Reimagining the Cosmos
by On Being

What follows is the transcript of an On Being interview with Krista Tippett in conversation with Brian Greene.

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Mr. Brian Greene: To me, the question of whether there are three dimensions or 10 dimensions is so captivating that it does impact my desire to live. And again, I don't mean that in some melodramatic sense. If tomorrow we established that there are three dimensions of space, I'm not going to sort of jump off the Empire State Building. But what I mean is that these questions about the rock bottom structure of reality do inform my life. They are not esoteric scientific issues that I leave in the office when I go home at night.

Krista Tippett, host: The discoveries which the physicist Brian Greene spends his life pondering lead to a thrilling, mind-bending view of the cosmos and of the human adventure of modern science. Think of the certainties many of us grew up learning in school, now overtaken by the constant reimagining of the cosmos that is modern physics.

The quaintly simplistic idea that the atom consists of a proton, a neutron, and an electron; the word "space" to describe what we now understand as a sphere teeming with mysterious energy and matter; and the fact that in our lifetime the science fiction scenario of parallel universes has become a compelling mathematical possibility. Brian Greene works on this frontier, and he increasingly believes that the deepest realities are hidden from human senses and defy our best intuition.

I'm Krista Tippett, and this is On Being.

[music: "Seven League Boots" by Zoe Keating]

Ms. Tippett: I spoke with Brian Greene at Columbia University's Davis Auditorium in 2013. We were there at the invitation of Columbia's Center for the Study of Science and Religion and its director, the biologist Robert Pollack.

Ms. Tippett: Brian, I've been following your work for a long time, and I'm so happy to finally be having this conversation.

Mr. Greene: Oh, thank you.

Ms. Tippett: I always start my interviews, whoever I'm speaking with, by just asking if there was a religious or spiritual background to your childhood. I actually find you quite philosophical, kind of between the lines, of a lot of your writing, and are there roots to that?

Mr. Greene: Well, I'd say there are. From a former religious standpoint, I would say that there was ritual, and there was a cultural emphasis on heritage, but there wasn't really a religious focus, per se. I mean, I was Bar Mitzvah'd, but two months before I turned 13, I finally met with a Rabbi, and he recorded what I was supposed to say. And I listened to it, and I memorized it, and I said it at the event in the synagogue. And everybody was crying in the front row as I was saying it. I had no idea what I was saying. I really had no idea what it was about. But I enjoyed the gifts that I got at the end of it.

[laughter]

Mr. Greene: Both my parents, but my father in particular — he was a composer. And he really loved ideas. I mean, he was — didn't go to college. He liked to say that he was a SPHD, a "Seward Park High School Dropout." In 10th grade, he was on the road performing, but he has a very spiritual, philosophical outlook on life. And that certainly permeated my childhood.

Ms. Tippett: And a huge collection of books, right?

Mr. Greene: Yes. Absolutely.

Ms. Tippett: So, I think one thing that you have really brought to many people in your career, both as a scientist and as a writer, and with your work in medias, kind of really helping people see and take delight in the human drama of scientific discovery. You've written, "Science is the greatest of all adventure stories." And I also wonder — how far back do you trace that? When and how did you start to perceive science as a great adventure story?

Mr. Greene: Well, I think like many who are in theoretical physics, there was a love of mathematics at an early age. And for me, personally, it was in high school that I finally recognized that this game of mathematics could be parlayed into a description of reality. In fact, there's one experience when I was taking Advanced Placement Physics where we had this problem that I remember really crystal clear. It had a baseball attached to, like, a piece of chewing gum that was stuck to the ceiling. And the ball was swinging as the chewing gum was stretching. And you're asked to figure out the trajectory of the ball. I mean, who really cares, right?

But there I was at my desk doing the calculation, getting the answer, and it was one of these "holy cow" moments that you had this formula that would predict what would really happen. I remember running down the hallway to my dad, and saying, "Look at this formula that would tell you what would happen with the baseball and the chewing gum." And for me, it was one of those moments of this kind of pursuit is a way into the deep mysteries of the world.

Ms. Tippett: So, when we were — when Bob and I were communicating back and forth and planning this, they asked me to come up with a title. And I don't generally like to come up with a title before a conversation because I want the conversation to be surprising. But we did say "Reimagining the Cosmos" because as I looked at…

Mr. Greene: That's a good one. I like that.

Ms. Tippett: Yeah, well, as I looked at the sweep of your work and at physics, and especially, I think, physics and our time, that seems to be one way of describing what physics is doing.

Mr. Greene: Oh, yeah. For sure. I mean, what we have learned over the last 300 or 400 years, really since the time of Isaac Newton, where his focus was on the physics that you could see the motion of objects, the motion of the moon in the mathematical equations that still bear his name. That was the physics that you could see. And ever since then, we've been jumping off from that starting point to describe the physics that you can't see. It's all part of a narrative which is going beyond everyday experience to try to lift the veil and really, as you say, reimagine how the world is put together.

Ms. Tippett: You make the provocative point that, in fact, our intuition doesn't serve us well at all. That our senses, which is the way we move through the world and the way we perceive reality, mislead us.

Mr. Greene: When we are asking deep questions about reality, I think that is the case. I mean, if you went by your senses, you would think that this table is solid. But we now know that this table is mostly empty space. If you went by your senses, you would think that time is universal. It ticks off the same rate for everyone, regardless of their motion or the gravity that they are experiencing. We know for a fact that that is not true. We all carry our own clock, and it ticks at a rate that is hugely dependent on those features of motion and gravity. So there's a very long list of things that you would be completely misled by if you relied on your senses to understand how that feature of the world works.

Ms. Tippett: So, The Hidden Reality is your latest book, right? That's your newest book?

Mr. Greene: Yes, that's right.

Ms. Tippett: And, that takes on this very, kind of, fiction science subject of parallel universes, multiple universes, multiple realities, which I guess is one of these very wildly…

Mr. Greene: Far out.

Ms. Tippett: Yeah, far out potential implications of string theory. And you go through several different iterations of that, different possibilities. I think — well, first let's just talk about that a little bit, about the whole idea of parallel universes. I mean, there's this great line that one of the implications of this is there is no such thing as a road untraveled.

Mr. Greene: Right. We sit there, the math jumps out of the page, kind of grabs us by the lapel, slaps us in the face, and says, "Look at me. What this is telling you is there might be parallel universes." And we say, "Oh, that's curious. Let's think about that, investigate it." So that's the typical rhythm of the way in which these ideas surface.

This idea that you're referring to comes out of quantum mechanics, which is this new way of describing the fundamental particles of nature that emerged in the early part of the 20th century. And the new idea is that you can only predict the probability of one outcome or another. Newton wouldn't have said that. He would say, "Tell me how things are, and I'll predict how they will be. Period. End of story." Quantum theory says, "No, no, no. I can tell you there's a 30 percent chance of this, 50 percent chance of that, 20 percent chance of that outcome over there." In fact, one of the proposals is that every

outcome happens, they just happen in distinct realities in parallel universes.

Ms. Tippett: So somewhere, all of those possible outcomes were made manifest.

Mr. Greene: That's right. So basically, any outcome allowed by the quantum laws of physics would see the light of day, but the light would be flowing through a different universe.

Ms. Tippett: OK. So all of this science, without wanting to, raises a lot of really basic philosophical, ancient philosophical questions about destiny and fate and choice. Do you — I understand that's not what you're studying, and the mathematics doesn't speak to that directly.

Mr. Greene: Well, it sort of does. I mean, when you ask the question about choice, I presume you were indicating things like free will.

Ms. Tippett: Yeah.

Mr. Greene: And by no means would I say that we have got the be-all and end-all mathematical description of reality. We're struggling to get there. But as a snapshot, if you look at the equations that we have today, there does not seem to be a place anywhere in those equations where you say, "Oh, OK, and here is where human free will comes in to how things are going to evolve." Right? There's no term in the equations where that happens.

Ms. Tippet: OK. We'll come back that. [laughs] I mean, so I keep — well, let me just do this. I keep thinking of another thing Einstein said, that science is good at describing what is, but it doesn't describe what should be. And there's a way in which the way we've tended throughout human history to talk about something like free will or fate or destiny or choice or just the human condition is in terms of what we can control, what life we can create.

Mr. Greene: Right. So, we live our lives as if we do have control. And I think it's the only way that you can live. You tell yourself this interesting, perhaps untrue story that when you reach out for the glass, you're making a choice to pick it up. And I do it too. I sort of felt like I just picked that glass up because I made a choice. But fundamentally, I don't think that I did.

But putting that to aside, yes, we feel we have control, we act as though we have control. And then Einstein's quote comes into play, because once you have control, you can shape the future, and you can shape the future according to distinct values. And, yeah, I think that is the only way that we humans can live, at least in this epoch, until we evolve to some other form. And, sure, there is no way to look to science to tell us how to shape things from some sense of value judgment.

Ms. Tippett: OK. Let's talk about the Higgs boson. [laughs]

Mr. Greene: From free will to the Higgs boson.

[laughter]

Ms. Tippett: That's right. I'm sure they're related somehow too. I want you to — you wrote an article for the Smithsonian magazine last summer. And I'd like for you to tell the

parable of the fish that you said physicists tell each other.

Mr. Greene: Oh. Yeah, right. So the — let me just motivate it first. So, the idea of this Higgs particle, Higgs boson, I think most people have probably heard about it or read something about it, suggests now from experimental data, that a theoretical idea that was pure mathematics when it was introduced, might be correct. Which is that the universe may be filled with an invisible substance called the Higgs Field, and as particles try to burrow through this environment, they feel a kind of resistance, which is where their heft, or their mass comes from. But we have to accept this strange idea that there is this invisible substance that is all around us.

Ms. Tippett: And I love the idea that mass is interactive.

Mr. Greene: That's right. So, mass comes from an interaction. Exactly right. It's not something that is just sort of imbued from the get-go, or from the outside. Now, a parable that gives us some sense of how you can take that very strange story and make it seem less strange is to just think of fish in the ocean, or fish in a fish tank. Right there, swimming around, and they're really not aware that there is a part of the universe that's not filled with this watery substance. In fact, this water is so familiar to them that that is emptiness, that is their universe.

So there you have some beings that are living within an environment that is suffused with essentially an invisible something, water, and yet, because they're in it all the time, they don't know it. We are in the Higgs field all the time, we experience our interaction with it all the time, and that's why we don't even know it. And that's why it takes these dedicated experiments to clue us into something, which at some level, should be obvious.

Ms. Tippett: So, this is what I — I think I understood from reading your article and — in a way that all the articles I've read about Higgs boson have not quite helped me grasp. That what the large hadron collider did is that it was able to jiggle this field enough to cause a tiny droplet to spill off and then provide some kind of evidence.

Mr. Greene: Yes. That's exactly right.

Ms. Tippett: That there was something to this theory.

Mr. Greene: That's right. So this machine slams protons together near the speed of light. And through that collision, the ambient Higgs field, like water, if you had two submarines crashing into each other, the field gets jostled, and if you jostle it the right way, which happens about one in every trillion collisions, you can flick off a little speck of the field, which is the Higgs particle that we believe is found.

Ms. Tippett: And that this is a new form of a matter.

Mr. Greene: Yes, that needs to really be emphasized. So the discovery of a new particle is exciting. The discovery of a particle that has been predicted for four decades is exciting. But it's even more exciting because there has never been a particle like this before. So, just to quickly tell you why, we've known for a long time that the familiar particles, like electrons and quarks, protons, and neutrons, they're not even fundamental, but they all share the property that — spin around. Sort of like a top. There's a quantum mechanical twist to this. But it's not such a bad image to envision that they're spinning around like a top.

The Higgs particle is the only particle, only fundamental particle that we have that doesn't spin around. It's a spinless species of particle. And that may sound kind of esoteric. Who really cares whether it spins or not? The reason why that's very exciting to us, we have made use, in our equations, of spinless particles, hypothetical ones, for decades. They play a role in our understanding of the big bang.

Ms. Tippett: But you couldn't be sure — you couldn't prove they existed.

Mr. Greene: You couldn't even know that even that species was real.

Ms. Tippett: Right.

Mr. Greene: So, now we found one species that has this spinless property, which gives us a little bit more hope that the other versions that we've used in our equations might be true, as well.

Ms. Tippett: Oh, that's really interesting. And so, explain something else to me. In this context of the Higgs field, you talk about this as being a manifestation of nature's version of nature versus nurture.

Mr. Greene: I do recall saying that.

[laughter]

Mr. Greene: The funny thing is I'm sitting here now, and it has such a nice ring to it. I do not know what the heck I was referring to any longer. It was like last summer. Can you tell me what I meant when I said that?

Ms. Tippett: Yes, allow me.

Mr. Greene: And let me just see if I can tell you. I remember the editor at the Smithsonian said, "It sounds nice, but we don't really get it." I was like, "It's so obvious what it means." And now I'm sitting here; I can't remember what I was referring to.

Ms. Tippett: OK. So what you were talking about is that there's an interplay between these fundamental laws, and there's also an environmental factor.

Mr. Greene: Oh, yeah. There we go. Thank you.

Ms. Tippett: Yeah. You're welcome. You can call me any time you want to understand your own articles.

Mr. Greene: Yeah, thank you. So, you've got the fundamental laws of nature, which we think of as nature's way of grabbing hold of the universe and causing it to evolve in certain ways according to those laws. But there's also a feature of the things that we experience that is just out there. It's almost a historical happenstance that in our realm space is filled with this field and we also experience the effect of it. So, it's the fundamental laws together with the environment that really come together to shape our experience, even from our fundamental understanding of the Higgs field.

[music: "Afterlife" by Jon Hopkins]

Ms. Tippett: I'm Krista Tippett, and this is On Being. Today, with physicist Brian Greene on

reimagining the cosmos.

[music: “Afterlife” by Jon Hopkins]

Ms. Tippett: Let’s come back to these existential questions again. You quote Einstein a lot. You also quote Camus a fair amount.

Mr. Greene: Yeah, they’re both dead. They can’t really come back and say, “Don’t misuse my words that way.” So it’s kind of a safe thing to do.

Ms. Tippett: [laughs] But you seem to have been quite taken when you read Camus’ writing. Was that the book that you pulled down from the top shelf of your father’s library?

Mr. Greene: Yeah, that’s true. No, it was. My dad had a very varied library that sort of spanned a whole variety of subjects. And one of the books was a Camus book, The Myth of Sisyphus.

Ms. Tippett: Was it the The Myth of Sisyphus book?

Mr. Greene: Yeah. And it’s kind of an amazing thing that in the opening sentences, Camus talks about how knowledge of certain features of the world, like whether or not there are three dimensions. This is…

Ms. Tippett: Did he say that?

Mr. Greene: Yeah, yeah. And whether or not the brain has this or that many distinct processes that are going on. He basically listed a variety of scientific questions, and he said all of those are secondary because the only true philosophical question, he said, was that of suicide. Now for a young kid…

Ms. Tippett: Like the choice to live or to choose not to live.

Mr. Greene: The choice to live or die. That’s the only question that ultimately matters. And when I read that, I was quite young, and it was almost kind of a shocking sentence to read, but it also seemed to me right. I mean, that is the only question that ultimately matters to the individual. But then, as I got older, I began to see things a little bit differently because, to me, the question of whether life is worth living, to me, is intimately dependent upon what life is and what reality is because ultimately your life is lived within reality.

So to me, the question of whether there are three dimensions or 10 dimensions is so captivating that it does impact my desire to live. And again, I don’t mean that in some melodramatic sense. If tomorrow we established that there are three dimensions in space, I’m not going to sort of jump off the Empire State Building. But what I mean, is that these questions about the rock-bottom structure of reality do inform my life. They are not esoteric scientific issues that I leave in the office when I go home at night. And it’s that distinction that ultimately struck me as not as accurate as it might be in his writings.

Ms. Tippett: And for you, as for many scientists, I think, science is essential to the fullness of understanding of humanity just as literature and art and music are.

Mr. Greene: Yeah, absolutely right. I mean, we have these arbitrary distinctions and cordoning off of science in particular. It typically sits at the outskirts of culture, and we

sort of wheel it in whenever we have a problem. We wheel it in when we love the technological advances that it gives rise to. But still, science is generally pushed off to the side relative to those things that really matter to a full life.

And I think that is tragic because science deserves to be right smack in the center of culture, because it is our quest to understand who we are and how we fit into the big picture, just as great poetry is, just as great literature is. So it's not this separate activity. It's all part of the human swirl to make sense of a fundamentally senseless position that we find ourselves in.

We're thrust into this world on this rock that's orbiting a nondescript star in the outskirts of an ordinary galaxy. Wow. I mean, can you imagine being thrust into a more bizarre and strange reality than that? And what we've been doing for thousands of years is just trying to piece by piece get some understanding of where we came from, where the universe came from, and where it's all going. So, to me, that is not distinct from what the poet does or what the philosopher does or what the great writer does or the composer does. They just do it in a different language.

Ms. Tippett: I was very struck by the letter you received from a soldier in Iraq. And the real comfort and meaning that he was able to take — I mean, that's one of those juxtapositions between what the mathematics is telling you and this person in one of these very dark, gritty experiences of life.

Mr. Greene: Man, that's absolutely right. I was, at first, surprised myself to receive that letter. And just to say what it was, it was a soldier who was writing basically from the battlefield and saying that out there in the sort of dusty difficult environment of Baghdad, he had one of my books with him. And he would dive into the book whenever he could because, as he wrote to me, he said it kind of gave him the ability to rise above all of the distressing and dangerous and frightening aspects of the local environment of wartime and lift himself into this realm of big questions where he could just feel like all of the difficulty and all the tragedy around him was put in context by virtue of seeing the larger picture of reality.

And I think that is what science can do for you. It really can allow you to lift yourself out of the everyday, if that everyday is dangerous, if that every day is somehow unpleasant, even if that every day is wondrous. But it can allow you to lift above it and experience reality in a different way.

Ms. Tippett: So, I was recently speaking, I think it was a religious setting — or it was a university setting, and somebody asked me — a professor of the humanities talked about his concern that there's this new way of emphasizing the importance of science over the humanities. And one of the reactions I had is that I feel like sometimes when this is brought up culturally in terms of education and preparing people for the future, it's leaving out this sense of wonder and of science's place in the deepest questions, the greatest mystery and explanation of reality and who we are.

Mr. Greene: You're right. The urgency to fund stem education largely comes from this fear of America falling behind, of America not being prepared. And, sure, I mean, that's a good motivation. But it certainly doesn't tell the full story by any means. Because we who go into science generally don't do it in order that America will be prepared for the future. We go into it because we're captivated by the ideas.

And I think that's how you get kids excited about this, by — I mean, and look, you look at

any of the times when a government is willing to spend significantly on some undertaking, it's largely because they're afraid. They're afraid that they're going to be taken over — Sputnik. They're afraid that somehow they're going to fall behind. And it's unfortunate that fear drives so much activity of that sort when the reality of those in the field are not driven by fear; they're driven just by the excitement of discovery. And if a kid can get that aspect, get that perspective on science, it's a very different reason, a much better motivation for pushing forward.

Ms. Tippett: And that understanding of science suggests a really interesting interplay between science and the humanities too.

Mr. Greene: Yeah, for sure.

Ms. Tippett: It opens up your imagination about what that looks like.

Mr. Greene: Yeah, that's right. Because when you recognize that these big questions of the ages that have, for a long time, been sort of viewed as part of the philosopher's archive or the poet's inspiration, now science is starting to give us some insight, real insight into how the universe began, real insight into what things would be like in the far future. When you recognize that there are Earth-like planets out there, how does that not change your perspective on reality? So, all of that needs to be folded in. And I am enormously impressed that there are so many artists, so many filmmakers that contact me, contact other scientists because they want to be inspired by these ideas.

Ms. Tippett: Right, that's new.

Mr. Greene: They want to understand them at a level where they can begin to infuse their own activities with the knowledge that science is revealing.

[music: "Touch Tone" by I Am Robot And Proud]

Ms. Tippett: You can listen again and share this conversation with Brian Greene through our website, onbeing.org.

I'm Krista Tippett. On Being continues in a moment.

[music: "Touch Tone" by I Am Robot And Proud]

Ms. Tippett: I'm Krista Tippett, and this is On Being. Today, with physicist Brian Greene. I interviewed him at a public event of the Center for the Study of Science and Religion at Columbia University in New York City. Brian Greene is a professor there of physics and mathematics. He brought the field of string theory to a wide audience with his book and television series, The Elegant Universe. We're in a big conversation ranging from free will, to the meaning of the Higgs Boson particle, and his insistence that the deepest nature of reality is hidden from us.

Ms. Tippett: So, I'd like to come back to this — the hiddenness again. I think it's perplexing. There's a sense in which, if even if we accept this and respect it, that our senses mislead us about the nature of reality, that that kind of thwarts the ability of ordinary human beings to internalize the lessons of science.

Mr. Greene: No, you've just got to learn math.

[laughter]

Ms. Tippett: I mean, you said once — you said that assessing life through the lens of everyday experience — and you really meant what reality is — is like gazing at a Van Gogh through the lens of an empty Coke bottle.

Mr. Greene: Yeah, right. I said that? I think that's not a bad metaphor.

Ms. Tippett: [laughs] OK, but well, I mean…

Mr. Greene: There are better metaphors. But, yeah. I think it's — the thing that we have to recognize is that since the 1800s, we've learned that lesson. We can do a calculation using quantum mechanics to 10 decimal places, 2-point-whatever — 13596 — 10 decimal places. That's the result of a mathematical calculation. We then go out and measure the magnetic properties, and we find that digit by digit by digit, 10 decimal places long, the observation agrees with our scribbles on a piece of paper.

How can you not be in awe of that? And how can you not be convinced that that is revealing some deep truth about reality that you simply are not privy to with your eyes or your hands or your ears? There's no sense that allows us to directly experience the quantum world, but the mathematics allows us to understand it and make predictions that agree with observation. That's a very powerful story.

Ms. Tippett: There's also a lot, at least right now, that is the substance of our day that can't be measured. I mean, do you think that, at some point, something like consciousness or love might be measurable?

Mr. Greene: How did I know you were going to love? Man, I was saying, "Is she going to the love question?" And I was right. I do. I don't mean to sort of sound like some heartless, cold scientist. I hope I don't come across that way because that's not how I am. But I do strongly believe, based on what we know today, and that could change when we have deeper understanding tomorrow, that all of consciousness, all of our emotions, is nothing but some physical process playing out inside this messy, gray blob inside of our heads.

That, to me, does not diminish consciousness. It does not diminish the experience of love, or happiness, or sadness, or any of those things that make us human. But it does, I think, reveal the true underlying process responsible for those sensations. And it's nothing but certain things happening inside this gray brain of ours, and one day we will understand it well enough to map it out in detail.

Ms. Tippett: Alright, so let's take this very ordinary experience we think we have of time. It's just — it is, again, the substance, the structure of our days as we perceive it. So, our senses tell us the story of Newton's clockwork world, right? We, a hundred years after Einstein told us, explained that time is relative, we cannot internalize that. I mean, he said it's a stubbornly persistent illusion. We have this stubbornly persistent illusion that our senses constantly reinforce that time is an arrow moving forward. It's linear. There's past, present, and future.

Mr. Greene: Yes.

Ms. Tippett: We cannot internalize that. But you, you live, you live with — you have your hands in this understanding of reality all the time. So, how do you experience — are you

able to experience time differently in your human sense because of what you know as a scientist?

Mr. Greene: So, if you ask me, is the past gone? Yes. I would answer yes to that. Is my father dead? Is he gone? Yes. That is how I answer as a human being. I can try to recognize that, as Einstein taught us, the past is really not gone. It is as real as the present or the future. You just have to recognize that different observers, different individuals in the universe moving at different speeds slice up reality in different ways.

So, yes. I know that stuff. I teach it. I make my students answer problems and take exams on it. But if you ask me, have I been able to really stitch it into the fabric of my own experience of life? No. It's very hard. It's very hard to overcome the day-to-day features of the world as our senses allow us to experience them.

Ms. Tippett: Just kind of break that down for me, like in a moment where you really make this attempt.

Mr. Greene: Yeah. So, I mean, there are times I'll walk down Broadway, heading to get milk at Westside Market, as many in this room no doubt have done, and I'll pass somebody. And I will imagine how my watch is ticking off time at a different rate from their watch, and how as I look at their watch, I see time ticking off slowly. As they look at my watch, they see my watch ticking off time slowly. Sure, I play that game. And it's sort of a fun thing to try to put yourself into the true bubble of reality as physics has described it.

But it's not as though there's any intuition, deep intuition associated with that. If you were to wake me up at 2:00 in the morning, and sort of rouse me from a deep sleep and ask me any of the real questions about time, I'd answer as a human being. I wouldn't answer based upon the knowledge of somebody who has studied the physics.

Ms. Tippett: It doesn't feel elegant to me.

Mr. Greene: Well, yes. I mean…

[laughter]

Mr. Greene: I can envision that one day we evolve to a point where maybe we are actually experiencing life at fast speed, or life at strong gravitational potential. And then, we would find our intuition shifting toward the true reality that comes into play there. But at low speeds and low gravitational potential, the Newtonian world-view does a fantastically good job of describing how the world operates, and that's how our intuition evolved. And that's what we are stuck with.

Ms. Tippett: OK. Let's take some questions for a few minutes. And then we'll come back and close up here. I believe there's a — what will people do? Just — here's a microphone.

Audience Member 1: Hi, Dr. Greene. What's the best evidence we have for string theory right now? Some of the best and most credible evidence that you know of we have for string theory? Thanks.

Mr. Greene: Yeah. The evidence is that string theory is right. Good. So, other questions that you guys would like to…

[laughter]

Mr. Greene: No, OK. So, the quick answer to your question is absolutely nothing. String theory is a completely mathematical undertaking, and at the moment, there's no experiment that we can point to which would say there is the evidence for this idea. And for that reason, string theory really should be called the "string hypothesis." "Theory" in science is a very specific meaning. And string theory does not rise to that level as yet.

Now, having said that, let me just point out that we have tested quantum mechanics. We know it's part of the way the world — we have have tested general relativity. We know it's how it's part of the way the world works. We believe the universe has got to have a consistent description of the laws of physics. And without string theory, quantum mechanics and general relativity or our theory of gravity — they do not come together in a consistent way.

The amazing thing is within string theory, you find, for instance, the Higgs field or something that can be the Higgs field. You find that you can incorporate electrons and quarks and neutrinos. You find that you can incorporate the gauge symmetries that give rise to the weak force and the strong nuclear force.

So all of these ideas that have been slowly, systematically developed over the 20th century, they all find a natural home within string theory, which to boot, puts together gravity and quantum mechanics. So there are many reasons to be excited about the theory, many reasons to have enough impetus to study it. But we've not made contact with experiment as yet.

[music: "I'm 9 Today" by Mum]

Ms. Tippett: I'm Krista Tippett, and this is On Being. Today, reimagining the cosmos with physicist Brian Greene. We're taking questions from the audience at Columbia's Davis Auditorium.

[music: "I'm 9 Today" by Mum]

Audience Member 2: Thank you, Dr. Greene. Thank you for all your work and the way it's informing my guild. I'm a theologian. So I have two questions, really. I either did not understand or am not convinced or persuaded by your conversation about free will. Because it sounds as if your proposal situates us in a very deterministic universe, and that we are simply, in some sense, almost robots acting out of these general laws. And that there's no novelty within this very, very complex and creative entity that we are as conscious beings. That's my first.

Mr. Greene: So, yes. It is hard to accept.

[laughter]

Audience Member 2: So can you say something…

Mr. Greene: But I wouldn't go as far as to say there's no novelty. But yes, free will may go away.

Audience Member 2: So, free will, meaning choice. There's no such thing as choice?

Mr. Greene: That's right.

Audience Member 2: I do not choose to love. I do not choose to extend myself. I don't choose to live, to get back to Camus.

Mr. Greene: Well, it all depends on what you mean by "choose." So, if by "choose," you mean that you could have done otherwise, then I would say yes. But I would say that you need to redefine the meaning of the word "choose." "Choose" is the sensation of choosing. Now it is the fact that the laws of physics were just playing themselves out, and that is fundamentally why you did what you did, but to choose is to have the sensation of making that choice. And we all have that sensation.

And that is a definition which I think works well. It does require a little bit of rejiggering of your intuition to recognize that it may be the case that it — the laws of physics that are behind the scenes doing it all. But yes, that sensation of choice is real. And that's what we should redefine free will to mean.

Audience Member 2: Free will to…

Mr. Greene: Free will is the sensation of making the choice. Even though, behind the scenes, the laws of physics were pulling the strings.

Audience Member 2: Thank you. I'm still not persuaded.

[laughter]

Audience Member 2: My second question, though, has to do with positing the divine reality, which — let's use the "God" word. Why do you keep positing it above and beyond since we in the theological guild are not doing that anymore?

Mr. Greene: Well if you use the word "God" to mean a being that is composed of the same stuff that we see in the world around us, governed by the same laws that that stuff is governed by, then God is a perfectly coherent and sensible idea. And if that's what you mean by it, then we're talking the same language. But if you mean what traditionally is meant by God, which is a being that can intercede, that can cause things to happen that are not governed by the laws of physics, then we are talking different languages.

And I should say I'm not saying that that idea is wrong. It may be right. It may be that God is behind it all. Maybe God set it all up, and there's some variations of these ideas where God sits back and lets it all play itself out. And that could well be what's going on. What I really mean to say is not that the idea is wrong, but as a scientist, I find it profoundly uninteresting because it gives me no new insight into any of the deep questions that we've been talking about here. Doesn't help me calculate anything. Doesn't help me gain some insight into these big mysteries. It simply takes one mystery and uses another three-letter word to re-label that mystery. And that is why I don't find it interesting. Not that it's wrong; I don't find it interesting.

Let me just point out I find the dialogue between science and religion exceedingly interesting, because to me, it's a conversation that really speaks to who we are, and where we've been, and our desire to understand, and the stories we tell ourselves, and root to trying to get deep understanding. I find that profoundly interesting. When I said it's uninteresting, I meant in terms of the questions of physics. It doesn't allow me to gain any progress in those questions.

Audience Member 3: Dr. Greene, you speak quite beautifully of this mad mathematical reality that undergirds our understanding of our experience, that we get at through these deep questions. And I'm on board with that as much as a lay person can be listening to you in translation. But my question is, as the answers to these deep questions become more and more counterintuitive, how useful or how real is any of this as it becomes accessible only to people who can understand these sorts of wonderful mathematical answers?

Mr. Greene: Well, again, things that are complex to us, a hundred years from now, we'll be teaching it in second grade. So, we see this all the time. And so, I don't think we can judge things by a snapshot of a moment in time as to things that we're comfortable with and things that we're less comfortable with. But I think that it's important to recognize that, as we were discussing before, even the abstract esoteric ideas of quantum mechanics, you are carrying around quantum mechanics in your pocket if you have a cell phone.

The fact that you have that device, the fact that you have a personal computer, the fact of anything with an integrated circuit, it all relies on this fancy math of quantum mechanics that allows us to manipulate electrons, to make them go through these tiny microscopic circuits. So, these ideas are not just mad math; they're not just weird and abstract insights into the way the world works; they actually have a way of infiltrating our everyday lives.

So, I think that makes it clear that these do matter, regardless of whether the person with the cell phone understands Schrodinger's equation, it really does matter. And in time, I think the barriers between those who understand these ideas and those who don't will, again, lower. Because over time, ideas that seem impenetrable to one generation becomes second nature to the next.

Ms. Tippett: So, Einstein said that he had a cosmic religious sensibility that was about wonder and awe and a sense of mystery, and that that was enough. Tell me, do you have a cosmic religious sensibility, or is that a phrase that resonates with you? Or how would you describe that?

Mr. Greene: Yeah. Again, it all depends on what these words mean.

Ms. Tippett: Right.

Mr. Greene: But — so, without labeling it…

Ms. Tippett: So, what words would you use for yourself?

Mr. Greene: Yeah, without labeling it, I would just describe it as I have a deep sense of the amazing harmony of the way the universe is put together, that with these very simple mathematical laws that really can be written down on a t-shirt — this is not apocryphal — I mean, my kids have such a t-shirt, and they wear it sometimes.

Using those laws, we can understand really how the universe evolved from a split second after the beginning — the Big Bang is still a mystery — but we can understand how it evolved from a split second after the beginning more or less 'til today and understand its gross detailed features pretty well. That's an amazing thing. That is spiritual to me. The fact that it all — this complexity in the world out there can be reduced to a few simple

ideas. The power of the math, to me, is almost a spiritual experience. So, yes. I would say if that is a good definition of what is religious, then I'm very religious.

Ms. Tippett: I'm just — you mentioned your kids, and I'm just imagining how handy it would be for them to tell you that they had no choice to do what they did because they have no free will.

[laughter]

Mr. Greene: They do. And they're right. They never get punished. But I had no choice to punish them. That's the response.

[laughter]

Ms. Tippett: Just following on that idea of spiritual sensibility — another idea, image that Einstein used was of a mind or an intelligence behind the universe, by which he did not necessarily mean a creator God. But, especially with regard to this matter of hiddenness, and this thing we've been circling around the whole time that what you know to be the nature of reality is not something we can perceive in the thick of experience, which is all we have.

So, if you think about — and I don't know if this is a useful term for you — but if you think about a mind or an intelligence or even that order behind the universe, then how do you imagine that? It also has something that incorporates hiddenness as a way of making its point.

Mr. Greene: So, I mean, the important thing to bear in mind — I think many physicists have this perspective — we don't envision that there's some mind behind it all, but we do…

Ms. Tippett: Right. No, yeah.

Mr. Greene: But I would say that we do envision that there are these powerful laws that can do things that you wouldn't expect them able to do, based upon the most naïve look at the equations. I mean, how could it be that general relativity, the simple equation in quantum mechanics and the standard model of particle physics — if we put that into the mix, over the course of billions of years, can somehow conspire to yield you and me, this complex, cognizant being?

How could we really just emerge from the laws of physics acting through evolutionary change? But that's the power of the math. So if you want, there is the hidden hand. Call it the hidden hand of God if you want. I would simply call it the hidden hand of the equations. And that gets us from the beginning to here.

Ms. Tippett: OK. I think that's your last word. Thank you, Brian Greene.

Mr. Greene: My pleasure.

Ms. Tippett: Thank you all for coming.

[applause]

[music: "Summer Colour" by I Am Robot And Proud]

Ms. Tippett: Brian Greene is a professor of physics and mathematics at Columbia University. He is also co-founder of the World Science Festival. His books include The Elegant Universe and The Hidden Reality: Parallel Universes and the Deep Laws of the Cosmos.

[music: “Summer Colour” by I Am Robot And Proud]

Ms. Tippett: So, one piece of my conversation with Brian Greene still really has me puzzling, and we couldn’t fit it into the show. One of the scenarios that string theory suggests is that what we perceive as reality, including ourselves, is like a hologram.

Mr. Greene: A lot of physics comes into the history of this idea, but the proposal is that we may actually be a holographic projection of laws of physics that exist on a thin surface that surrounds us, say, at the far edges of the universe, much as a hologram is a thin piece of plastic which, when illuminated correctly, creates a realistic 3D image. We may be the 3D image, if you will, of the physics that exists on that bounding surface.

Ms. Tippett: Doesn’t that raise the question of the source of this information? I mean, one of the analogies you used — it’s like we’re the skyscraper to the architect’s blueprint, or — but who’s — what is the source of that blueprint?

Mr. Greene: Right. It’s hard to answer.

Ms. Tippett: To hear more of this and other fascinating ideas from my conversation with Brian Greene, find the unedited interview at onbeing.org or wherever you download your podcasts.

[music: “Twinkle Twinkle” by Kettel]

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