Skain's Domain

Episode 9 - May 18, 2020

0:00:00 Adam Meeks: Alright, we're getting hands raised already. We got... We'll have a lot of questions tonight.

0:00:05 Sean Carroll: And they're not gonna be falling.

0:00:07 AM: Yeah.

0:00:07 SC: No shame.

0:00:09 AM: I know.

0:00:09 Wynton Marsalis: Okay.

0:00:09 AM: Hey everybody. Thanks for joining us, another episode of Skain's Domain. My name's Adam Meeks. I'm the video producer at Jazz at Lincoln Center. Tonight, Wynton will be joined by Sean Carroll, Research Professor of Physics at Caltech and External Professor at the Santa Fe Institute. Sean is a theoretical physicist specializing in quantum mechanics, gravitation, cosmology, statistical mechanics, and foundations of physics. And we're thrilled to have him tonight. Later on in the hour, we'll get to questions for Wynton and Sean, and I'll remind everybody on how to do that once we get to that point, although it seems like everyone already knows, 'cause they're lining up. That's all I have for the frontend, so Wynton, I'll hand it off to you.

0:00:58 WM: Alright. Thank you very much Adam. Thank you all for joining us again, Skain's Domain. Each week we gather to discuss matters significant and trivial. But the more trivial a subject, the more intensity we bring to the discussion. And we feature multitude of different voices and so forth, but tonight I'm joined by an extremely special guest. You heard a lot of his pedigree, but he has a book that's just come out. It's entitled, Something Deeply Hidden: Quantum Worlds and the Emergence of Spacetime! With an exclamation point. He also has a podcast called Mindscape and he interviews smart people. Sometimes some are smarter than others. I was on it. I don't know how I got on it, but it's about interesting ideas with all types of ranking topics and subjects. He's also a lover of jazz and of progressive rock. He is a friend of Chicago Greats like Buddy Guy and the late Von Freeman and the pianist singer Patricia Barber. And he started loving the jazz musicians he knew and went on to all the musicians who were known to recordings, like Trane and Miles and Mingus he said he really loves Duke so his taste is impeccable. He also loves "Emerson, Lake & Palmer", and "Yes" and "Genesis" and "Cream" and the host of rock bands that was populated at that time with musicians who really could play.

0:02:13 WM: If it's not for this pandemic, Jazz at Lincoln Center patrons and everyone in the world would have become much better acquainted with this conceptual and tangible genius because this past April our orchestra was scheduled to do the world premiere of mostly the music composed by Sherman Irby, entitled "Musings of Cosmic Stuff" to the writings of tonight's guest. As it is, we hope to share this work with all of you as soon as the circumstances allow. In the meantime, I've invited him to join us. I'm so happy that he's come this evening because he is a captivating speaker, and he knows how to make these important connections for us. I expect that we're gonna all come away with this... From this with some good conversation material with friends we're trying to impress, as well as some new insights and perspectives that we can use to nourish our souls and our minds and spirits. I know I plan on it. Please welcome the fantastic Dr. Sean Carroll.

0:03:07 SC: Wynton, thanks so much.

0:03:11 WM: Thank you, man. I'm gonna start with Thelonious Monk. He said that all musicians are subconsciously mathematicians. So I wanna know, does your expertise and knowledge of math and science and physics affect the way you hear a piece of music?

0:03:26 SC: Yeah, I think you can't help but hear that, right? I mean, science, math these are ways of looking at the world, ways of figuring out certain kinds of perspectives to take, questions to ask. We all know, as soon as you see the time signature and it says 4/4 or 7/8 or whatever, there's math there already, right, in music. So there's math in the rhythm, there's math in the pitch and the tone, there's math in how the different notes compare to each other. You have 12 notes in a scale and you pick out some of them to make the major scale. And why is that? Why do you pick out some notes to make a major scale and different notes to make a minor scale? Well, math is the answer, roughly speaking. Certain frequencies beat against each other in pleasant ways, certain frequencies kinda work together to make us a little more somber. So I can listen to music without my math hat on. I can listen, I can just get into it, I can just enjoy it, I can lose myself. But knowing the math... It's like Richard Feynman, my predecessor at Caltech, he said, "Anyone can look at a rose and enjoy the beauty of the rose. A scientist can look at the rose and enjoy the beauty and know where it came from and why it's reflecting certain kinds of light and stuff like that." So it's not that you need math to understand music but it gives you a little bit of a way of thinking about it.

0:04:49 WM: So do you find yourself, again, if you're listening to a piece, do you find yourself trying to figure out what the form is or how many bars it is? Because I know I had the chance to check out some South Indian music and a friend that I was with was counting it for me. Man, I didn't know where I was. When he was counting it, I could kinda follow it but he'd get to a certain point, then he would say, "Okay, you count it." I would be like counting with my hands the way he do and I was absolutely lost. I would say, "Is that it?" He would say, "No." So do you find yourself thinking about the forms in those ways or do you just kinda allow your spatial intelligence to... What's your...

0:05:26 SC: No, I mean, I think I'm you there, except I'm sure that I'm nowhere near as good as you. There's a famous story about Albert Einstein, who used to love to play the violin, and he became famous. Einstein, right? So he could hang out with anyone and he hung out with a professional violin player. And at one point, they were playing the violin together. And the violin player says, "Professor Einstein, don't you understand anything about time?" I mean that's, in some ways, he understood more about time than anyone else in the world, but that doesn't mean you're good at counting. So I'll try, I'll listen, I'll definitely if I notice... If I'm listening to Dave Brubeck... Time Out, I love trying to figure out what time signature the different pieces are in and stuff like that. But my music theory and knowledge is still pretty amateur. I love it. I'm truly amateur in the sense of someone who loves something.

0:06:20 WM: Great. Well, I want you to make some of these connections for us, doctor. So you know a musician, when you improvise and you play solos, you are thinking of a macro form like the head, the number of choruses you're gonna play. Who soloed before you, who solo's after you. You have macro-objectives. Where you wanna go with your solo. How you wanna build things. How you wanna break them down. What is the rhythm section playing. Then you have very micro-objectives. The notes you're gonna hit. When your gonna bend a note or scoop it. What's each harmony as it passes. All the kinda little details. And if you're writing a piece, you might write a long piece, hour to hour and a half long or something, you write out the entire macro-outline and everything you do. But when it comes down to it, you have to put a dot and dash over every note. So I know you think about huge spaces and unbelievable volumes, but you're also a master of the quantum world. How do you conceive of macro and micro?

0:07:17 SC: Yeah, I know when I think this is, The question. I love in your intro, how you said, "We are most passionate when we talk about the trivial things." But today we're gonna be completely chill because we just covered the biggest, most important ideas you can talk about. In the science context, what you're talking about, the relationship between micro and macro goes under the label "emergence". We think that there's a way of talking about the universe that is entirely micro, right? You and I, the world, the universe, the stars, and the galaxies, we could, if we wanted to, just say, "This is just a bunch of particles, quarks, leptons, photons. They are obeying laws of physics," and we basically know what the most important laws of physics are for the universe we see around us. So we can just say, "That's it. That's the universe," but we'd be missing out on so much if we did that, right? That's sort of called the naive reduction mystic way of looking at things. Just breaking them down to the pieces and saying that's all there is. Because that's not all there is, right? If you can say... You can look at a star, or you can look at a table and say, "That's a star, that's a table." You've already told me an enormous amount about that object without telling me anything about what its atoms are doing, what its particles are doing.

0:08:38 SC: Someone can describe a piece of music to you. They can say, "Oh, that's very melancholy." Or they can say it's in a major key or it's in a certain time signature. They haven't told you any of the notes, right? But they've given you important pieces of information. So this is actually not only a fascinating and important subject for scientists, it's one we don't understand very well. What is the relationship between the macro and the micro? We know they're both there. We can even talk about atoms, we can talk about in your body. We can talk about molecules, we can talk about cells. We can talk about organs, we can talk about people, species, but how they relate to each other, is a tough one. And furthermore, how they come together. There's something... There are two things going on. This is a good little distinction to draw. When you write a piece of music it's top-down, right? There's... Your brain is thinking, your musical sense is thinking what notes should go here, blah blah blah blah blah. It's fairly clearly from you to the music. But when you have a bunch of musicians improvising together, you can also get something wonderful and magical from the bottom up, right?

0:09:47 WM: Right.

0:09:48 SC: And that's the thing we don't understand, collective behavior. We have buzz words, we have fancy words to talk about it. We talk about self-organization, and criticality, and complex systems, and feedback, and nonlinearity. There's a lot like I warned you. If you wanna call it a day and just have six hours of discussion about this, we could do that, but you've put your finger on something really, really important.

0:10:13 WM: Yeah, I do. I want you to expand on this thought. On the concept of the difference between the individual hero and collective action, just because we have a tendency to be, if not cultured, very individualistic. Whereas, our constitution is designed to be balance of power and kinda the use of reason. But every time someone will get publicity or be known or be able to rise above the pack, that's considered to be the most important thing. Now, it's interesting that you brought... The most difficult thing in improvisation probably is to have a group of people who have the same level of interest and giving order, form, and logic to a thing from their perspective. So I know you, but just from your studies of the universe and the tendencies of things, we had talked about entropy before and just the tendency of things to become random. I wanna just get a sense of what you think about what it takes to make form come together. From a seeming random thing of four or five people get on a bandstand, what does it... Can you relate the anti-forces of non-entropic forces or forces that are going against the tendency of things to become random?

0:11:27 SC: Yeah. Again, hugely important great question. And it's all about time. We'll get into time later, but it's all about being dynamical and flowing and changing. It's not a static thing. So here's a little story I like to tell. Entropy, for people out there who have not yet read my books... I don't know what you're...

0:11:47 WM: There's not that many of them.

0:11:49 SC: Not that many, right. Entropy is a way of talking about how messy, how disorderly, how random and disorganized things are, right? So the classic example is take cream and pour it very gently on top of a cup of coffee, it's low entropy. All the cream's on top, all the entropy is on the bottom. And if you mix it, then it becomes high entropy. It's messy, right? Everything is everywhere else. But here's the thing, simple versus complex is different from low entropy versus high entropy. When you were just cream on the top, just coffee on the bottom, that was very simple. And when it's all mixed together, it's simple again. It's all mixed together, right? But in between, on the journey from being simple to simple, then it becomes complex.

0:12:38 SC: There's swirls of cream and coffee mixing with each other, there's these beautiful patterns that form. And it's much like a piece of music that sort of, you start with silence, you build up, things happen and then you go back to silence again. And so I like to think of it as saying entropy is not your enemy, entropy is your friend. The fact that entropy is increasing isn't the thing we're fighting against, it's the thing we're taking advantage of, we're making use of that. When those musicians come in, to not quite plan out ahead of time what they're gonna do, let it be spontaneous and into the moment, letting your ego be pushed down and their creativity come up. They need entropy. You need some loosey-goosey-ness, right? You need some disorganization to make that happen. But you wanna take advantage of that and make something really special.

0:13:32 WM: So in that way, it functions like defense in sports or the lines of delineation or something that makes you have to strive for something.

0:13:40 SC: Yeah, there's some constraints. There's some things you can do. The good news is, there's a law of physics, the second law of thermodynamics. It says that entropy increases until you hit maximum entropy and everything is dead in a closed system, in a system that doesn't interact with the rest of the universe. But we do interact with the rest of the universe. We eat food, we go outside, we have the sun in the sky, right? We talk to each other, we interact with other people. That's what gives us this ability to keep going and to not reach maximum.

0:14:14 WM: So I wanna ask you a question now. It's interesting to hear you talk about that, the interactions we have with people because we imagine, who are not in your field, we imagine that just the lonely hours and the hours of intense thought that it takes to address very complex subjects. Quantum physics, quantum mechanics, entropy, quantum entanglement. Just all of these terms in the math equations that drive us crazy. We look at a blackboard full of these equations and we think of a lot of time spent alone. So I wanna ask you a question about theoretical... Things that are theoretical, because, in music, we also have a very beautiful relationship to our theory. You can have the music-theoretical concepts and theoretical writings that are very profound and interesting to study. It's theory. But when you hear the music, it is virtually unlistenable. Is there a equivalence to be found in theoretical mathematics, in physics, where you can look... Could you look at an equation and think, "Man, this is a beautiful equation? I can't wait." And then when you actually get down to it, it's like, "Hmm."

[chuckle]

0:15:26 SC: Yeah. Sadly, we have exactly that. In fact, the joke in science is a beautiful theory is often killed by an ugly fact. But the thing that we want...

0:15:38 WM: We need that in our politics.

0:15:40 SC: Yeah, the ugly fact. Actually fairly more ugly things. The thing that we want, our goal in science, is to correctly capture some part of the world, some part of the behavior, and the essence of reality. Whereas, in music or in art, we have different goals. We're trying to move people, make them think, connect with them at a deep level. But either way, there's some standard for success, right? You've succeeded or you haven't. And separately from that, there are different standards or you can be classified as... A theory can be beautiful or elegant or sort of irresistible, but wrong if it doesn't fit the data. And you're too polite to say this, but it works for people too, right?

0:16:28 SC: There are people who are proficient who are good at... They play really fast, or they can play really intricately. There's scientists who are really good at pushing around equations, solving mathematical formulas, and so forth. But when push comes to shove and you have to perform on the stage or actually come up with a theory that is correctly describing the world, something's not there, right? Something's not quite really working. It's not quite there. So the subtext here is that people do fall in love with the math, with the beauty, with the elegance of it. I mean, there's a long line of physicists throughout history who've said really dopey things about how a certain theory is so beautiful, it can't possibly be wrong, right? That's like saying a certain piece of music is constructed in such an elegant way, that it's going to sound good when you play it...

0:17:22 WM: Right.

0:17:24 SC: Whether you agree or not. But that's just not how it works. And what we find by doing science is that, very often, beautiful ideas are true. There is some relationship. We're lucky enough to live in a universe where reality is very beautiful and elegant in some way. And likewise, a good musician or good composer, who is very technically proficient, can create truly beautiful things. But that's not the point. It's the tool you use to get to the point, right? And knowing the difference. Sometimes you can get a little bit lost in the math. A colleague of mine, Sabine Hossenfelder, just wrote a book of physicists, that the English title was called Lost in Math. For more illustrious reason, you can forget, you can take your eyes off the prize sometimes, whether it's in physics or in math.

0:18:15 WM: So when you say take your eyes off the prize, what is the prize?

0:18:21 SC: The prize is understanding the real world. So, you know look, I'll give you a very specific example. And I'm not... And this is... Let me give two examples. Two or three examples, because some things we're finished with, we know what the answer is, and some things are still works in progress, right? Johannes Kepler was a brilliant astronomer. He was the first one to say, "Planets don't go in circles around the sun, they go in ellipses," right? They come closer and they go further away. Brilliant mathematical step forward, but he was also kind of mystical about it. And he thought that there was some underlying theory of geometry that explained all this and explained why there are exactly five planets. But now we know the planets don't move exactly in ellipses and that there are not five planets. So he just fell in love. He made a big contribution but he fell in love with the steps along the way and it sort of guided him in the wrong direction. Einstein, very famously, tried very, very hard to unify the forces of nature later in his career and he didn't succeed. He sort of had become detached from... And I'm a huge fan of Einstein.

0:19:33 WM: Right.

0:19:34 SC: I think he's underrated, if anything, honestly. He was just brilliant and insightful in every way, so let me say that. But he did kind of putter along there for the last years of his life playing with equations in a way that didn't really match up. And these days, of course, we work in progress. We have string theory. Superstring theory. This very famous idea. A lot of publicity from Brian Greene in Columbia, right there in New York City. But the majority of super-duper intelligent and theoretical physicists, who are thinking about how to unify all the forces of nature into a single beautiful framework these days, they are fans of string theory. They think that string theory is the way to do it, and there's been literally zero experimental evidence in favor of string theory. So there's a backend. There's people who are saying, "Look, what are you doing? You're wasting your time." That's where Lost in Math comes from. You're just so absorbed by the technical beauty of what you're doing, you've taken your eyes off the prize. You've forgotten that your job is to describe the world. And personally, I'm somewhere in between. I'm not so seduced by the beauty of a theory that I'm willing to say, "This theory must be right, even though we have no evidence for it." Eventually the evidence will come and I'm gonna devote my career to thinking about it, but I'm also... I recognize that it might be right. Science is hard.

0:21:03 WM: Right.

0:21:03 SC: When you have the... The difference between doing a live performance and doing a recorded, in the live performance you get instant feedback, right? Like you succeeded or you didn't. But when you do a recording, it might take a long time before you hear any feedback. And in theoretical physics, we can come up with great ideas and it might be a long time before the universe gives us feedback. But I do think that there are a number of my theoretical physics colleagues who don't worry enough about the [0:21:31] ____ cause. About actually describing the real world. They do the physics in their little domain, with their friends who are also doing similar physics, and at no point do they compare it to the real world and I do think that's a shame.

0:21:48 WM: That has a strong relationship to music. Where you can get in a thing of thinking that people are so un-hip, it doesn't really matter what they hear. We hearing something they don't hear, and they just happen to be here watching what we're doing. So I wanna get a little bit into the theory of relativity because I find a lot of similarities between that and jazz. And I'm gonna just lay it out kinda how I'm thinking about it and just have you educate me much deep and further about it. I think that I'm gonna just take apart some basic concepts of it and say how I think it's related to the theory. Let's just start first with the concept that time is relevant. When my little brother was a kid, we would sit him down in a bedroom that he could tell us when a minute was over. And he was always right. And the rest of us were always 40 seconds, a minute and 15 seconds, 35 seconds. My brother Jason was always one minute, boom, he's right on that. So from that, we said, "Well, okay, time has got to be very personal." And it's also a concept in jazz. A medium tempo to one person is not a medium tempo to all. The relationship between bass players and drummers, a bass player will always be moving ahead of the beat. And the drummer will say he's rushing and the bass player will say you're dragging. So our concept of time is two people working and pulling on a beat.

0:23:10 WM: Now, the other one is space is related to time. If you get a song and you get to look at the music out here in front of you and you have to play a solo on it, there are slashes on the sheet. And when you look at a lot of slashes, you're either happy or sad. Now, you're happy because it means your solo went for a long time. But the more you get into that form, if you see these really intricate sections and this, that you say, "Man, I have a lot of space in this that I have to address the music and do something meaningful." So at the point you're looking at the space, the space is laid out for you and you see the harmonies passing and those harmonies pass in time. And the rhythm section is playing time. So space is related to the time. The time is relative, space is related to time. You're trying to play in time and the other musicians are playing what they think is time. You're looking at space and they're looking at space. So how would you take those concepts, just in terms of... And I'm gonna get into it some more kinda concepts of how things are relative to each other, and the effect of mass and other things. But I just wanna get our audience to just kinda understand those concepts as it relates to music.

0:24:16 SC: Yeah, yeah, yeah. No, I think this is really good because there is an analogy here that is actually a pretty good one. And if there's any physicists listening in the audience, any who would mention, it's an analogy, okay? Like when you say your brother is a metronome.

0:24:32 WM: Thank you.

0:24:33 SC: You don't mean he's literally a metronome, right? You say, oh, he's...

0:24:35 WM: Right.

0:24:36 SC: Like a metronome. There's some similarity there, right? So...

0:24:39 WM: Right.

0:24:39 SC: The transitions playing in an ensemble that's a lot like relativity in a lot of ways. And the way that I like to think about it is, Einstein comes along and says that time and space are part of spacetime. Part of one together four-dimensional thing, like you said. So what is that supposed to mean, right? Well, I think what it means is, in space, literally space is where we live, right? It's the directions around us where we can travel. And if two people leave New York and drive to Los Angeles, but they take different routes, one goes North, one goes South or whatever, one cuts across, so now one gets in the airplane and just flies, their beginning point and their ending point is the same. They left New York and they arrived in Los Angeles. But that doesn't mean they traveled the same distance, right?

0:25:29 SC: It depends on how they moved. If you zoom around in different directions a lot, you can start at the same point, and end at the same point, but do a lot of traveling, right? Travel a lot of distance. Time doesn't seem that way to us at first glance. It seems that time is the same for everybody, right? The ticks on our watches should be the same no matter what we do. And Einstein says actually no. Einstein says time is like space. If you go from one moment in time if you and your friend leave a single place at a single time and you say, "Alright, we're gonna rendezvous back at a different place and at a different time," and one of you just sort of moseys in a straight line, goes directly there, at the right speed to land there exactly when you're done and the other zips out at the speed of light, okay? Somehow your other friend has a spaceship or something like that.

0:26:22 SC: The universe has a certain amount of time that passed, and that's universal, that's just the same for everybody. But Einstein says there's a separate notion of your personal time like you just said. The time that you experienced, the time that elapsed on your wrist-watch, right? And those will not be the same for those two people because they traveled through the universe differently. Just like someone who takes a zig-zag path through space doesn't traverse with the same amount of space. Someone who takes a zig-zag path through the universe doesn't experience the same amount of time. That's what relativity says. The little footnote is, if you take a straight line through space, that's always the shortest distance, right? If you zoom around and do crazy things, you will always travel a longer distance. And it works the other way around. If you zoom around in time, you always get there faster, you always experience less time. That's why if you watch Interstellar, Matthew McConaughey flies out near the speed of light, he comes back, and then his daughter is much older than he is, okay? So he experienced less time by zooming out there.

0:27:30 SC: And there's a lesson there for the musicians, right, because there is a time that is different for everyone. The technical term, just so you know, it's called the proper time for each observer, for each measurer, for each musician. We have our own time. In relativity, there's an equation that tells you what it is. In the group, there might not be an equation, but we do still have the issue of synchronizing, of playing nicely with our friends and making sure that our personal experience of time matches what the bigger group is trying to do.

0:28:00 WM: Well, what do you perceive the challenge of that being? Because jazz musicians are arguing all the time about time. Because our time references every beat and if you, man, you're rushing, you're dragging or you're not in the time, I'll be... Herbie Hancock used to always say my time wasn't good, so he wrote a song for me for my first record called I'll Be There When the Time Is Right. We were always joking with each other about time, I would ask my brother when I was 18 or 19, we'd be playing together, I would say, "Am I rushing?" And he would always name some great Russian, Pushkin or Brezhnev or... He'd find some way to say, "Yeah, man, you were rushing." And even in great rhythm sections, I know this, they'll start to go back and forth, so. But we know that, also, in the theory of relativity is the concept that objects move relative to each other. So if you're on the bandstand, there is no absolute time. There is the time we're all working out. What do you think... Does it need... Does it require manners? Or sometimes you're playing with somebody who really doesn't have good time. So you don't wanna necessarily... Because you know that the other part of the theory that objects warp time as they move through the universe, and mass causes an object to curve. So you don't want the mass of somebody who's not playing it in time to make you curve it toward their time. How do you look at the integrity of dealing with different times at once?

0:29:23 SC: Yeah, I think that the interesting thing here is actually how we tell time. I mean, there's time as it is, as a concept built into the fabric of the universe. But then there's how we measure it. One way to define time is, time is what clocks measure. Okay? And then you say, "Okay, well, what's a clock?" It's something that tells time. It's a little bit circular, but a clock is just something that kinda does the same thing over and over again, repeatedly, predictably, compared to other clocks, okay? That's what a clock is. The only way we can tell time in physics is because the world is full of things that are oscillating back and forth, and it's predictable. You know that every year the sun is gonna go up and then come down again 365 times, 365 and a quarter to be precise. So that relationship between how long a year is and how long a day is, is what allows us to tell time.

0:30:24 SC: Now, human beings are not as good clocks as a good wristwatch or the sun or anything like that. But we have a whole bunch of processes in us that are rhythmic and predictable. Our heartbeats, our breath, our nervous system. And furthermore, it's fascinating to go into the neuroscience of how our brain actually keeps time. It's actually more like an hourglass than a pendulum going back and forth, we have all these systems in our brain that sort of build up a little bit and then collapse, and then build up and then collapse. And this is sort of keeping time in that particular way. And we have different systems on different scales using different methods. There's short-term timekeeping, long-term timekeeping. Like Jason might have been very good at telling how long a minute is but is he good at telling how long a day is? It's hard to measure, right? Or a year.

0:31:19 SC: It's a different system inside us. And guess what? Have a cup of coffee, have a glass of wine, have a beer, have a good meal. Your timekeeping is affected by all that. And it goes back to what we were saying about entropy and about complexity. We're not closed systems, we human beings, we're very complicated, we have a micro world inside of us doing all sorts of different things, and it emerges in some complicated self-organized way to give us who we are. But when someone's not keeping time very well, it might be that there's a little mismatch in their micro world, whether it's the neurons in their brain or the chemicals in their body or something like that. So I would, in fact, cut some slack to different people. If they do it once, I would say like, "All right, maybe you should've had a cup of coffee before coming."

[chuckle]

0:32:10 WM: Right.

0:32:10 SC: If they do it the same way every time, then they need an adjustment.

0:32:14 WM: So, what you're saying, it leads me to think about the concept of judgment, and what you think about things. One thing that happens, when you're playing, is everybody is playing and a lot is going on. And depending on the type of person you are, you can have the tendency, and I would say with most people you have the tendency to... You can only hear a snapshot at any moment that passes. You have a tendency to think you made a mistake or you did something wrong or something. And then your soul is affected because of the negativity of your way of looking at things. Or you didn't play what you wanted to play. So because you didn't play what you wanted to play, you can't hear what you did play. Then later you will listen to a tape or something...

0:33:07 WM: And I'm not talking about just myself. Just years of listening to tapes with musicians, be it students, or not even professional musicians, just people who were playing as a hobby. You listen to a tape later with no pressure of time or no perception and you listen. You'll find all kind of things you didn't hear. So when you're playing, what was a moment of possibility, becomes probability, becomes group action. And then your disappointment tends to go along those scales.

This is possible, this is probable. I didn't do what I wanted. Now we're onto the next minute. So I wanna know, can you relate this to the thought experiment of Erwin Schrodinger's cat? Just what your perception is, what something is in that liminal state between your perception and the reality and the actuality? I crammed kinda a lot in there because I just want you to flow between there because I see how you like to get in between the cracks with stuff.

[chuckle]

0:34:00 SC: Yeah, there is a lot in there but that's okay. In fact, let me separate out two separate things. One is, obviously, when you're literally playing in real-time and it's all going on around you, there's certain issues you have to face. You don't get to call time out and say, "Let me think about what note to play next," right? You gotta go with it in the moment. Whereas, when you're doing science, you do get to sort of... When you're trying to think of a new theory of how the universe began or what the dark matter is, you can take your time, as it were. But I think the important similarity there, just psychologically, is that you have to be able to take a risk and fail. And there's many, many people who don't like that. Well, they don't like it when other people take a risk and fail, let's put it that way. And that's not just... I mean, it sounds bad, people criticize you if you take a risk and fail. What I mean is, we don't know all the answers, right? We're not done with science, with physics. We're trying to do better, we're trying to learn new things. So you have to be a little speculative, you have to stick your neck out a little bit. You have to have a crazy idea now and again. And the old, wise people, who are your heroes, right, they've heard all the crazy ideas before and they know why they're wrong. And they can just tell you in an instant, "Nope, here's why that won't work." And they're usually right.

0:35:29 SC: But not always. And I've had good ideas and I've gone to... I mean, half-baked ideas, not serious ideas, but I've gone to people I admire and said, "What's wrong with this idea?" And they told me what was wrong with it, and I said, "Oh, I guess that's right." And I forgot about it, and then two years later, someone publishes a paper with a brilliant idea because I wasn't smart enough to see why my famous older mentor was wrong. So there's absolutely this give-and-take of taking a risk. Usually risks fail. Sometimes they lead you someplace wonderful and new and that's great. So even though you know that most risks fail, you have to create space where they're allowed to happen and the failure is okay and you move on, right? Now, quantum mechanics is a good analogy for this and that's where Schrodinger's cat comes in. And again, analogy time, but, you know...

[chuckle]

0:36:28 SC: Here's quantum mechanics. Quantum mechanics comes along in the early 20th century. I would absolutely say that quantum mechanics is the most impressive accomplishment in human intellectual history in any field, because not only is it an incredibly successful, so far undefeated, theory of how the world works, but it's also completely bizarre and crazy, right? No one would have invented this. It's not that impressive to get a good theory of the world, that in retrospective, "Oh yeah, sure, that makes sense, now that you say it." Whereas, quantum mechanics came on the scene almost 100 years ago and we still don't understand it, right? But it works. That's just the weird crazy part. And one of the things it says is, let's imagine you can observe something like you can observe where an electron is. A little tiny particle, okay? It says, even though when you observe it you always see it somewhere when you're not observing it, it's spread out all over. Not equally all over, but there's sort of a cloud of probability that says, well, it's likely to be here when you look at it. It's unlikely to be over there, but it's still possible it could be over there. And this is called a superposition of all the different places the electron could be.

0:37:43 SC: But the idea is really, really hard to swallow but it's correct, is that it's not that we don't know where the electron exists. It's not that it's somewhere but we just are not sure. It's that it literally isn't anywhere until we observe it, and then it comes into existence. And the equation that governs this cloud of probability was, as you mentioned, by Erwin Schrodinger, who's a famous quantum physicist. But he didn't mean it. He invented the equation, but he didn't realize at the time that the way we would start thinking about that equation was as a way to calculate probabilities of things. He thought that was just a step too far, and this idea that things really were in superpositions before you looked at them and then they weren't after you looked at them, that just seemed a little nutso. It still seems a little nutso to us today so I don't blame him. But what he did was he invented this thought experiment, the Schrodinger's cat thought experiment, to show you and himself how crazy it was. So you're gonna have a little nucleus of an atom and it's gonna decay, okay? We have a Geiger counter, we can put it next to some uranium or something, and we can detect the nuclei decaying in the substance.

0:39:00 SC: What quantum mechanic says is that until the Geiger counter detects it, it's not that it has decayed or not decayed, it's a superposition of both. It only becomes decayed or not decayed once you observe it. So Schrodinger says, "Fine, I'm gonna hook my Geiger counter up to a hammer that will hit and break a vial with poisonous gas and it's all set up inside a box with a cat. And what you're telling me is," Schrodinger says, "What you're telling me is, until I observe, until I open the box and look at the cat... " The cat is neither alive nor dead. If the Geiger counter does not click, the cat's alive and it's fine. If the Geiger counter does click, the hammer breaks the vial, the poisonous gas fills the box and the cat dies. And we might say classically... Classical mechanics is what we had before quantum mechanics. We might say, "Well, we don't know whether the cat is alive or dead." But according to Schrodinger, quantum mechanics says it's not that we don't know, it's that the cat is in a superposition of both being alive and being dead. That's the reality of it. That's not just a way of just characterizing our ignorance. That's what is actually going on. Until you open it and then, boom, it's one specific possibility. So I think... Sorry, a long-winded explanation, but I think...

0:40:21 WM: No, that's not.

0:40:23 SC: Yeah, yeah, I mean, I think that it comes into the music because what happens is, in the moment, when we're playing and you're improvising, there's a lot of things that could happen in the future. The past is more or less...

0:40:36 WM: That's what I was getting ready to say. That's right.

0:40:38 SC: We might not be able to remember it, but we can't change it either, right?

0:40:42 WM: Yeah.

0:40:42 SC: From the audience. You could decide right now, this is a really boring presentation and you could leave. But you can't decide not to have come to the presentation, right? You can't make a decision now that affects the past. So one way of thinking about that is that... I mean, one way of thinking about it is that there is a future that's gonna happen and we don't know what it is. Another way of thinking about it, using the analogy, is that all the futures are there, and we have to figure out which one we're gonna bring into existence by observing things in certain ways, by acting in certain ways. So, I mean, not only jazz but my usual metaphor for this is playing poker. When you don't know what the next card's gonna be, you don't know what your opponent has. All you know is what your cards are and you can't make the classic mistake of guessing, "Oh, that person must have a pair of tens." You have to say, "Oh, there's a whole set of possibilities that they could have," and you have to take them all seriously. And you have to do your part to steer them in the right direction, but until the future arrives, all those possibilities are real.

0:41:51 WM: That's great. I'm interested in that liminal state.

0:41:54 SC: Yeah.

0:41:55 WM: Because when you're playing, you're always in that state. You are never in the state of... Even when you play something, it's like you're saying, you have a particle that would be in many positions. And then you're looking... Science says people play, they're looking up here. Dizzy told me he asked Louis Armstrong, "What are you looking for when you look up there, Pops?" He said, "I don't know, brother Diz, but I always find it." You're looking up there and it's I could do this or this could happen or that. And somebody plays an idea and it's... So it's literally, it could be anything in every moment. And then you start playing it and then once it start, everybody says it's this and then it's something else. So you're always in the state between the cat, it could be one thing or it could be another and then we're always reaching that point. So I wanna go from what you just broke down for us so clearly to the way that you play faster than the speed of light, faster than... Sometimes you're playing with somebody and you all will play the exact same thing and, I mean, it will all be so random.

0:43:02 WM: Man, there's no way. And that's not like one or two notes. It'll be literally a row of notes. And then other times, a person will play the perfect opposite accompaniment of what you play, because they get to a certain richness in the music, you want to have opposites going on. And I want to talk about horn players. Sometimes we play together. I remember Walter Blanding and I worked on a record and we were trying to play with each other so hard, we just looking at each other playing these horn parts. And we're trying to anticipate everything that we're playing, a swell into notes and build. And we're trying to improvise on the parts while we're playing. And we were trying to come together and surf the murky waves of the present, past and to create a moment of the future that we can grab. So... To which you were saying, on a bandstand, you don't know how quick other decisions are gonna be made and sometimes they fit perfectly statement or counter-statement. How can you relate that for me to the first thing I asked you when I mentioned I was interested in and to quantum entanglement? Can you break that down for us and show us how it could perhaps be related to things we do when we improvise?

0:44:08 SC: Yeah, I mean, I absolutely can. Now, just because I'm a licensed practitioner here, I have to be careful and say, it is not quantum entanglement that has jazz musicians playing similar things with opposite things. It's an analogy, okay?

0:44:23 WM: Right, right.

0:44:24 SC: But the thing is, I love analogies. I think analogies are absolutely brilliant. I do a lot of consulting for Hollywood movies. I consulted on Thor and the Avengers. And people are saying, "Where's the physics in these superhero movies? What is that?" Well, you can be inspired by ideas in real science to talk about fake science, like they do in the movies. Likewise, the idea of quantum entanglement, it's just so deep, so resonant and so different from what most of us experience in our every day lives. It's an incredibly rich source of understanding things that we do come across in our everyday lives. The idea of entanglement is, we said we might not know where an electron is. It's worse than that. The electron actually is in a combination of everywhere, okay? It's not that we don't know, but it has some position. It's in a superposition of all the different possibilities. So imagine you have a particle that decays into two particles back to back, okay? So this is something that happens all the time. We discovered this particle called the Higgs boson in 2012. All the time the Higgs boson decays in a snap, the particles always go back to back, because the Higgs is sitting there, it's stationary, it's not moving. It has no momentum, no velocity. So it must be that the two particles it dissolves into are going back to back. So they have a net-zero motion.

0:45:51 SC: But we don't know where either one of them is going. Usually, the Higgs will just decay into a particle going anywhere. If you say, "Well if I detect one particle, what is the probability it's going in one direction or another direction?" It's anything. It's equal probability it's going in any direction. And the same thing for the other particle. So you know that these two particles are completely unpredictable. But if you observe one of them, if you measure one of them, you instantly know where the other ones going because it had to be going in the opposite direction. Wherever the first one's going, the other is opposite. That's because they're entangled. And that it can be true, even if you wait a million years like you let these particles move apart forever, and then you detect one of them, the other one is halfway across the galaxy. It instantly has a definite position because you measured this one. This is what Einstein couldn't deal with, this is what...

0:46:52 WM: Right.

0:46:52 SC: He called it spooky action at a distance. He thought that he'd know. I mean, he's Einstein, he's the one who knows you can't go faster than the speed of light, right? But it seems in quantum mechanics that you can, or at least that there's an influence that somehow gets communicated faster than the speed of light. Now you can go through the math, you can check. You cannot communicate, you cannot send a signal faster than the speed of light. So I think this is where the analogy becomes interesting with the musicians because it's not that one person makes a decision and communicates to the other one, right? There's no time for that.

0:47:29 WM: Right, right.

0:47:32 SC: They're in sync somehow, right? And because it's the real world, we can sort of talk about realistic explanations, for well, they were practicing before and they forgot that they had this phrase they really liked, or they grew up in the same tradition, or they were listening to their bandleader, or they've... Whatever it is, there's some common causal influence in their past, but for all intents and purposes, in the moment, the effect is that these people are acting in synchronization without passing signals back and forth trying to synchronize themselves.

0:48:07 WM: Right.

0:48:07 SC: And that's a very good analogy for quantum entanglement. So the reason why I think analogies like this are useful is that it expands our brains a little bit in terms of how we can think about the relationship between different people doing things at different times. You know, we're all marching into the future together and it's interesting to see the choices we make, how we make a set of possibilities into one actual reality.

0:48:34 WM: I love what you just said about how we make a set of possibilities into a reality, that we are... Something we can perceive and even if we can't perceive it, that it actually comes into being. So the last thing I wanna ask you before I open it up because I know people wanna ask you questions, is you are very... A lot of times we have a tendency to think of a physicist, or a theoretician, or a scientist, we tend to think of it as somebody very dry and cold. You embrace the void, you embrace the kinda unruly, entropic human aspect of science. How do you come to that way of being? Because I could imagine it would be kind of difficult in the academic environment, where sometimes there's not a respect for that, as if it takes away the purity of it.

0:49:24 SC: Oh yeah, no, I mean, again, hours and hours of conversation ahead of us on this one. It's a... There's two things that go on that are both true. One is you can use science, math, physics, whatever it is, as an escape, right? You can forget about human beings, you can say, "I'm gonna lose myself in my equations and my beautiful pristine theories." And the nice thing about that is, the great thing about physics, even in comparison to other sciences, is the precision, right? You're right or you're wrong. And you know there's... When you do a homework problem, even as a first-year undergraduate student, if someone says, "How many seconds does it take for the ball to go from the top of the building to the bottom?" It's not like interpretations.

[chuckle]

0:50:16 SC: There's really a right answer there, right? And that's basically it. And so you can... And the real world is scary with human beings, and diseases, and politics, and economics, and art, and literature, all of these things that are hard to pin down. There's a certain kind of person who finds an escape in the purity, the simplicity, the definiteness, the rigor of mathematics and science. On the other hand, the flip side of this is the people. My friends, who are professional physicists, these are smart cookies, right? They've had a lot of education, they got a lot of IQ points. They could be making a lot more money doing something else, right? They could be very successful trading on Wall Street, or being investment gurus, or whatever. But the only reason why the thing that they would choose to do is theoretical physics, or theoretical whatever, or observational whatever, experimental physics, is because they are passionate about finding out how the world works, right?

0:51:20 SC: But many of us, myself included... You know, I got hooked when I was 10 years old and I was reading about the Big Bang, and black holes, and I had no idea what it meant to do that for a living, right? Like there's no one in my family who did anything like that, no one I knew did anything like that for a living, but I knew that's what I wanted to do. The idea that the human mind could take in little pieces of data from experiments and from that extrapolate to something true across the universe is just amazing, and it's absolutely part of the passionate, artistic side of human beings that brings that to life. And the final thing that you sneaked in there was different people will react to their passions differently, right? And I'm sure this is true in music, just as in science or academia. You're passionate about what you do, also you gotta earn a living, you gotta put food on the table, right? And again, like being a professional musician, getting a job that pays you money as a professional physicist is enormously hard. If you get a Ph.D. From the California Institute of Technology where I am, you know, a top-five physics institution, almost everyone who gets a Ph.D. In Physics from Caltech would like to be a professor. Maybe 25% of them will become tenured professors, and many more wanted to come to Caltech and couldn't make it.

0:52:51 WM: Right, right.

0:52:52 SC: It's an absolute narrowing of the pipeline. So if you have some crazy ideas, if you have some idiosyncratic ways of doing things, it's a balance. You have to decide how much to let your freak flag fly, and how much you think about what other people care about. One of the reasons why I was lucky is because my crazy ideas have come later in life.

[laughter]

0:53:24 SC: When I was young, I was really legitimately, earnestly into the same ideas as everyone else. And so I could do that, and I was very happy doing it, and people liked it that I did it. And these days, like the last 10 years of my career, I'm like, "You know, I think that this kind of thing that I'm doing is stuck." I don't see a lot of forward motion. I gotta be bolder. I have to be more dramatic. I have to think outside the box. I have to be a little crazy and shake things up a little bit. And yeah, people don't like that as much. If it works, they'll say oh yes, they knew all along that was gonna work. But along the way, you know... Hard to get money, it's hard to get attention, it's hard to get people to reread your papers, etcetera. But I love it, so I'm gonna do it.

[chuckle]

0:54:11 SC: And yeah, why would I be doing this if I didn't love it?

0:54:13 WM: Right. Okay, I love that.

0:54:16 Sherman Irby: I just wanted to ask you: How unique is having an organism or anything that's able to contemplate the environment they are in or try to contemplate whatever they are in?

0:54:34 SC: Yeah man, I wish we knew how unique that was. As far as we know, it's super-duper unique. You know this is a... And again, this is opening a can of worms, because it's something we don't understand as scientists. We can talk about... There's parts of the world that represent other parts of the world. So when someone walks down the beach they leave footprints, right? And that footprint is a representation of someone's foot. You know, you can infer from that piece of information that someone walked down the beach. But the beach isn't thinking about it, right? The beach is not sort of imagined. And the process of not just having a memory, not just storing some information you get about the world, but then using that to contemplate hypothetical futures, imaginary futures, the ability to comprehend imagination. That's something that is incredibly important, on the one hand, and I wanna say unique. I don't think it's only human beings that can do it. Certainly, you can look at not just chimpanzees, but also crows, you know, the birds, crows, they're incredibly good at solving little puzzles and stuff like that.

0:55:53 SC: But I think it's perfectly clear that human beings do it to an extent that the rest of the kingdom of life does not. We can talk about it. We can write novels. We can create art in symbolic ways that animals cannot. And we are the only thing in the universe, as far as we know, that has the ability to do that, to talk to each other about imaginary, hypothetical futures and then to sort of come together and agree to bring them into existence. That's why even though I think about the whole universe all at once, I'm still incredibly interested in the question of life on other planets, life elsewhere in the universe, and also artificial life, life that we make in a laboratory here on Earth. Because right now, it's... It didn't have to be this way, but every living being on earth is related. As far as we know, and we have very good data, every living being has a common ancestor four billion years ago, okay, the last universal common ancestor. Life didn't begin 20 times and we now have 20 different kinds of life here on Earth. Either life only began once, or life began 20 times, and one of them beat up the other 19 and they all died out. So we don't know whether this life, intelligence, consciousness, imagination, is unique in the universe to us, or whether it's everywhere. And I would really like to know.

0:57:20 WM: Yeah, you right. Thanks for those ribs yesterday, Sherman.

0:57:26 SI: Watch out now.

0:57:30 WM: You made me do it.

[laughter]

0:57:30 SI: Sean, if you knew about it...

[laughter]

0:57:38 WM: We have any questions for Doc? For Sherman? Or...

0:57:40 AM: Yeah, let's get to some questions here. I've got one from Prince Pace.

0:57:44 Prince Pace: Hi.

0:57:45 WM: Prince, go ahead.

0:57:50 PP: Hi, everyone.

0:57:50 WM: Alright now.

0:57:52 PP: Hi, I'm calling from the UK tonight. It's my first time actually joining. It's usually late, it's past three now in Manchester. I really do appreciate the Skain's Domain every week. So my question is: I practically taught myself music. Never had any formal education really, I learned in church, really. And my question goes this: with Omnibooks, and real books, and things that have transcriptions in them from the jazz masters, Ben Webster to Lester Young, Dexter Gordon, etcetera. How do you... What do you think about books like that, and how do you see that translating? 'Cause everyone thinks, or most of my teachers think, well, "Stay away from that." Which I do agree with. Do a lot of listening to. But where do you think that goes in terms of sight-reading, and also using that as some sort of guide to actually grasping the music, if that makes any sense.

0:59:05 WM: Well, first, I appreciate you asking a question, and thank you for staying up. I'm gonna give you a short answer, and then I'm gonna kick it over to Doc, and he can give you something. And then Sherman, 'cause Sherman and I may think very differently about it. I'm not a fan of that kind of thing until later. I think after you can hear things, it's good to read them and look at them and work on your hearing. But to learn how to play, there's so many nuances that are not in a sheet of music. A sheet of music is one-dimensional. So you wanna be two-dimensional with your hearing, and three, four, five with things that you're gonna notice. That's just how I look at it, but I'm gonna relate it to when Sean said he started being interested in the universe and black holes and the big bang. He said he started with the big bang. I don't know if it was related to books. It was like a passion for that, and I think the passion is expressed in the ideas, but I'm gonna let him kinda go into... When you starting to do something what does he think is more value to be guided by, that type of information or to follow your way.

1:00:08 SC: Oh yeah, you have to be in-between. That's just an obvious answer, you can't be one side or the other. So I'm not only a physicist I'm also a writer, I write books, I write articles a lot. And what writers tell each other, is learn the rules so you can break them. Figure out what the great people did so you can do it slightly differently, not so you can do that. You don't wanna do the same thing that Einstein did if you're a physicist, you don't wanna write the same way Jane Austen did if you're a novelist, but you wanna understand how they did it and then you, who are unique and bring something to it, you might go, "Well, I would do it slightly differently and maybe that open something up." I'm a big believer, that as much as I love the human power of imagination, it's nothing compared to the experience of reality. Our imagination just doesn't measure up to all the different things that other people can think of and the universe can throw at us. So, I like Wynton's... He gave a little caution there. Later maybe, think carefully about what the greats have done and so forth. When you have a little bit of self-knowledge of where you're coming from but don't dismiss it, get... And try your best to figure out what they did because they might have some tricks up their sleeves. There is a reason why they were the greats.

1:01:31 WM: Yeah, yeah, I wasn't talking about it, the greats don't know what they did, I was saying; learn them by hearing. I speaking more of a method, but I understand what Sean is saying. Definitely both methods, you don't have to choose. Somebody said soul of it or intellect, but we human beings, we have both. But Sherman has a lot of interesting ways he looks at stuff and a lot of times we don't have the same perspective but he comes to great conclusions. Sometimes I'm struggling with a voicing of something I'll call Sherman. I'll send him a passage and he will orchestrate it, and I'll study his orchestration and how he came to things and he has a very unique way of looking at music and hearing it. So we're gonna see what Sherm thinks about what you're saying.

1:02:11 SI: And I think all of that is true, all of what you all said was true. I feel that with books and things like that, written on transcriptions, I'm not a big fan of transcriptions, that's just my thing. I like studying songs instead of studying solos but when I do study a solo, I'm looking at forms, I'm looking at first how the song was put together, how the solo was put together, what did they do in order to play a certain kind of line on top of what the harmonic change was. I study those things, I look at a microcosm then I come back and look at the whole picture, the Charlie Parker Omnibook I did, like any saxophone player, especially alto players we work through it. I'm glad that I never tried to really memorize the solos. For me, it was more, "Okay why did he do what he did?" It was just always that question for me is, why? Why does this work?

1:03:19 SI: Then I figured out why it works, and then how can I do it in a way that I want to do it? Then when I figure out what the formula is, I can input my own stuff into it. It's almost like I was working with my daughter on her math today and she looks at it, and it's just so big, it is so much, stuff it's a full-page, scatterings of all these different formulas and things, I said, "Wait, wait, wait, wait, wait, look at the formula, understand the formula: V equals this times this times this, Okay?" Just stop right there, just contemplate that then add in the numbers that you need to add in and it becomes very simple. It's not as confusing at that point when you really just start to come up and understand what the formulas are and then you put in your own stuff in it, that's what works for me.

1:04:05 PP: Right, right, right. Sorry to ask a follow-up question in that sense. So how does that translate to when you are actually learning phrases or leaning passages of lines and making that come into your own music? Is that sort of the same way you learn how they did it and make up your own stuff or do you just copy and paste until you get the hang of it?

1:04:31 WM: Everybody's method is different but I tend to say, do like a baby does. When a baby learns a language they learn the general song of it then they fill it in, but we all have different ways, like what Sean was saying and what Sherman said, but I tend to think that if you... Be comfortable being a baby for a little while. At times, we get to a certain age, we want to be able to do everything, take your time and listen and use your ears and hear and imitate and then you'll start to hear things like if you want to learn another language. That's what I think and if Sherman or Sean if y'all think something different?

1:05:09 SI: I know I agree with that.

1:05:12 WM: Okay, you got to go to bed man, It's three o'clock.

1:05:15 SI: That's right.

1:05:18 PP: Thank you very much.

1:05:20 WM: Thank you for staying up, we're very appreciative.

1:05:22 PP: Thank you, God bless.

1:05:23 AM: Thanks, Prince.

1:05:24 WM: Good luck man, handle your business.

1:05:27 AM: Alright, let's take another one. This one's coming from Antoine Drye.

1:05:31 WM: Antoine.

1:05:34 Antoine Drye: Hey! Wow.

1:05:36 WM: That's what I'm saying. Look out Twine.

1:05:36 SI: There he is.

1:05:39 AD: Well, I had my question before I really knew what was happening, so I'm hopeful that this can relate, but actually either way it will help me. So even if it's not helpful to anybody I'm sorry, but hopefully, it will help me. But my question is about algorithms and if they relate to... I know they relate to math, but do they relate to time and if so how do they relate to music, especially improvised music and chord changes or even just composed music? And then also... How do I say... So I read this book called Weapons of Math Destruction, and it talks about how algorithms can also be detrimental when applied generally. And I wanna know how that all can relate as well in terms of time, and just inside of music and outside of music. And I'm sorry if that's sort of a little bit off-topic.

1:06:42 WM: Well, what do you think about that, Doc?

1:06:44 SC: No, I mean, I think algorithms and time have a very intimate connection. There's a whole field of study called computational complexity theory, where all they do is ask how long it takes a certain algorithm to run, right, like if you give it a 10-digit number, does it take 100 steps or a billion steps or whatever. In fact, there's a famous theorem in Math that there's no way of knowing if someone hands you a computer program, in general, there's no way of knowing whether or not it will ever stop running if you start it, whether there's an infinite loop in there somewhere. It's literally impossible to answer. And so time and, of course, for practical reasons, right, we want our algorithms to be fast. Now, how it relates to music. I think that's a little bit more metaphorical, right. It's a question of, "Are you being formulaic? Are you thinking about your music in the sense that when this happens, I will always do that." And that's an algorithm, but I think that it's better to loosen your definition of an algorithm 'cause algorithms can be probabilistic, algorithms can be, "Well, when this happens, 90% of the time we'll do this, but 10% of the time we'll do something else." And that's crucial not just to music, but to poker, and also to basketball, and also to life. If you're too predictable, that's when it gets boring. It might be something you do that is the best thing you can do, but if it's the only thing you do, then...

[chuckle]

1:08:17 SC: Sometimes you've got things you're less good at doing.

1:08:21 AD: But does an algorithm... Can an algorithm have many phases, though? Like does it necessarily mean, like, you can be doing this, you can stay... When you say the same thing, like, I can say, "I'm playing a C7 chord, but I could play something totally different." So how does that... Is that still within an algorithm? Could it still be within an algorithm but be something different?

1:08:43 SC: Yeah, absolutely. I mean, algorithms are very, very loose, is a very, very loose idea. An algorithm says, "Something, comes in and something goes out." That's basically it. It doesn't... Like I said, it doesn't even say the same exact thing comes out every time. It's a strategy. I mean, replace the word algorithm with strategy or with recipe or something like that. It's a framework and you can play within it.

1:09:07 AD: Right.

1:09:09 WM: Thank you, Twine. Twa-zine.

[chuckle]

1:09:16 AD: Thank you.

1:09:17 AM: Alright, let's... We've got time for just one more. Before we get to that, I just wanna quickly remind everybody about all of the live events we are continuing to host each week. We've got question and answer sessions with Wynton and special guests, master classes, and conversations with members of the Jazz at Lincoln Center Orchestra, live performances streamed from artists' homes, free education classes, and more. Just check out jazz.org for our weekly schedule and further information. So with that, let's take one more question. The last one is coming from Sonalii Wardlaw. Hey, Sonalii, can you hear us?

1:09:58 Sonalii Wardlaw: Yeah, I can hear you.

1:10:00 AM: Alright, go ahead.

1:10:01 SW: Okay. I guess my... This was a very great discussion, by the way. I have a lot of information, of what I have to read and lookup. But my question was: I've always been intrigued by infinity, that things have to somehow come to an end at some point.

[chuckle]

1:10:26 SW: But in terms, when you're dealing with anything as far with the arts, especially like with music, and in my case, with painting. Like you can start with a color and a stroke. With music, it's that certain note, and when I'm listening to music, you hear that certain note, and you want it to continue, but you know it can't continue. So at what point... How do you determine when it will end, because when you're having... I guess like you said with different musicians everyone has a different idea, a different concept, but when it all comes together, it makes that music. But somewhere in the back of your mind, you're just thinking that can go on and continue and continue. So how do you know when to have it end? I don't know know if I'm making any sense.

1:11:38 WM: Well, I'm gonna start by just... It ends, if you play a piece of music, it's got to be over eventually. So a lot of times when you solo too long, people start playing riffs or something to let you know, "Hey, take your horn, we've heard enough of this." But I'm gonna turn it over to Dr. Carroll. I wanna say one thing that's funny about that, is a couple of years ago when we first met, I asked him the question about, "Does the universe just go on forever? Or does it come back to the Big Bang?" So I told him, "I thought that it comes back to the Big Bang." He said, "No, no, it just goes on forever, and then it freezes." So I'm gonna give him our last word tonight and let him just give us his concept of infinity, and what direction things...

1:12:21 SW: Okay.

1:12:22 WM: Are going to go in.

1:12:24 SC: Yeah, another wonderful, great question here. When the song should end when the solo should end...

[chuckle]

1:12:30 SC: I don't have any strong opinions, but I've listened to solos when I've gone like "okay" and others are willing to keep going. Better to end a note too soon than a note too late, right?

[chuckle]

1:12:42 SC: But when it comes to the universe, it's a tough question, too. Does the universe... Is it gonna go on forever, did it go on forever? The Big Bang was 14 billion years ago, but we don't actually know whether the Big Bang was the beginning. It was certainly a major event. There could have been a universe before the Big Bang. We actually, we have a better idea now than we did 20 years ago about the future of the universe. The universe is expanding. 14 billion years ago, it was all packed into a very hot dense state and has been expanding and diluting away and cooling ever since. And we had this question when I was in graduate school and I was your age. We didn't know whether it would just expand forever or maybe expand for a while and re-collapse into a big crunch. Then in 1998, we discovered something interesting. If you look at galaxies very, very far away, we've known since the '20s that they're moving away from us, right? They're receding.

1:13:42 SC: What we discovered in 1998, is that if you look at a galaxy, not only is it going away from you but it's accelerating away from you. It's going away from you faster and faster. If you come back a year later or a million years later and measure its velocity again, it's increased its velocity away from you. That's surprising. It's not what we expected, but we do think we know why. There was an idea from Einstein in 1917, where empty space itself can be full of energy that is very gentle but is pushing everything apart. And if that's true, which 20 years later, 22 years later, that that fits the data perfectly, it's never gonna end. The universe will empty out. Stars are shining now, they'll continue shining for trillions of years. But eventually, like a song, they will have to end. They will run out of fuel. Their entropy will hit the highest point. The universe will become dark. It will become... Everything is spread out so it's very empty and it's very cold. And that will last forever. For infinity years for the future.

1:14:49 SW: Okay.

1:14:50 SC: That sounds depressing, a little bit. But I like to turn it around the other way. This moment in which we live is the interesting fun part of the history of the universe. Our current epoch is the time when the universe is shining as brightly as it ever will, has more complexity and interest and stuff going on as it ever does. We live in the best time in the history of the universe. That gives us a little bit of responsibility to make it as good as we can.

1:15:26 WM: Hey man.

1:15:27 SW: Okay.

1:15:27 WM: Thank you. Sonya, thank you.

1:15:29 SW: Yeah.

1:15:30 WM: Sherman, thank you.

1:15:32 SI: Yes, sir.

1:15:33 WM: Dr. Carroll, thank you so much for your time, and your effort, and your energy. Everybody who's on with us, thank you all so much for joining us. We hope you all enjoyed it. It's been thoroughly enjoyable for me. I can't wait, Sean, till we get together again, and I can't wait till you and Sherman... 'Till we do our thing in the hall next year sometime.

1:15:52 SC: That sounds great. Can't wait.

1:15:55 WM: Man, thank you so much for spending some moments of your evening with us.

1:16:00 SI: Doc.

1:16:00 SC: My pleasure. Thanks for having me on Wynton. Good to...

[overlapping conversation]

1:16:02 WM: Great, man. Fantastic.

1:16:05 AM: Alright. Thanks, everybody. Take care. Thanks for joining us.

1:16:09 WM: Until we meet again.

1:16:12 SC: Bye-bye everybody.

1:16:13 SI: Bye-bye.

1:16:14 WM: Bye.