

Rationally Speaking Episode 133: Sean Carroll on “The Many Worlds Interpretation of Quantum Mechanics is probably correct.”

Julia Galef: Welcome to Rationally Speaking, the podcast where we explore the borderlands between reason and nonsense. I'm your host, Julia Galef.

As our long time listeners may have already learned, my erstwhile co-host and co-founder of the podcast, Massimo Pigliucci, has recently amicably resigned in order to focus on other projects, and he's now serving in the role of trusted advisor. This is one of the first podcasts that I'll be recording on my own.

Here to join me for this exciting new era in the Rationally Speaking podcast is today's guest, Sean Carroll. Sean Carroll is a professor of Physics at the California Institute of Technology. He's also the author of the popular books "From Eternity to Here" and "The Particle at the End of the Universe". He also maintains the excellent blog, Preposterous Universe, where he writes about cosmology, philosophy and, sometimes, important topics like hot dog toppings. Sean, welcome to the show.

Sean Carroll: Hot dogs are very important. Julia, thank you very much for having me on. It's extremely flattering to not only be on for the second time but to help usher in the new era of Rationally Speaking with you taking the reins. I'm very excited to see what you'll do.

Julia Galef: That's right, help us usher in the new era! And in fact, I should have said “to welcome you *back* to the show,” because you are now part of that rarefied group of guests who gets invited back to Rationally Speaking, so - welcome back.

Sean Carroll: Thank you so much.

Julia Galef: The topic that we'll be focusing on today is the idea that the Many Worlds Interpretation of quantum mechanics is probably correct. This is something that Sean has been discussing especially in the last year, on his blog. In fact, I think you have a blog post with that exact phrase as its title.

Sean Carroll: Yup, that's right.

Julia Galef: [00:02:00] Sean, I just want to utter the disclaimer that I'm not a physicist nor do I have any particular background in studying physics. I think that applies to most of our listeners too. Do take pity on us, and try to pitch

your explanations at the level of a smart layperson, if you would. I know you're good at that.

Sean Carroll: You will be a physicist by the time the podcast is over.

Julia Galef: This *is* a magic episode!

Sean, I was thinking that maybe to start, you could just briefly explain what this controversy is about. I think it's one of the most interesting controversies in physics, at least to non-physicists. It's a relatively unique controversy, in that way -- that the question of whether it's fair to say that there are Many Worlds, is actually a sexy topic even for non-physicists.

So maybe you could just explain what it is that the theory of quantum mechanics says, and why there is room for different interpretations.

Sean Carroll: Yeah. I think there's a lot of shrubbery that needs to be cleared out on the ground before we head into the deepest stuff.

I had a previous blog post called "The Most Embarrassing Graph in Physics". It was a graph that was about the fact that professional Physicists don't agree on what quantum mechanics says. This is very embarrassing to me because quantum mechanics has been around since the 1920s, and we've had a lot of time to think about it. We use it, we teach it to our undergraduates and it's enormously successful and it's certainly correct -- at least there's some very good approximation to how reality works -- and yet, we don't know what the theory is. It's not just that we don't know how to go beyond that, we don't even know what it is. To me, that is very embarrassing.

The version of this spread around in certain circles has me saying that *quantum mechanics* is very embarrassing, and that's the opposite of the truth. Quantum mechanics is awesome. [00:04:00] We physicists' inability to understand quantum mechanics is embarrassing.

Julia Galef: It's awfully hard to preserve the nuance in a claim like that as it travels from blog to article to blog, etc.

Sean Carroll: It occasionally happens the nuance is degraded in the course of claims moving through the internet, yes.

The point is the measurement problem of quantum mechanics. You may have heard that you have a quantum mechanical system like a particle in

a box or an electron in an atom and so forth. What quantum mechanics gives you is not what the outcome of your measurement will be, but the probability of different possible measurement outcomes. A particle might be spinning. It might be spinning either clockwise or counterclockwise. You can put that particle in a state where there is no definite answer as to what your measurement outcome will be. Is it clockwise or counterclockwise? It only tells you the probability.

This really, really rubs people the wrong way because -- not only does it rub people the wrong way because probability seems like a weird thing to arise in physics. We could learn to deal with that.

But it arises when you make a measurement, which is really, really weird. When you're not looking at the system, when there's no measurements going on in the conventional way of presenting quantum mechanics, everything is 100% deterministic, and there's no probabilities involved at all.

Why in the world should a measurement -- which sounds like the intervention of a human observer -- have anything at all to do with quantum mechanics? That's the measurement problem. That's the source of all of the anxiety that people have.

Julia Galef: Right. And it's my understanding that the fact that this happens, and the very precise probabilities that we measure -- that's completely uncontroversial, and basically accepted by all physicists.

Sean Carroll: That's completely uncontroversial. In fact, [00:06:00] we're very, very sure that it's not just that we haven't tried hard enough and that if we try harder, we will be able to predict things with 100% accuracy. Quantum mechanics really works this way.

And no one is really imagining that if we just think harder, write a better theory, we'll be able to get rid of the probabilities. The question is how you make *sense* of this idea that a measurement gives you only probabilistic outcomes.

The traditional textbook way is to draw a distinction between the classical observer, you, and the quantum system, and it's an interaction between the classical observer and the quantum system that gives rise to this measurement process. Nobody likes this textbook way of doing things, even though we still teach it in all the textbooks. So we're all trying to do a little bit better.

The Many Worlds way of doing it better is to say the following things: Think about the way that quantum mechanics describes reality. The idea is that there is a wave function, a quantum state that you can use as an algorithm to give you these probabilities. And just take that formalism absolutely literally as a description of everything, including the observer. Don't allow for any new elements, don't allow for any collapses of the wave function, or probabilities, or anything.

The claim is that if you just take that seriously, just take seriously the parts of quantum mechanics that everyone agrees are definitely there, it automatically happens that you get apparent collapsing of the wave function, and probabilities, and things like that.

What actually happens is: you have the particle that is either spinning clockwise or counterclockwise. You also have the observer. And what the so-called measurement process is, is simply the observer -- which could be a person or a dog or a video camera or a rock or a single photon -- the observer interacts with the quantum system.

What happens is that, if before [00:08:00] the interaction there was a quantum probability of the spin being clockwise and also, another probability it was spinning counterclockwise -- after the interaction, there is a world where it looked like the spin was clockwise and the observer saw it spinning clockwise. There's another world where the spin was counterclockwise and the observer saw the spin counterclockwise.

This is a straightforward prediction of the apparatus of quantum mechanics that everyone believes is true. As Ted Bunn put it, if you don't want to believe, you need to invent a theory of 'disappearing worlds' in quantum mechanics. The worlds are already there. It's just matter of, do we attach reality to them or not?

Julia Galef: Right. This seems like the crux of what I've understood to be the disagreement between the Many Worlds camp and what we could call the Copenhagen camp -- or what you call the classical interpretation?

Sean Carroll: Right.

Julia Galef: As I've understood it, the Copenhagen camp is basically saying, "Look, what seems to be happening is the particle, or the cat or whatever, is in a superposition and once someone observes it, the superposition collapses. The cat is either alive or dead. Let's say the cat is alive. Then that's true, and it's false that the cat is dead.

If you want to posit that there is an additional world in which the cat is dead, that's an additional hypothesis that you need to defend. The burden of proof, or burden of evidence, is on you.

Whereas, the Many Worlds camp is saying, "Look, the math describes all of these worlds as existing to equal degrees: the world in which the cat is alive, and the world in which the cat is dead. If you want to claim that only one of those worlds is real, then the burden of proof [00:10:00] or evidence is on you."

Sean Carroll: Your first description of the Copenhagen version is right, right up until the end. I think that the burden of proof statement is just not quite correct...

There's at least four different ways of getting around this measurement problem. The Many Worlds one, which I just gave you. There's the possibility that collapses of the wave function are real and truly stochastic, truly unpredictable and just happen every so often. This is called the dynamical collapse theory. There are hidden variables, which say that in addition to the wave function which normally describes all these different worlds, there's also some hidden variable that points to one correct world, and that's the one we're in.

Then there's this modern version of the Copenhagen interpretation. These are called epistemic approaches to quantum mechanics, where you try to say that the wave function is not reality, it is just a way of describing our knowledge of reality. Observing something, doing a measurement, is just like doing a measurement that you would do in Bayes' theorem. You update your information because you learn something new as part of a measurement outcome.

Julia Galef: So probabilities are a fact about our uncertainty about the world, not a fact about the world.

Sean Carroll: That's right. It's our ignorance of the exact state of the world, that is correct. That is their ambition anyway. The Epistemic people don't quite yet have a full theory. They don't quite, as I understand it, have a full formalism where they're able to answer questions like, "So what am I in this, and what is the true state of the world that you're talking about?"

But this is their ambition, because they don't want to take the wave function quite seriously. I think that it would be wrong for a Copenhagen or epistemic person to point to a Many Worlds person and say, "The burden of proof is on you to say that the other worlds are there."

The other worlds are in the wave function. They're there. The Many-Worlds person says [00:12:00], "Let us take that wave function as representing all of reality because that's *the simplest thing to do*. The epistemic person says, "No let's not. Let's just take it as representing our knowledge."

I think that the burden of ... I wouldn't even phrase it in burden of proof language. I would say that both camps have questions to answer. Both camps have challenges that the other one can raise to them, like, "You haven't answered this question". Like I just said, the epistemic people don't quite yet have a full theory of what people are, and what their world is, and so forth.

The Everettians such as myself -- because Hugh Everett, by the way, is the person who invented this Many Worlds formalism -- we have questions too. Like, why do we see apparent collapses onto some states and not others? What exactly divides the boundary between one world and another? How often does the wave function branch? Why does the probability come out the way it does?

That's why it's an embarrassment, because all of these approaches have huge, looming, unanswered questions, even though it's our most successful theory of Physics.

Julia Galef: You mentioned the concept of simplicity. I've encountered a lot of confusion -- also *experienced* a lot of confusion -- over, how do you decide which theory is simpler than another theory?

For example, I've heard critiques of the Many Worlds, or Everett, interpretation of quantum mechanics, to the effect that, "Look, if you're going posit this infinite or uncountably large number of worlds in order to explain this data we're getting, then that's an incredibly extravagant, or incredibly complex, theory. And we should really go for a simpler one, in which there is only one world -- the world that we can see, basically."

Sean Carroll: I would say there are various reasonable critiques of the Many Worlds program; that is not one of them.

Julia Galef: Right. That's what I thought you'd say. [00:14:00]

Sean Carroll: Yeah. To put it as bluntly as possible, that's just wrong. That's just a mistake. It's just a misunderstanding.

Because, again, we're not positing many, many worlds. We are taking the formalism of quantum mechanics that is always there. The Hilbert space, that we call it, which is where the wave function lives, it's the mathematical structure that a particular quantum state is an element of. The Hilbert space is just as big for someone doing a different interpretation as for someone doing Many Worlds. It doesn't get any bigger. Hilbert space is big. It includes a lot of possibilities. All we're saying is, Hilbert space is *all there is*, then you stop after you have that. There's not other structures or other rules or other interpretative dances that you're allowed to do.

To say that positing a lot of worlds is extravagant is to get it exactly backwards. We're positing the minimal mathematical structure needed to make sense of quantum mechanics. Everyone posits Hilbert space. We're just admitting that it's real rather than denying that.

Julia Galef: Would it be fair to say that Hilbert space is the set of all possible worlds?

Sean Carroll: You can think of it as the set of all possible measurement outcomes in some sense, very roughly speaking. For instance, if you have a single particle moving in a box, the Hilbert space looks like it's a vector space. It's sort of a set of dimensions and there's one dimension for every point in the box. How many points are there in the box? There's an infinite number of points in the box so it's an infinite dimensional space. That's a very, very big space and that bothers people. It's a big number, just like the number of points on the real line between zero and one is a big number. It's an infinitely big number. But that's why we pay the mathematicians the big bucks to figure this stuff out.

Julia Galef: I've heard it said that positing that our world, the one that we're observing, is the only *real* one, despite all the other possible worlds or possible measurement outcomes [00:16:00] described as part of Hilbert space... Saying that is, some people claim, like saying that the Earth is at the center of the universe. You can explain all the astronomical data that we can collect, while also holding a geocentric model of the universe -- but that requires a lot of contortion. And there's no real justification for positing that the Earth is at the center of the universe, the same way there's no real justification for saying that our Everett branch is the only real one.

Sean Carroll: I think that's right. I think that if your main objection to the Many Worlds version of quantum mechanics was that we only see one world and therefore you're not comfortable buying into the possible reality of all these other worlds, that's just not good at all. That's an issue for you and

your therapist. That is not an issue for physics. There are, again, physics issues that we can talk about, but I think that if this simple mathematical formalism fits the data, then it is not extravagant.

People have this idea that somehow we need to separately list all these worlds that are there but they're already there in the wave function, the mathematical description. No one denies that if you believe in quantum mechanics at all, that I can write down a wave function that would be interpreted as one world in which something is going on and another world in which another thing is going on.

It's just that you need to go through a contortion to say, 'But things like that aren't *real*.' And the Everettian is self-confident enough to say, "Yeah, that can be real, no problem."

Julia Galef:

I think I might still be confused about, to what extent this disagreement involves a disagreement over what we mean by 'real,' or 'exist.'

We had Max Tegmark on the show [00:18:00] maybe a year ago. As I'm sure you know, his Mathematical Universe hypothesis could be colloquially summed up as being, 'The universe is *made of* math.' That's instead of what most people might think to say, which is that the universe can be *described* with math, but it actually *is* something much realer than math, and math is just this abstract construct that describes it.

And I wonder how much of this disagreement over the reality of these other Everett branches just comes down to what we want to call 'real.'

Sean Carroll:

I think it's an important issue to get straight, but I don't think that one is that hard. It maybe difficult in that some of the epistemic people, the people who don't believe that the wave function represents reality but just our knowledge of reality, it is occasionally true that they are hard to pin down about what reality is. They don't want to say that there is some underlying reality. They really just want to be utterly operational and say, 'All we ever do is make observations, and we're going to predict the outcomes of those observations, don't ask me questions about what is real.'

But except for those people, who I think are a minority, everyone agrees that there is something that is the real world, and our job as scientists is to find the best mathematical representation of it.

I agree with you in that it's not clear what is meant by this claim, that the math *is* the world. I don't know what it means. But I do know what it means to say the world has all of these branches in it, or the world doesn't have all these branches. I think there's a straightforward difference there. In fact, it's an experimentally accessible difference.

The real well-posed alternatives to Many Worlds quantum mechanics are things like these dynamical collapse models, or these hidden variable models, and they make experimental predictions that can be tested.

[00:20:00]What we all care about is using the formalism to make these experimental tests, but at the end of the day, once you find the formalism that fits, I want to say good, now you describe reality, I think that's okay.

Julia Galef: What kinds of experiments might we do to distinguish Many Worlds from its alternatives?

Sean Carroll: It depends on the alternatives. Many Worlds is just the formalism of quantum mechanics taken straightforwardly and literally. So, give me an alternative and I can test it. For example, there is something called the GRW theory for the three people who invented it, Ghirardi, Rimini and Weber. They say that every particle has a probability per unit time of suddenly localizing itself. Its wave function tends to spread out and then bang, in some unpredictable moment, it is now located in one position.

That's a very testable thing. There's sort of a rate per unit time that this happens. You can look for it, it would sort of deposit energy in a crystal, if there were a particle that was in that crystal. Maybe you could like, look for it in dark matter detection experiments or something like that, but there's a physical process, that is there. In hidden variable theories, there's another variable. That variable can lead to predictions that are different than simply the standard Schrodinger equation of quantum mechanics.

In both cases, there's a limit. These are two theories that add something over and above the Schrodinger equation, but they add it in such a way that there's a limit in which everything just becomes regular old Everettian quantum mechanics and becomes indistinguishable. You can't ever fully rule it out, but if one of these theories describes reality then you have a hope of actually finding out that it's true.

Julia Galef: I definitely heard many times that the problem with Many Worlds [00:22:00] versus Copenhagen is that you can't do a test that would give

different results based on one versus the other theory. That sounds like it contradicts what you just said. Why do you think that's such a common misconception?

Sean Carroll: I've heard many times that human beings are not causing global warming either.

Julia Galef: This seems like it's at a different level though!

Sean Carroll: I don't know if it is.

Julia Galef: Do you think they're just empirically wrong?

Sean Carroll: Yeah. I think that if you gave me a well-formulated, full and complete theory of Copenhagen quantum mechanics and it was not identical to Many Worlds quantum mechanics then I could propose an experimental test. Again, it seems like it's hard to "test" Many Worlds, because Many Worlds is just quantum mechanics and we test it all the time. It's *alternatives* to Many Worlds that we need to be able to test.

Every interference experiment, every double slit experiment, every time that you do anything that is fundamental in quantum mechanics, you're testing the existence of superpositions of wave functions that describe different possible classical outcomes, which is the entire content of Many Worlds. You need to tell me an alternative, and then I'll start planning my tests.

Julia Galef: It sounds to me like the confusion comes over whether we should accept Many Worlds as the default, as the bare bones, not extending the uncontroversial math of quantum mechanics any further that it already is -- and if you don't accept that that's the default interpretation, then I could see people demanding some kind of test which you think is irrelevant.

Sean Carroll: You put your finger on something important there. I think that what really bugs people is that to take Many Worlds seriously implies the existence of all these things we'll never observe. But every physical theory implies the existence [00:24:00]of things we'll never observe. There are just things that they're far away, we'll never going to observe them.

That can't count by itself as a strike against the theory. You could also say, "Well, I don't care." You could say, "I don't care about the existence of these other worlds." That's fine as long as you have some absolutely

well-formulated version of quantum mechanics that you can use to make predictions.

For example, I've recently written papers about cosmology that really do rely on the Many Worlds version of quantum mechanics being correct, which is not to say that I prove that it is correct. I say, "Look, under the Many Worlds interpretation, here is a certain thing that happens in cosmology which is extremely relevant to making predictions for our observable universe. If you have a different interpretation of quantum mechanics, you will get different predictions for these phenomena."

I think that it bugs people because people are old and crusty... and if they can't see it with their eyeballs, they don't want to believe it's true. I think that we should accept the best mathematical formalism as a correct representation of reality and take it from there.

Julia Galef: Do you think that what you just said is equivalent to saying, "Let's use Occam's razor?" That the simplest explanation that fits the facts is most likely to be true, or is the one that we should assume.

Sean Carroll: It does. It's very similar to that. I think that the mistake that people make is thinking that they're using Occam's razor by trying to cut down on the number of universes. When you're constructing a theory of Physics, you don't apply Occam to the number of elements in that theory. You don't say that the set of integers is less simple than the set of numbers 1, 5, 7, 18, 29, and 3,000, even though there are fewer numbers in that set. The set of integers is much simpler. It's much easier to describe what that set is.

Likewise, you don't discount Many Worlds of quantum mechanics because there are Many Worlds, you ask how simple [00:26:00] is the theory? You apply Occam's razor to that. By my criteria, Everett and Many Worlds come out ahead.

Julia Galef: Do you feel like Occam's razor needs some justification as a heuristic for scientists or philosophers, or is it just self-evident?

Sean Carroll: I don't think either one. I think it's a rule of thumb.

There would be an interesting dilemma that scientists would have if you had two or more theories that were exactly, equally simple and made exactly identical predictions for every observable phenomena, but were different for certain unobservable phenomena. Then you'd be stuck.

Fortunately, we're nowhere near having that situation, so it's a very academic exercise. But if you have two theories that give all the same predictions for all the same observable phenomena, and one is way more complicated and baroque than the other one, then, it's some principle of reasoning. It's just, of course, we will talk as if the simpler one is true until we have a reason not to.

Julia Galef: Do you think that there's any path dependence to the extent that physicists fall into the classical or Copenhagen interpretation camp? Do you think that's partly the result of historical accident, that it came first or became popular first? That that's one reason that the Many Worlds or Everett camp has had to fight harder than otherwise it would have, to be taken as the default, or taken seriously?

Sean Carroll: Yeah. I think there's no question that quantum mechanics is very, very non-intuitive. It always has been. In fact, as much as I like to say that the current state of our understanding of quantum mechanics is an embarrassment, what was accomplished back in the 1920s and 1930s is absolutely astonishing. The fact that the physicists of those days were willing to so [00:28:00]thoroughly overthrow the entire structure that we thought was going to work, of Newtonian mechanics, because that's what the data seemed to require.

There is reluctance, and Schrodinger came up with Schrodinger's cat, the idea that a macroscopic object like a cat could be in a superposition of alive and dead, *because* he thought it was absurd. He used that as an example -- and we're celebrating the 80th birthday, by the way, of Schrodinger's cat, it was 1935.

Julia Galef: Happy Birthday.

Sean Carroll: Happy Birthday, part of it that's still alive.

He was trying to say, "Look, you can't possibly think that this crazy theory that I helped invent actually applies to the macroscopic world, do you?" Then Everett, in 1957, comes along and says, "Yes, I'm just crazy enough to believe that."

I think that, yeah, a lot of it is just intuition and discomfort and a certain ornery, commonsensical stubbornness. Of course that's a horribly unfair thing for me to say because no one who actually disagrees with me would describe themselves that way. But that is my cheap, free psychological evaluation, and it's worth it back what you paid for.

Julia Galef: That phrase that you used as the title of one of your blog posts, that “Many Worlds is probably correct,” do you say that because we so far haven't had any successful tests of other alternatives to Many Worlds, or is there some additional reason why you think it's probably correct?

Sean Carroll: I say it because the ingredients of Many Worlds are exactly the ingredients that everyone agrees are a part of quantum mechanics. We simply don't add any new ingredients. Then, it is our burden as defenders or advocates of the Many Worlds interpretation to say that that's enough. That that minimalist, spartan, pared-down version of quantum mechanics can account for our experience and our data. I think it can. That's why I think [00:30:00]it's probably correct.

If you have some terribly difficult puzzle and you realize that there's a really simple-sounding solution to it, that's a good thing. You say, "Okay I'm going to move on and worry about other problems now."

For the early universe, we had inflation, inflationary cosmology, which is a wonderful theory that helps explain certain features that we observe of the early universe. But it's not a complete theory, it makes all sorts of assumptions that we don't yet know how to justify. It's very shaky in certain ways. I'm in favor of it, but I wouldn't go so far as to say it's probably right. We don't know enough yet to say.

Whereas, with quantum mechanics, when we had such a simple possibility that seems to fit everything fine, there I'm willing to say it's probably right.

I could be wrong. I advocate it because I think that it is discounted both within the popular imagination and among professional physicists, more than it should be. But if all of my colleagues were going around saying that Everettian quantum mechanics is obviously right and we don't need to think about it, I'd probably be on the other side saying, no, because I'm skeptical.

Julia Galef: Right. Do you know what the breakdown actually is? I've seen different figures. Some surveys suggest that Many Worlds is definitely the minority, other surveys suggest that it's just recently become the majority view.

Sean Carroll: Yeah. I think that's just simply accurate because there's a huge selection bias depending on who you're asking. These surveys are typically carried out at conferences which are devoted to some subfield – and in Physics,

which subject you're in dramatically affects which interpretation of quantum mechanics you like the best.

They're all respectable. These other approaches, whether it's dynamical collapse of hidden variables or epistemic informational approaches. People should be working on them and people should be trying to push them forward. Because people might think we're on the right track, but no one in their [00:32:00]right mind can say we're finished, and we completely understand quantum mechanics.

I think we will. I don't think it's this irreducibly mysterious thing that will be bothering us 100 years from now. I think we'll figure it out. But I don't think we're there yet.

Julia Galef: Sure. Can we switch tacks now and talk about implications of the different interpretations? Like, what does it matter whether Many Worlds, versus any of the other alternatives, turns out to be correct?

Sean Carroll: That's a good question, because it doesn't matter in terms of building a better smartphone, or curing measles or anything like that. It's certainly a task for physicists, and it's one that until recently was completely academic in the sense that we had a good set of rules of thumb that were more than good enough.

Part of the reason why the issue has garnered more attention recently is the technology has improved to the point where we're now working at the quantum boundary – the quantum classical boundary, I should say. We're seeing the appearance and disappearance of quantum mechanical effects. There's a claim that photosynthesis makes intimate use of quantum mechanics in a way that it wouldn't happen in the same way if it were just classical mechanics. We're being driven to really examine these questions very carefully.

But at the end of the day, I think that we get trained as scientists to be extremely instrumental. We want to solve the problem. We want to predict a number. We want to say what's going to happen if you poke the system in a certain way -- which is fine, but I don't think we should then mistake that instrumental task for our original motivation. No 12-year-old girl becomes fascinated by physics because she says, "Someday I want to be able to predict the outcome of where photons are going to make marks on a photographic plate."

Julia Galef: Clearly, you don't hanging out with the same 12-year-old girls I hang out with...

Sean Carroll: No, no, no. The ones you hang out with would say, "I want to understand how the world works." You don't want to say [00:34:00], "I want to make observational predictions." They want to figure out how reality operates. That's the difference. I think that everyone gets excited about science because it's supposed to be satisfying our curiosity about how things work, not just a task we have been given to make a prediction about a certain experimental outcome.

Julia Galef: Sure.

There is a philosophical, or ethical, implication of Many Worlds that's ... maybe you don't think this follows, but it seemed intriguing to me, that if there's an uncountably large number of Everett branches out there, in which there are copies of me that are almost identical to me, that in some sense I should *care* about those copies almost as much as I care about myself. I don't quite know how to process that.

Sean Carroll: I think that it is an issue. I think that it is perfectly valid to think about this. I think that it is not as simple issue, and it's easy to go wrong by thinking we can sort of jump straight to what the implications are.

For one thing, let's be clear, it is not that everything that you can possibly imagine happens out there in the Many Worlds. There are some things that happen within the quantum mechanical wave function and some things that don't happen. It's not like every possible version of your life has been taking place out there in the multiverse.

But still, you're right. I have an app on my iPhone called "Universe splitter." You can ask it a yes or no question, and it will send a signal to a laboratory and send a photon down the beam splitter and there's a quantum mechanical probability, 50/50, whether the photon goes left or right, and it gives you the answer back onto your phone.

If you say, "Well okay, if it comes back A I'm going to have Chinese food tonight and if it comes back, B) I'm going to have Thai food," [00:36:00] and you actually do, then, there is a universe where you had Chinese food for dinner and a universe where you had Thai food for dinner.

Julia Galef: It's a random number generator, but with philosophical implications?

Sean Carroll: It's a generator where all the possibilities come out true. So if Raskolnikov does this and says, if Universe Splitter says yes I should kill that person, or says I shouldn't... then there's a universe in which you're a murderer and one in which you're not.

I think it's absolutely worth thinking about the moral implications of this. Of course, we could go on to have a whole other podcast about the origins of morality and our moral intuitions and our pre-cognitive, emotional responses that get in the way of coming up with a rational response to this kind of abstract dilemma.

Julia Galef:

Yeah. I think for the people who are worrying about these implications -- and there are not many such people -- but for them it's usually not about trying to derive some new system of morality to take this into account. It's just a process of making sense of how I should *feel* about those copies of me, that feels like a lot of the moral reasoning that we do on a day-to-day basis -- like, if my actions hurt someone who I can't see, does that make them any less bad, does that mean I should care about them any less, just because I can't see them?

There isn't necessarily any "right" answer to these questions, but you can hold two of your moral intuitions up against each other and notice that there's a paradox, or an inconsistency, and feel your intuitions start to shift to converge in accordance with each other. That might be something one might want to do regarding all of the Everett branches, if one wants to take Many Worlds seriously.

Sean Carroll:

Yeah absolutely. I think that is a perfectly valid thing to contemplate. [00:38:00] The good news is, the reason why this is not a absolutely pressing moral issue, is because if our understanding of Many Worlds is correct, then nothing that you in this branch of the wave function can do, can ever possibly affect anything that happens in the branches that have already branched off. You might care about what's happening in those other branches but you can't do anything about it. It's not really ... It doesn't seem very plausible to assign moral responsibility to your future actions on the basis of things going on in other branches.

Julia Galef:

Right. There was this case -- I don't remember who this was -- one Everettian who I know, she was crossing the street and I guess she wasn't looking where she was going, and the car slammed on its brakes to avoid hitting her.

She was really shaken by this -- which that made sense to me, It makes sense to be shaken if you're almost hit by a car -- but she then explains that the reason she felt so shaken was that she had "lost a lot of measure." In other words, there were a lot of almost identical copies of her who *had* gotten hit by the car, since it was kind of a toss up whether the car would have hit her or not. Over the set of all copies of her --

Sean Carroll: I'm not sure that attitude can be consistently maintained if you also believe in a block universe version of time, where eventually we're all dead.

Julia Galef: I'll pass that on! I don't know if that will cheer her up or not.

There was one other ethical implication I wanted to ask you about. We have a few minutes left.

I don't know this is correct, but if there are an infinite number of sentient beings across all of these Everett branches, then it becomes really hard to talk about trying to increase the amount of total happiness, or average happiness in the universe, or decrease the amount of total suffering [00:40:00] in the universe. Because we've just concluded that there are infinite amounts of suffering and happiness no matter what you do, which makes it hard to do any kind of utilitarian calculus. What do you think?

Sean Carroll: I think that, again, it's a long conversation because I think that we need to lay some groundwork, kind of epistemologically, and ontologically, about free will and things like that. If you really believed in the Everett interpretation and quantum mechanics, you shouldn't believe in the libertarian notion of free will. You're just obeying Schrodinger's equation, that's what you do. If you want to speak the language of wave functions, then you should not also be speaking the language of choice and moral responsibility.

But I would say that there are emergent languages and vocabularies we can use to describe reality in a more readily accessible way. One of those languages and vocabularies refers to human beings and agents able to make choices, and have moral responsibility for those actions. At that level, it makes perfect sense to say, like, how should we act given some moral goal that we all agree on? But once you get there, you don't have any controls over the other branches and the wave function.

In fact, I think that there's a utilitarian mistake in thinking that it's even possible to care about every person in the multiverse equally. It's okay to think about people closer to you and people you can affect more than people who are in other branches of the wave function. But I think this is a whole fascinating thing that certainly someone should give us a grant to write a book about.

Julia Galef: Right. And perhaps it was unfair of me to bring it up one minute before the end of the podcast!

Sean Carroll: It's a great example of how our underlying view of what the universe is [00:42:00]being so non-intuitive. The scientific image of the world given to us by the last few hundred years of thought is so very different than the manifest image that our morality, is based on. People moving in a world where life is something is special, and a few thousand years old and what have you.

A lot of our intuitive moral judgments aren't up to the task of dealing with this world that we find ourselves in. Right now, it's fine that we're talking about the Many Worlds and the multiverse and whatever. But a hundred years from now, when we're talking about immortality and human-machine interfaces and genetic engineering, we're going to be way far away from the stuff that we have been evolutionarily programmed to deal with. Thinking about these thought experiments is a good way to do the calisthenics of getting there for the more practical problems in the future.

Julia Galef: Right. Amen to that. We are just out of time for this part of the podcast. I will wrap things up and we'll move on to the Rationally Speaking picks.

Sean Carroll: Great.

[Musical interlude]

Julia Galef: Welcome back. Every episode on Rationally Speaking, we invite our guest to recommend a pick -- a book or movie or website, whatever tickles your rational fancy. This episode we invite our guest, Sean Carroll, to offer up the Rationally Speaking pick of the episode. Sean?

Sean Carroll: Since we've been talking about [00:44:00]quantum mechanics, I'm going to plug a book that maybe you and your audience have heard of, but doesn't get nearly enough attention as it should -- which is Scott Aaronson's book *Quantum Computing since Democritus*. I think it's a clever title but maybe one that doesn't really situate it for the New York Times best-seller list. But this book, *Quantum Computing Since Democritus*, to me, it should be this generation's *Godel, Escher, Bach*.

If you were my generation -- I'm older than I sound on the podcast -- *Godel, Escher, Bach* was this book that arrived and we all bought and leafed through it. There was all this math and pictures and it was crazy and inspiring, whether or not you really understood it. I think that Scott's book is very much like that. It grew in an unusual way as a transcription of a course he gave, so it's very conversational, very imaginative. There's dialogues in there. There's crazy thought experiments. And he's teaching

you Quantum Mechanics and complexity theory. He talks about consciousness and free will. It's a tremendously stimulating book that everyone should read.

Julia Galef: Wonderful. I've had that on my to read list for a while. I've found it too daunting to actually start. But certainly, it's been recommended to me by many people before you -- although never quite as persuasively, I have to say. I hope if another edition of the book comes out, you can put that quote, "This generation's *Godel, Escher, Bach*" comment, on the cover!

We are all out of time. Sean, thank you so much for coming back to the show it's been a pleasure.

Sean Carroll: Sure, my pleasure. Thank you very much for having me. We're looking forward to great things in the Julia era.

Julia Galef: Thanks. You and me both. I'll put your pick up on the podcast website and I also encourage all our listeners to check out preposterousuniverse.com, which is Sean's [00:46:00]extremely erudite and enjoyable blog.

This concludes another episode of Rationally Speaking. Join us next time for explorations on the borderlands between reason and nonsense.