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So if you enjoy what we're doing here, please consider becoming one. As always, I never want money to be the reason why someone can't get access to the podcast. So if you can't afford a subscription, there's an option that Sam Harris, Doug, to request a free account and we grant 100 percent of those requests. No questions asked. Today, I'm speaking with Frank Weltech. Frank won the Nobel Prize in physics in 2004 for work he did as a graduate student.

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He was also one of the earliest MacArthur Fellows and he has won many other awards for his scientific work and writing. He's the author of several books, but most recently he has published a fantastic primer on the state of physics, and that is called Fundamentals 10 Keys to Reality. He's also written for The Wall Street Journal. He is currently a professor of physics at MIT and he's also the chief scientist at They Will Check Quantum Center in Shanghai, China.

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And he also has appointments at Arizona State University and Stockholm University. Busy man, anyway, you will hear that Frank is a wonderful explainer of physics, and I really couldn't have asked for a better guide to this terrain. We discussed the difference between science and non science, the role that intuition plays in science. And then we plunge into the matter at hand, we discuss the nature of time, the prospect that possibility is an illusion and that only the actual is ever real.

[00:02:19.830]
We talk about the current limits of quantum mechanics, the uncertainty principle, spacetime as a substance, the unreasonable effectiveness of mathematics in science. And the possibility that we might be living in a simulation, we cover the fundamental building blocks of matter as we know it, the structure of atoms, the four fundamental forces wave particle duality. The electromagnetic spectrum, the many worlds interpretation of quantum mechanics, the prospect of infinite space time, we really get the full tour here and I thoroughly enjoyed it.

[00:02:57.820]
And now, without further delay, I bring you Frank, we'll check. I am here with Frank will check. Frank, thanks for joining me of a very great pleasure to be here. You have written a wonderfully accessible book and you've written several books. But the new one is Fundamentals 10 Keys to Reality. And I highly recommend people read it because it's just a a fantastic and just amazingly digestible introduction to really the whole history of physics. But our modern picture of the universe, which we'll talk about here, but by no means fully cover.

[00:03:41.610]
But before we jump in, how is it that you have an opinion about the nature of physical reality, what it could maybe summarize your your intellectual perch over there in Massachusetts? Well, I I grew up very curious about the world from many points of view. During a time when. Science was very highly valued, partly because of the Cold War and the memory of World War Two, which was relatively fresh, although that was before my time. And so at the same time, I was very interested in cosmic things.

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I was very I was raised in the Catholic Church. So I got exposed to these ideas that there are deeper meanings to the world. And read Bertrand Russell read, Einstein was a big hero. So it sort of seemed like a very narrow sort of seem like very natural to me to deepen my knowledge of science and physical reality. And that's what I spent the bulk of my life doing. And it's been a great trip and I've

learned a lot have it a lot of surprises, a lot of adventures, a lot of positive feedback and and I feel I've learned a lot.

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If I if I if I could transport myself back to myself as a teenager, I would have a lot to convey. And that's that's one of the things that I was thinking about as I wrote this book. The the other spur to it was conversations with intelligent friends who wanted to know what I was doing, what I had learned, what's really going on at the frontiers of science, how do you separate the wheat from the chaff? And and and also what does it all mean?

[00:05:40.350]
So so I really wanted to take the opportunity to answer my friend's questions and my own questions from way back when and at the same time. And just fortuitously at the same time, my grandson was born and I started to think about what I'd like to tell him when he's asked these questions and also watching the process of how he constructed his world, making basic distinctions between self and not self, and getting the idea that the world is organized into a three dimensional space with objects that have some kind of permanence and regularity.

[00:06:21.270]
These very basic things we. Learn about the world that get us get us by very well, and yet I reflected that the scientific view that is revealed to our most accurate experiments and critical thinking once we use telescopes and microscopes and spectrometers and accelerometers and all the other kinds of things that allow us to get more accurate perceptions and also to think and also to think critically about them. It's a different world. And I'd like to say you have to be born again to come to terms with reality.

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You have to not only learn some things, but also unlearn some rules of thumb that that you construct for yourself as a child.

[00:07:08.700]
Yeah, well, I would like to try to recapitulate that journey for our audience here and really start with the the minimum set of assumptions and and overturn some of the assumptions that that make it difficult to think scientifically. I'm struck with how unintuitive many of the tools of scientific thinking are, and they're hard to make intuitive. Some may we kind of bootstrap ourselves to new intuitions on the basis of others that are almost defied by where we land before we jump into the physics of things.

[00:07:51.120]
Maybe we can start by differentiating science from non science. And I guess one way to do that, and this is actually something you you mentioned early in the book, is to describe why something like astrology isn't science. How do you make how you demarcate science from non science?

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And that's just a conceptual endeavor. Yes, it's a it's actually a complex question. And the short answer is that science works and on science doesn't work.

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So it could have been that it could have been that you could make successful predictions for people's personalities, for their destiny based on the positions of things in the sky when they were born.

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But over centuries of trying to refine that that possibility into an actual tool for making useful predictions, it hasn't been very successful, whereas a very different interpretation of what the things we mete out in the sky mean and the forces they exert and what kinds of influences they could possibly have back here on Earth has been much more successful. That's kind of led to one successful prediction after another. And nowadays we can put men in space and really do many impressive things with GPS system.

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And look look back to the Big Bang and make predictions about how distant galaxies are going to look and how the microwave background that's put together and many, many other things that that work. So we have, on the one hand, a coherent body of explanations that's built on patient. Investigation with the most accurate instruments we can find and demanding very high standards of proof, know they're trying to push things as hard as possible, make them quantitative, make them precise, worrying when things don't quite agree, instead of trying to explain it away.

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And that's been so, you know, you can compare and contrast and you know it when you see it. One of them is scientific, the other is not scientific. I think that that's that's the difference.

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I mean, so it's not even it's not even the subject matter so much as the approach and whether whether it's critical, whether it takes correction and whether it works.

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And those are those are the defining criteria, whether it's scientific, that if we could put the final nail in the coffin of astrology, it seems to me obviously disprovable in at least two ways or one and a half way. And one way to to see that it's almost certainly not true in its basic assumptions is to recognize that this idea that the position of the stars and planets must affect the life course of a of a person born based on the time and place of their birth.

[00:11:04.370]
That's belied by the fact that that a doctor or nurse walking by in the hall exerts more of nature's forces on the child than anything up in the heavens.

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Yes, if you take seriously the successful description of the world, there's no room in it for such astrological influences. That's that's that's true. So, so. And on the other hand, we have a lot of circumstantial evidence that it's I mean, we have a lot of more than circumstantial evidence that the principles of that description are remarkably complete.

[00:11:37.670]
And so the fact that there's no room for it for astrological influences means there are no astrological influences. I think that's fair.

[00:11:46.550]
And even short of that, even if even if we didn't accept physics yet, you could still run the experiment of finding two babies born at the same moment in the same hospital. Yes. You know, mere feet apart. And you just have to find two such babies that have importantly different lives.

[00:12:03.380]
Well, famously, people talked about, I think, going back to St. Augustine, if not earlier, because St. Augustine didn't like astrology either. And he argued about identical twins having very different faith. Right. And you might say they're well, they're not quite at the same time. But if your predictions depend so sensitively on the exact time they're there, they're almost impossible to make in practice. So. So it becomes empty, right?

[00:12:31.850]
Yeah. OK, well, now we've pissed off the astrologers. We can move on to the more controversial.

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You know, you can you can have fun with it if you if you have a sense of humor and it gives some people it gives people a thing to talk about and break the ice sometimes on dates or whatever. But but no, as as as as a serious enterprise for predicting the future or predicting someone's personality. I

don't think it's serious at all.

[00:12:59.280]
All of the fun you should have with it is to give everyone Charles Manson's astrological chart and notice that virtually everyone finds something resonant in it with their own personality until they find out who started it. So then let's start with this issue of intuition and how we use it in reason generally and in science specifically. And many of the intuitions we need to use in science are. Mathematical and they get pushed into areas where most people's intuitions reliably fail.

[00:13:35.580]
I guess I'm wondering if I think everybody's until they hear, but the only way to build up intuition is to sort of work with nature and think about examples and think about very simple examples and get to more complicated ones and figure out what the equations and experiments are telling you.

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So here's a very simple one which boggles the minds of most people. I'm wondering if you, as a a physicist and and mathematician, ever really get your intuitions around this? You take something like the the validity of exponentiation. The very simple way to to illustrate its power is that you ask someone what would happen if you could take a very large sheet of newsprint and fold it upon itself 100 times in a row. Right. And since people imagine doing this and they sense that there's some trick in the offing here, but when you ask them how thick the resulting object would be, many people suggest something like the size of a brick or they get to see how the trick is done and they think, well, maybe it could be 10 feet tall.

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If you could you could fold a piece of paper that that many times. But of course, it's light years across this galaxy size. If you could do such a thing, if you keep it up right now, do you actually have an intuition for that or do you just know that the powers of two have those consequences? Well, I do in the sense that I can very quickly figure out what the answer is and I'm not shocked by it.

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So and that's I guess that if you if you want to call that intuition, I guess. Yes. And I also you know, I'm also alert to the fact that this kind of question is taking me out of the realm of familiar experience. Right. Very rapidly. So so that's that's what I meant by building up intuition. You build up intuition by thinking about hard examples and thinking them through and really digesting them. And then you can have intuition that's correct and useful about things that you didn't have intuition about before, when where you had incorrect intuitions.

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That's that's that's a small example of this process. I love to call being born again that that you have to go back and really open yourself up to reality and take it as it comes and speak and speak its language in order to get the most out of it.

[00:16:06.840]
OK, well, let's see if we can baptise everyone with the vision science here. Yes. So here's the starting point for apes like ourselves, with our open eyes and outstretched hands, we interrogate the world around us. We, as you point out at a certain point, differentiate ourselves from the world and we begin to act in it and upon it. And we develop intuitions about space and time as the context of our adventures here. And we have a sense of events that happen in space and time.

[00:16:46.330]
So things seem to happen. Yes. And we have a a thirst for at a certain point, we have a thirst for a causal explanation for why and how things happen and. And we have some sense that with an explanation, we'll be able to be less surprised in the future by future happenings. Let's start with time and obviously we're going to land in space time eventually and a more sophisticated description of things. But how do physicists think about time?

[00:17:21.060]
Well, there's a lot to be said about time. In fact, the accurate measurement of time using atomic clocks is one of the great frontiers of physics now. We can we can synthesize clocks that lose or gain time relative to one another at the level of one second over the lifetime of the universe. And accurate clocks are a central central feature of the GPS system and all kinds of things. So we have successful ways of measuring time.

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And of course, our whole apparatus of predicting what's going to happen in future is based on using equations that contain a variable called T.

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That's time that is has is is what is the basis of our intuitive notion of time? I don't think there's a separate thing. That's our intuitive notion of time, but our intuition is is a has I say a handy description of the underlying physical reality that people have. Captured in the equations and the basic equations that describe how the world works, and it's very remarkable because there's, well, the deepest facts about time or is that it's a one dimensional manifold and and that there's only one time everybody, everybody and everything in the universe marches to the same beat.

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It's an amazing thing. If you think about it, it didn't have to be that way. Computers don't necessarily work that way. You can ship things off to another module that runs at a different speed and so forth. Are memories and psychology certainly don't work that way. We can look back, we can leap into the future. But the physical world. And it seems to. It seems to. We have only one time that everybody agrees on and we humans sort of experience that in music and dance when we can keep time with ourselves and also with others and not run into inconsistencies.

[00:19:34.480]
But the time of intuition is a measure of change, right. We have things in the world that change with a certain frequency. And these things are clocks. You can either something you point out in your book that we make a lot of this, but certain things are reliable clocks. But really everything is a clock. Your aging body is a clock. Everything is a clock. That's right. I like to say everything is the clock. Some of them are harder to read than others.

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But the precise meaning of that, if you think about it, is that when you write down the equations that describe change, there is a quantity in those equations called T. And as I said, there's only one such quantity that seems to work for everybody. And that so in principle, if you measure the change, you can infer, you know, a measure of what's happened. You can infer how much T has changed. And everything is a clock in a broad sense.

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But of course, we want to have clocks that are portable and and reusable so you can keep measuring an interval of time accurately the same time over and over again and things like that. So when we when we think of clocks as as the instruments of time, it's it's a special case where where they are specially adapted, adapted to make the the readout of time easy. But but in a larger sense, everything that changes as a clock. I think that that's correct.

[00:21:02.230]
I mean, human beings are clocks. They age. So in principle, if you could study the cellular processes really accurately, you might be able to to use a human as an actual clock. But if we can all do that roughly, we can estimate people's age and so forth.

[00:21:18.180]
Mhm. Yeah. Every time I look in the mirror in the morning, I know what time it is, it's later. But what do we make of this intuition that time itself flows or moves because of what, what we're talking about is a measure of change. Yeah. And against what could we say. Time is changing or moving. That seems

like a a contradiction a time itself. Yeah. Yeah. Time itself. I'm I'm afraid I won't be able to give you a really satisfying answer, because in the current formulation of physics, the fact whether I mean the axiom, I guess the assumption.

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That time is a one dimensional continuum is rock bottom. We don't know how to explain it in terms of anything simpler, at least I certainly don't and I haven't seen anyone else do that either. So, in fact, what's truly amazing to me is that and I don't understand that and I don't like it in some sense, is that the concept of continuum that was developed by the ancient Greeks and is in Euclidean geometry, for instance, that you have this infinitely divisible uniform essence is what we use for time in the basic equations of physics, even though we know that in reality things really change when you get to short distances.

[00:22:48.860]
In short times, you have to bring in quantum mechanics and things that have irreducible jiggle and fluctuations and wave functions. It's a completely different world in many ways, and yet they're still in the equations. There is this one dimensional continuum. It's time that Euclid would have recognized.

[00:23:11.090]
In what sense might time be an illusion? Is that or just a mere construct that is useful for modeling the change we see in the world? But but I mean, like what happened to the concept of a block universe in physics?

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There might be that well there there might be deeper levels of description not yet constructed. So it's hard to talk about what they are with any precision. But I can't preclude the possibility. I mean, I'm very sympathetic to the possibility that there would be deeper levels of description in which these Euclidean concepts of continuum run out of steam and we have to be replaced by something else. But so the idea that there are atoms of time that time is fundamentally discrete.

[00:23:59.140]
I think if they're going to be atoms, they probably have to be atoms of spacetime will come to that.

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But I guess but the fact that that the continuum has to be replaced by something else I think is is a very appealing thought, because continuum is a very, very complicated concept if you try to define it precisely in axiomatically, the ancient Greeks really struggled with it. And it's really only in the 19th and 20th century that mathematicians got to a satisfactory description. But it's really complicated. It's not it's not simple and it's not the sort of thing that I would like to have as rockbottom in our description of reality.

[00:24:39.870]
Hmm. I'm tempted to open that door and find out why a continuum axiom is imponderable, but maybe we'll get to that. I just I want to linger on time for a second. What's happened to this concept of a block universe that was a maybe 100 year old notion in physics, the idea that past and present and future might all exist simultaneously, despite the fact that we seem to perceive it through a keyhole of a seemingly moving present?

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Yes.

[00:25:11.030]
Yeah, well, that that's more an attitude, I would say, than that. Then a strict. A distinct statement about the universe. I mean, mathematically, if you have a one dimensional continuum of time and then you have space and events inside, you can describe three dimensional space plus plus one dimensional time as a three plus one or four dimensional space.

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And then it's just a space and but the I guess the and that's a very legitimate object of contemplation and sort of that's, if you like, a God's eye view. You can see everything that's ever going to happen or did happen all at once. If you could stand outside this four dimensional space and just look at it, although in some sense it didn't happen in that case.

[00:26:01.650]
Right. Then the notion of an event is an epic phenomenon of just how we're how limited our perception is. But in some sense and also the notion of possibility, I mean, we live in this in this space of time and space and space time where there are events which we think could have not happened or happened differently. And possibility is a thing. But in a block universe, there's no such thing as the possible. There's only the actual. And it's just it's not even certainly not punctate in the same in a way that an event is so to talk about.

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There's no process. There's just there's no verbs, really. There's just a single noun of the actual. And it does make a mockery of of of time and events and and possibility.

[00:26:50.590]
Yeah, well, that's the God's eye view. And yes, you can you can imagine a consciousness, I suppose, that just knows all and sees it all at once. Although you might ask, how is that entity thinking? What how does it implement logical operations or information processing? And I don't know that that's I think that leads to madness. But what I was going to say is I think the thing that can be said about this question is that the laws of physics as we have them now.

[00:27:28.610]
Directly statements about this blog world that they're not directly statements about. All of space time, they are statements about if you take. A slice at any particular time, you and know the state of the universe know what all the particles in it are doing and in a quantum mechanical description, what the wavefunction of everything is. So this is far beyond what you can actually know. But if you did in principle, you could calculate what's going to happen in the future and what's going to happen in the past.

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But it does have this natural division into. Slices and you have to take you have to start somewhere in order to reconstruct the whole thing so the laws don't naturally describe. The whole thing, they describe how things develop in time, at least, at least the laws we have now have that character. And then, of course, the other question is that what is this description for? Who is this description for?

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If it were for God? Well, then the block description might be appropriate. But for us poor mortals who are moving along world lines in space time, it's very useful to have a description that's not the blocked universe that gives us tells us how the different snapshots get put together and so forth. Let's step back from the God's eye view and get into space time and acknowledge the the reality of events. But even in this context, you have quantum mechanics now governing our understanding of how things happen at the smallest scale.

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That seems to give us a probabilistic picture of of what's going to happen in the future. And I'm wondering if even even within that frame, if it's possible this will sound paradoxical. But is it if it's possible that the idea of the possible is mistaken? I mean, given that there is simply what happens, how can you justify the possible? I think that question is very much. I think that is very much an open question. The there are aspects of quantum mechanics that are deeply mysterious and I think subject to change in the future.

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If we understand things better, we may or may not need to to change the equations. But for sure, I

think we need a deeper understanding of quantum mechanics is less than 100 years old, and it's a profound modification of how we understand the world that's going to take a while to really absorb. But if you study, if you take a look at how the equations are actually formulated, they are deterministic equations.

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But they are determinists so that so if you know and they are deterministic equations for something called wavefunction, so if you know the wavefunction at one time, then in principle you can solve the equations to figure out what the wavefunction and therefore the universe is going to be at the next time or what it was at the past time, for that matter.

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You can always run them backwards, however, and this is this is what's really weird. You can't know the wavefunction completely. Right. So the equation, we want you to tell it the wavefunction, but you don't you don't know the wavefunction. Not all, not only in practice, but even in principle. You don't know the wavefunction because you have to make incompatible process. You have to do incompatible processing on it to extract all this information, putting it roughly but precise.

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But but there is a precise formulation. So, for instance, the Heisenberg Uncertainty Principle tells you that even though you have a perfectly definite wavefunction, if you want to answer questions about the position of a particle, you have to process that in one way. If you have to if you want to answer questions about its momentum, you have to process it in a different way. And those two ways of processing are mutually incompatible. So you can't actually predict either one because you have incomplete knowledge.

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So that's the situation. Do we have equations that are perfectly definite? That would be perfectly definite to an observer who knew the wavefunction completely. But we're not that. And we have to deal with what are what are the consequences we can draw from the limited information that we have, including. Well, let's let's assume the equations are correct, but we don't know exactly what they're acting upon. So we only get probabilistic predictions, but it's deeper than a a methodological limitation, right?

[00:32:24.850]
It's a deeper than a methodological implication because in principle, because even in principle, you can't. PIN down the wavefunction sort of in trying to in trying to pin down some of the information, you destroy other parts of it. Right. There's no way of doing it noninvasive. But I guess I guess my question here and, you know, admittedly, it's a a philosophical one more than a scientific one, I think is given the state of affairs and the disposition here is to say that that certain things are possible.

[00:32:57.770]
And we understand a kind of, you know, probability. We summarize this possibility with a with a probability distribution of some sort. Yes. But is it scientifically wrong to say that we don't, in fact, know that? And it is possible? Again, this sounds paradoxical, but perhaps isn't. It's possible that possibility isn't even a thing. And there really is only the actual there is simply what happens. And then we have a story about what might have happened that we're adding to that picture.

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Is there some place to stand within physics to rule that out? No, I don't think so.

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I think the way these quantum mechanical wave functions I've been talking about are very rich objects.

[00:33:41.780]
And in principle, I'm contained in the quantum mechanical weight function. And you're contained in a

quantum mechanical way of. In fact, where we're contained in the same quantum mechanical way function that describes the universe as a whole and different parts of that wavefunction, which, as I mentioned, we don't know completely.

[00:34:01.550]
And in practice, we only know very little about it compared to what's its full content allows us to make only probabilistic predictions because there's a lot we don't know that we would need to know in order to make definite predictions. So it's relative to our knowledge, which includes, you know, everything that we know and all the measurements that we've made or the laws that we we think we know or all the experience that we've had relative to our knowledge, our predictions about the future are probabilistic relative to some unattainable, even in principle knowledge, some God's eye view of the world.

[00:34:43.070]
Maybe the equations are perfectly definite. So if that. If that somehow means something to you, that's also true, but in practice, it doesn't change things very much. So it's kind of philosophical determinism, but practical not. OK, so let's go back to the point of view of the mere ape trying to find his or her way in the world. So we have this intuition that we exist in a space of three dimensions. And it's that intuition is is born of this experience that we we really can't figure out any other direction to point than just some combination of backwards, forwards, left and right and up and down.

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And that's a pretty solid empirical fact. I would say there certainly are only three large dimensions. If there are other dimensions, they have a very different character.

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Right, right. Right. So and we do sense that time is distinct from space. And yet now physics has given us a a unified picture of spacetime, which is. Well, you tell me, how do how do we get.

[00:35:55.260]
Well, it doesn't make them it doesn't make them the same thing. No, but but but it's important in understanding the world to treat them together. So the idea that you can just stack up. A bunch of copies of three dimensional space, and this is a this is a time to zero, then 21 and so forth, that's not wrong, but it doesn't do justice to our understanding because for one thing, the theory of relativity tells you that let's just take the special theory of relativity, which is the first and simpler version, is that you can also slice things up in different ways you can take and this would happen naturally if if one in one set of observer sets up things, a division into space and time, and then you have other observers that are moving with respect to those that are constant velocity, it will be natural for them to divide space and time in a different way, to have different slices that sort of mix up the original space and time.

[00:37:03.700]
And the remarkable thing that relativity says is that they will arrive at the same equations. So it kind of destabilizes the notion of time as a separate entity from space because it says there are just there are other just as good times, at least from the point of view of the fundamental equations of physics. One, as any one time there were alternative times that are just as good now.

[00:37:30.550]
That's about the fundamental equations, it's not about the world we actually experience, of course, because there is a preferred time, namely the time that points back to the Big Bang and the uniform space. But you're saying that in a different frame of reference, the one set of observers could say that A preceded B, but another set of observers moving with respect to the first set could say that, B, proceed today. Yes, right. And that that falls out of Einstein's.

[00:37:59.770]
That falls out of there. Yes. So there is that possibility. But on the other hand, there are also the observers can also agree that some some events definitely precede others. So there's kind of a netherworld which is called the space like region. But there's also a time like region where you can

order things linearly. I mean, special relativity is a fascinating theory and we could discuss it easily for several hours, but for up for present purposes, it made the.

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Traditional separation into a unique time and space unstable. Now we are other other versions of time that mix in some space and have but are just as good as far as the fundamental equations are concerned.

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Or does the fact that there's a preferred frame at least defined with respect to the Big Bang? Give us a notion of simultaneity that that is valid.

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I mean, is there some place from which I can say, yeah, in in cosmology and cosmology, we we commonly use that language. When we say. For instance, that a given star was formed on 30 seconds after the Big Bang. We can say that about distant stars and there's a unique definition because they don't if you there's this preferred frame in which the universe, the distribution of galaxies looks uniform. If you move relative to that frame, then it won't look uniform.

[00:39:44.340]
There's some distortion and the colors won't be quite uniform either. And so so there is a preferred frame. And so there's a prefer there's a preferred frame. And you commonly in cosmology use that as as a way of synchronizing times across distant across distant galaxies. So but. But in everyday life. As opposed to cosmology, I mean, different frames are more or less equivalent if you if you cancel out the astrological influence of galaxies, so to speak, what's left allows you freedom in the definition of time.

[00:40:25.970]
There are many times that are equally good. OK, so we have a space time continuum of some kind, which is a it is a kind of medium, right? I mean, it is the kind o that's the other thing.

[00:40:39.110]
Right. That's the other thing is that when you go to the more advanced parts of physics, from special relativity to general relativity in particular, then you find that it's very, very convenient and really unavoidable unless you want or satisfied with extremely ugly equations. It's very, very convenient to treat the three dimensions of space and one dimension of time as a unified structure, because the equations display tremendous symmetry between space and time. There are still distinctions, but there's also tremendous symmetry between space and time.

[00:41:23.590]
And there you can only separate them at the cost of making the equations very unnatural.

[00:41:30.430]
But also we have, you know, further phenomenon like gravity, which seem best explained in terms of time itself being exact, the sort of thing that can bend, right? Exactly right.

[00:41:43.880]
That that's that's the leading idea of the general theory of relativity. And as I said, it's very difficult to formulate the bending equations in an elegant way without explicitly bringing in the idea of space and time as a uniform, as a coherent, integrated, three plus one dimensional entity.

[00:42:05.230]
OK, so we have this context of our experience. We have this condition of spacetime, which now disconcertingly we've learned is not just a mere context in which the things that exist can happen, but rather it is a kind of thing itself. Right? It it has, right. It's not a void. Yeah, it's not a void.

[00:42:33.100]

That notion was something that, you know, famously Aristotle rejected and and most thinkers rejected until Newtonian physics, which works very, very well with space being just sort of an empty platform or a stage through which particles move.

[00:42:56.410]
But in modern physics, we've reinstated space time as a substance.

[00:43:02.710]
I would say it's it has a life of its own in many ways. It's the primary entities we use to describe the world or fields and actually quantum fields. But there's space filling entities that vibrate. And the things that we call particles are excitations within these fields. But they fill the whole space and all the time. And the elegant description of how they work uses that description. And most dramatically, Space-Time itself is like an elastic medium that can bend and warp.

[00:43:40.180]
And the general theory of relativity, the kinds of distortions of motion we call gravity, are ascribed to that bending and warping of space time in very successful equations. And we also in very recent years have learned that so-called empty space actually weighs something like this is called the dark energy.

[00:44:02.110]
Einstein called it the cosmological constant. But basically what it is, is that Space-Time itself has an intrinsic density. So it's a substance by a it's a very respectable substance. By any reasonable definition, it's not it's not a void. OK, so again, let's see if we can somehow conserve our intuitions or at least notice when we're violating them here in building up this picture. So we have this people are listening to us. Let's assume their eyes are open or they can open their eyes and, you know, they see the space in front of them occupied by the objects on their desk.

[00:44:43.960]
And they're that they're perhaps their hands. If they wave their hands in front of them, they can feel the air. Right. Which is yet more stuff in this what once seemed like a void like condition. But we're now being told that this condition, the only place in which they experience their own being, has all kinds of structure that is not apparent and which is really only fully captured in the mathematical devices and discoveries we've we've used to tease out the structure, I guess.

[00:45:18.910]
But before we jump further into the constituents of things, do you have any thought as to why mathematics works here? I think I remember that Eugene Wigner wrote a paper, I think in 1960 or so about the what we call the unreasonable effectiveness of mathematics in the natural sciences. I mean, it just seems a very strange accident that apes like ourselves have enough linguistic ability, or at least some of us do, to develop a simple system that produces not only uncannily powerful description of what we can understand, but actually has predictive value.

[00:46:03.850]
It points into the darkness of nature and suggests what we might find there. And then, lo and behold, we find those things, whether it's, you know, the absurd energy in the center of an atom or more of the electromagnetic spectrum that we can't see with our unaided eyes. Why does any of this work? It's a gift. I don't know what it's rock bottom, and it doesn't it didn't have to be that way. No, I think.

[00:46:34.250]
I think it's been a continuous, continuous revelation and surprise and gift, as science has developed since since the 17th century, a sort of modern science where we make extreme demands of accuracy and test things very hard and so forth. It's been. The program is to try to understand things fully and deeply and probe. With all the accuracy we can muster. And yet at the same time, try to boil down what we found find into as compact a description as possible, even if the description has to be kind of in an unusual language, which we call mathematics, that's very different from what we hear at cradles.

[00:47:27.610]
And it's worked.

[00:47:32.290]
And a surprise after surprise, more and more layered Newton's theory of gravity and then Maxwell's electrodynamics and then quantum mechanics and relativity and quantum Croma Dynamics.

[00:47:45.130]
The equations get more structured in some ways, but I think there's a tendency that they've actually gotten more beautiful and certainly more comprehensible and more comprehensive, less comprehensible, maybe more comprehensive, so that now I think we've gotten very close, if not to the rock bottom foundation of understanding how ordinary matter works so sufficient for biology, chemistry and all forms of engineering. And we can summarize it in a few equations, and it didn't have to be that way. That's what that's why I say it's it's a gift, for instance, and I think there's an important thought experiment.

[00:48:30.830]
You can imagine and people have imagined and. People even have gone off the deep end on this, but but you can imagine that someday artificial intelligence is will be fully embodied and general intelligence is within computers. And you could even imagine that these artificial intelligences, we're not sensing the same world that we're sensing that they would be sensing electronic inputs that were designed by some programmer. So this would be these would be worlds in which intelligent design is actually true.

[00:49:07.920]
Right. But.

[00:49:11.030]
But the laws wouldn't have to have this character. The laws would be whatever the designer or the programmer imposed, and they wouldn't have to have the character of deep simplicity and mathematical coherence that we find in our world. So it's a gift. And I don't know any way to explain it other than to say that's that's the way it is. It's a wonderful gift for me.

[00:49:39.110]
Following that argument, couldn't we be in a simulation wherein we're no more in touch with the base layer of reality? But our simulation is consistent in all the mathematically satisfying ways, or at least seems to be thus far.

[00:49:53.360]
It could be, but it would be very, very wasteful programming practice to sort of hide so much complexity inside useless things that that don't directly support, presumably the interesting thoughts that are going on or the interesting games, if you think about Super Mario world or something. If I were programming Super Mario, I wouldn't make the bricks out of quantum mechanical atoms. Just it's just an awful waste to write. And and and also, you know, you really could make a lot of creative use out of having more than one version of time, for instance.

[00:50:33.920]
And you could have astrology being true. You could have people moving back and forth doing time travel. You can have all kinds of things once once you free yourself of constraints that we seem to have in our actual physical reality. But that doesn't seem to be the world we live in, for better or worse.

[00:50:54.950]
OK, so back to the world we live in which you seem to live because, you know, intelligent design. So I'm sort of joking, but not really. That's what I think intelligent design is maybe the future, but I just don't see much evidence for it in the world we actually experience. Yeah. This. Yeah. In other words, are there going to be intelligent designers that's going to be humans or their successors.

[00:51:25.490]
Yeah, well maybe you've heard the simulation argument that I think is originated with.

[00:51:30.500]
Oh I've heard it, I've heard and I've thought about it and I think oh no, I mean that that kind of idea is very old. Right. But the added wrinkle here that I think it's the the Rinkel he's introduced, which is there's just a couple of minimal assumptions you need to get what seems to be the the following probabilistic conclusion. If you assume that leaving aside the possibility of intelligent aliens that we know nothing about that have computers that might be running simulated worlds, if you just imagine that our species doesn't annihilate itself and we continue to get better at building computers, at a certain point we will build simulated worlds on our computers, complete with with conscious entities like ourselves.

[00:52:21.860]
Yes. And seemingly by definition, simulated worlds will outnumber real worlds because they're just they'll just be functionally infinite number of of worlds to create. So then just as a matter of probability, you should assume you're in a simulated world rather than a real one. Right?

[00:52:41.330]
Well, you know, probabilities are always relative to Pryors and and their. We have an alternative scientific framework in which things are what they seem, more or less, that the world, the universe follows the laws of physics as as more or less as we know them. And there was a big bang. And there has it just hasn't been time for those developments to take place if they're ever going to take place. And if you just look at the internal evidence, as we discussed our world, I don't think how should I say our world doesn't look like it's a programmed world.

[00:53:21.220]
It just doesn't. And so if it if it's programmed if there is an intelligent design to it, it's very non-intuitive.

[00:53:32.440]
It and and and let me put it as a challenge, I guess, to Nick Bostrom or whoever wants to propound that kind of idea.

[00:53:40.240]
Tell me something about the world that I can understand better on the basis of this picture and on the conventional, you know, the now conventional framework of physical science.

[00:53:53.620]
I know I don't know of any such example, and I don't think there is one actually on that point of intuition, which is. Yeah, it's interesting. They are our intuitions obviously have evolved in entirely in a context that has left us blind, both perceptually and intuitively to the domain. We're talking about the very small, the very large, the very old, the very fast rate we have. We have intuitions for for how, you know, throwing objects can behave local to the forces that that a human body can participate in all the experiments we do as babies.

[00:54:37.330]
Exactly. But mostly as adults unless we decide to study science. Right. But when you're talking about moving fast enough so that, you know, you're approaching the speed of light and time slows down or you becoming increasingly massive or the energy that that exists internal to the nucleus of an atom, or the fact that atoms are as small as they are, but nevertheless mostly empty space. Like all of these facts that we understand in physics are not facts that we should have any intuitions for.

[00:55:09.700]
So so one punch line seems to fall out out of this. And this is actually something that I've discussed with Max Tegmark before. Who you must know him. He's here. You're both at MIT, right? I've even written papers with him. Yeah. Yeah. So Max is a great guy. And his claim is that we should absolutely

expect the right answer written at the back of the Book of Nature to be deeply non-intuitive. Given that our intuitions we just get if we're going to take evolution and evolutionary logic seriously, we should be suspicious of any answer that is at all commonsensical to us or that is fits comfortably within our Apison intuitions.

[00:55:53.740]
Well, that's the way it's worked out. Yes. I mean, we how should I say. But it's not even it's not an open question anymore. We we know we know a lot. Maybe it's not the final language, but we know the language of nature and we know what the operating system is and maybe not in all details and but but for most practical purposes, we we we know what the operating system is. And surely it is not comprehensible or in terms in the in the terms that we use, we use in everyday life to get around.

[00:56:27.910]
That's that's that's really what I try to capture in this notion of being born again. You have to you have to learn a new way of thinking. That's mind-expanding requires you to revisit things that you thought you knew and and use an enormous imagination to come to grips with what accurate observations and critical thinking reveal. But the good news is that. It can be understood, and that's the amazing thing, which which I guess is this unreasonable success, if you like, is that.

[00:57:04.420]
It can be understood that and I've tried to convey this in a slim book, the the not, which of course doesn't contain the equations or but does, I think, contain the essential concepts and the kinds of philosophical questions that they settle or certainly address and with deep illumination. So. Yes, they are surprising, they're very surprising if that's if that's the claim. I fully agree with it.

[00:57:36.940]
OK, so let's go back to what exists here. If I last left our listeners with hands outstretched, waving them around in what they imagined was three dimensional space and feeling the air, and we've established that space time itself is not merely the void context of the things that happen. It is itself a kind of object. It's a kind of medium that the bending of which explains gravity, among other things. So let's introduce into this space. We're into this condition the minimal ingredients for the universe as we know it.

[00:58:22.180]
What is there in front of us and as us? What is the matter that gets introduced here?

[00:58:28.840]
So for most purposes of engineering and biology, of chemistry and most of. If you'd like to continue listening to this conversation, you'll need to subscribe at Sam Harris Network. Once you do, you'll get access to all full length episodes of the Making Sense podcast, along with other subscriber only content, including bonus episodes and Amma's. In the conversations I've been having on the Waking Up app, the Making says podcast is ad free and relies entirely on listener support.

[00:59:04.840]
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