about to tell you is a little bit bananas and kind of tricky to understand so you just tell me if uh, if I'm going too fast for you, okay Reuben?

Reuben: Okie dokie.

Ben: It has to do with how light is a wave but light is a really special wave. It has something called polarization. So, have you ever gone to a 3D movie?

Reuben: Yes, I have.

Ben: Right, you get these sun glasses.

Reuben: Except you can't leave them in the sun.

Steve: This is a good one. Reuben, you explain to him what you've heard about these glasses.

Reuben: Well, their black so they're kind of like, attract sun, and I'm not sure how but somehow if you leave them out in the Sun too long they explode.

Laughter.

Ben: No. No, that's not how they work. It's actually pretty wonderful. The explanation for how the 3D glasses work is actually pretty neat. Do you know how you can tell that how they give the illusion of three dimensions?

Reuben: Yes, I do.

Ben: You've got these two eyes, right, and each eye sees a slightly different picture if you close one eye then close the other eye and go back and forth the picture shifts, right. Your two eyes see slightly different images and the differences between the images they see change depending on how far an object is away from you. So right now I'm looking outside a window and if I close my left eye and right eye back and forth, the window jumps back and forth but the image far away from me hardly changes at all. And so my brain puts that information together and tells me how far things are away from me and that's how I see in in there dimensions. Have you ever seen 1950's type 3D glasses where one is red

Reuben: No

Ben: and the other is blue?

Reuben: Oh, yeah

Ben: Yeah, right. So that's the same thing. What happens is one of the lenses lets blue light through and the other lets red light through and then on these old time movie screens they would project two images, one that was red and the other that was blue and you know if there was something really close to the person that they wanted to pop out of the screen they would make those two pictures really, really different then if something was far away from the person watching the movie, far deep in the screen they'd make the pictures almost the same and because your two lenses would filter, one would only see the blue color, one would see the red color, because they're filtering like that your brain puts the information together and sees a three dimensional picture. The way they work in modern movie theaters isn't that different but they let you use color now instead of just red and blue and the way they do that is fantastic. It has to do with one of the basic properties of light. So, we've been talking about how light is a wave and the deal is that it has, it's a crazy word called polarization. In essence it's kind of like, give me the name of your friend.

Reuben: Zachary

Ben: Hey Zachary, how's it going? Ok, so imagine Zachary goes to jail, right. So you and Zach, you robbed a bank. Zachary's in jail but he didn't tell the cops on you and so you want to hang out with your buddy in jail so you're going to play frisbee with your friend okay? So, the deal is you want to throw the frisbee to Zachary who's on the other side of these bars. Now, if you throw the frisbee in a way that it passes between the bars it can make it through but if you don't line up the frisbee's orientation quite right, it will end up bumping into the bars. So, two frisbees might be moving in the same direction but one will be able to pass through the bars because it will be oriented up down and the other won't because it will be oriented left right. So, light does the same thing. It has this orientation to it as well, and so, when you go to a movie theater you have these two lenses, they're called polarizing filters but in essence they're just like jail bars. One of them goes left/right, the other goes up/down and then the light that comes from the screen, the light that's oriented left/right can pass through one of the lenses, the other lens will only let up/down light through it…

Reuben: Yeah

Ben: And so you can end up seeing two different images that are both in color and that's how these things work. So, it's just this very simple filter. So, Steve, do you have a pair of polarized sunglasses?

Steve: Yeah, I do. Well, I used to, actually, I've lost them. They're not on my right now.

Ben: Well, it's the same technology. Polarized filters. And there's something fun you can do. If you go to one of these movies and you steal the glasses. I know you're supposed to give the glasses back and I don't endorse stealing or robbing banks, but if, somehow you forget to hand in your glasses after the show, there's a fun trick you can play with them. If you have two of these polarized lenses, say you break your glasses in half, if you look through one, so you hold one of the sides up to your right eye and look at the other one, the other one will get light or dark depending on how you rotate it because the one in your hand, not the one up to your eye will only let light through that's oriented in a certain way and if it's oriented in a different way like the one that you're holding up to your face, if they line up then it will look clear and if it doesn't line up it will look black. and so you can actually rotate it around like that and it's amazing. Here's what I'm getting at, light that comes from Rayleigh scattering is polarized, it's all up/down light and so if you one of these polarizing filters that you took out of a movie theater and you go and look up at the blue sky with it, if you rotate the lens around, the sky light will get dark or bright depending on how you rotating it.

Reuben: That's awesome.

Ben: Oh, it's so awesome.

[35:52]

Reuben: Have you done it?

Ben: Oh yeah, it's fun. Well, that was lots of fun. Well thank you Ken, thank you Amanda, you've pleased me. Your efforts have born fruit and that fruit is sweet. Here is some fruit. Amanda, you get a blueberry. I'd like to thank my guest Steve van Breda and his son Reuben. Thanks Steve and Reuben, I hope you had lots of fun.

Steve: Yeah, we had a great time.

Reuben: Uh huh, it was lots of fun.

Ben: Cool!

Ben: Let's talk, you and me, my Ti-Phi-ters, Listen, I love this show and I hope you do to but for every listener to the show I know that there are a hundred other people who would love to listen but they don't know how. So, I want you to spread the word about our show and there are three ways you can do this. First, there's iTunes. iTunes is still the biggest place where people go to find new podcasts and iTunes puts the shows with the most ratings at the front where everybody can see them, so if you've got a minute give us an iTunes review. It will increase our rank and more people will see us. The second is to teach people how to listen to podcasts which is funny, but everybody you know has a smart phone or tablet these days and a very low percentage of these people know how to listen to podcasts, they don't know how much fun they could be having. So if you know somebody who would like to listen to the show ask them if they know how to listen to podcasts and if they don't point them to the Stitcher app because it's free and easy to use and it works on almost every hand held device and surely your grandmother will thank you for it! The third way to talk about our show is to tell people online about us. The internet is full of explanations about physics. If you see someone on the internet talking about a topic one of our episodes covers post a comment at the bottom telling them about the show. Alright, that's it, I hope you'll help us out and point new listeners in our direction, so thanks. So, that's it for the main part of the show, remember if you like to listening to scientists talk about science in their own words you might also want to hear other shows on the BrachioMedia Network like the Weekly Weinersmith where Kelly and Zach Weinersmith talk to academics about their research or Science Sort of where we talk about science in the news and also explain science and talk about beer. Editing for the Titanium Physicists podcast is provided by a gentleman named John Heath - thanks John you're the reason we sound so good lately. The intro song to our show is by Ted Leo and the Pharmacists and the end song is by John Vanderslice. Until next time my friends remember to keep science in your hearts.

After end song:

[39:09]

Steve: Would there be any animals on Earth that have differently evolved eyes than ours that would see the sky as a different color?

Amanda: Well, I don't know that they would see it as different color. That's a good question. They do have different sensitivities in what they can see so they don't have the same, like we have different rods and cones in our eyes that cause us to be sensitive or less sensitive to different colors of light and so animals have different sensitivities and different numbers of receptors of rods and cones and that allows them to see a whole different spectrum or more detailed colors that we can see. But I think some of them are more sensitive towards the infrared, like things that can see at night, night vision comes because you have more sensitivity to the longer wavelengths. But I don't think that would cause animals to see a different color sky. That's an interesting question, I haven't thought of that.

Steve: Okay, cool.

Steve: Rayleigh. R e i How do you spell Rayleigh? R a y l e i g h

Ben: What?! No, it's got an e in there.

Steve: R a y l e i g h

Amanda: Okay

Steve: There's an e. I promise

Ben: Well, alright. Google's too slow to tell me whether or not you're right. We'll go with that.

Amanda: I concur. He's right.

Ben: Okay, so it's called Rayleigh scattering. It's named after an old British guy I just told you that. I'm going to edit me saying this again out.

Ben: Hey Reuben, what's your favorite Pokemon?

Reuben: Um, kinda hard, Snorelax.

Ben: Oh yeah, why do you like Snorelax?

Reuben: I don't know. I just think he's kinda cool. Like, he sleeps a lot, I like that.

Ben: Yeah, I like that about Snorelax.

Reuben: He eats a lot.

Steve: Hey, I'm back. I have heard, actually, another neat application for the 3D tv, when you're playing against a buddy in like a first person shooter you can have the glasses so that one guy is looking at his own screen and its polarized so the other guys wearing different glasses and he's looking at the same screen but a completely different image.

Ben: Oh really.

Steve: Because the screen is constantly showing both, like if it was a 3D movie it would be showing constantly, two separate images from a different… but now it's just showing two completely different screens.

Ben: That makes sense.

Steve: Yeah, it does. This might be an experimental, you know people experimenting in their basement, but you can't cheat by looking at your buddy's, oh, he's in the tower…

Ben: Well, you could always lift up your glasses. Wait, no, you could always turn your, close one eye and turn your glasses sideways.

Steve: True, I guess you could.

Ben: I guess it's easy to tell when someone's cheating that way though.

Steve: Dude, no!

Ben: So, do you have any other questions Reuben or Steve?

Reuben: Um, Amanda, right now in science we're learning about space and so, we're watching this video, it's called Two the Planets and Beyond, its got like, around, I think it's eight people in space for six years and they're visiting all these planets, I really think you would like it.

Amanda: Wow. That's pretty great.

Steve: I think it's a BBC production I think and it teaches about the planets by having a narrative of different astronauts visiting different planets.

Reuben: And what I really like about it is that, they put it into a story and they, they, there's two episodes to it I'm pretty sure and it's just like people going on planets and just doing all these experiments. I think it's really cool.

Amanda: So, do they ever talk about what the sunset looks like or what the sky looks like on those planets?

Reuben: No, but um, they do talk about the Sun having a magnetic field.

Ben: Oh yeah.

Amanda: Yeah

Reuben: And so they, according to, if they want to go to this one planet then they have to go through, go really close to the Sun. So, if they want to go that close to the Sun, the Sun has a magnetic field and so they're going to have to make their own magnetic field.

Amanda: Oh. Will you tell me what it's called again?

Reuben: To the Planets and Beyond.

Amanda: Sounds great, thanks.

Reuben: You're welcome.

[44:02]

Steve: Excellent. Ah, Ben, I've listened to your other podcast about gravity and time distortion…
Ben: Oh, yeah…

Steve: So, I wrote this question down shortly after I listened to it and I hope I remember enough about it to make sense. So, this is the question I wrote down, if time experienced on Earth is used as a control reference point, is there any theory that might allow for time to move faster for the twin that leaves, so, like, one year on Earth for one twin might equal like ten years for the twin that leaves.

Ben: Yeah, Yeah. You could do that. In fact time, time… have we done this show yet? Yes, we have, okay, so time on the surface of the Earth passes slower than when you're out in orbit because you're sitting on a, inside a gravitational well. So, presumably, if you had a twin that went out to the edge of the solar system, and just kind of hovered around for a couple thousand years, he'd come back and his twin would be older than him.

Steve: But would there be, like with a black hole, say its a very dramatic difference.

Ben: Oh, yeah.

Steve: But is there any object or theory about an object that would be like an anti-black hole that would accelerate that process.

Ben: Okay, so there's something called a white hole. Sure enough, when you get close to a white hole, let's see, it would still be accelerating, I need to check the math. Gravity is full of these tricky things where, if you're damned if you do, and damned if you don't. But there is something called a white hole and it blows instead of sucking, and it only exists on paper. Essentially it's what you get if you take a black hole and you flip it upside down, or reverse it in time, so…

Steve: Times it by negative one.

Ben: Yeah, yeah. So, you flip time backwards and you get a white hole. I think in that case though if you stood near a white hole for a long time time would slow down. Time doesn't speed up when you get close to white holes… I don't think.

Steve: Alright. It was just when I was listening to the podcast I think, well, if we had that…

Ben: Yeah, it's fun.

Steve: But can we… yeah… excellent.

Ben: Okay, any other questions?

Reuben: No

Steve: No, this has been pretty awesome.