S. GEORGE DJORGOVSKI: And now let's push even earlier, the really early universe. So our current understanding of fundamental physics is that there are four fundamental interactions-- electromagnetism, the weak interaction, the strong interaction, and the gravity. And some time ago, electromagnetism and weak interaction were unified into electroweak interaction by people like Glashow and Salam and Weinberg.

And then the idea was like, well, at some point maybe there was unification between electroweak and strong, the so-called grand unified theories. And if you keep pushing at some point, maybe gravity was part of the whole thing. So essentially the idea is, as you go to ever higher energies-- meaning deeper in the past-- interactions becomes a more-- or if you look forward in time, they split when energy drops beyond a certain limit.

And so what used to be four different interactions-- well, it should be one interaction for splits in the gravity and everything else. Then that splits into strong nuclear force electroweak, and that splits into weak and electromagnetism. That's pretty theoretical. We know one of them works, which as electroweak. But everything else is speculative.

And this is very interesting because we can say something about all those from cosmological observations with probes, physics, beyond anything we can test in the lab. So what we call electroweak era is 10 to the minus 10 seconds after the big bang, roughly speaking. And at that time, the temperature is 10 to the 28 degrees Kelvin. We'd never make anything like this in stars or anything like that. At something like 10 to the 15 degrees Kelvin, trillion-- I'm sorry, quadrillion degrees. Again, much more than anything, the stars, electroweak, splits together. And that's as far as we can go in accelerators today.

Now if you push this by another 25 orders of magnitude, then ostensibly there is this grand unified theory transitioned between that grand unified theory and strong force on one side and electroweak on the other. And that may be driving what's driving the inflation. We don't know that. In the meantime, something interesting happens. Now if you look in the universe today, there is a lot more matter than there is antimatter. In fact, there's hardly any antimatter. And why would that be? Because in principle they are equivalent, there is no mass energy difference.

It's, roughly speaking, one particle in 10 to the 9, or 10 to the 10, that is the difference. So if somehow, in the early universe, there was this tiny, tiny imbalance between matter and antimatter. They're all going to annihilate, except for that one little excess. And the energy of annihilation is what provides energy content to the universe. This is essentially what eventually becomes microbackground photons. But why? Why would there be this asymmetry?

So as early as 1967, Andre Sakharov proposed the mechanism that explains that, which goes way beyond this class, but essentially involves violation of some symmetries with particulate physics, some of which are actually testable, others not yet. And departure of thermal from equilibrium, which is provided by the expansion the universe. And now people believe that Sakharov mechanisms is essentially why is a symmetry between matter and antimatter.

So just the fact that we're pretty sure that there isn't more antimatter than negligible amounts, that we see, because of the absence of gamma ray and annihilation fronts and such, is already telling us that this must have happened somehow in early universe. And let me introduce so-called Planck units. Max Planck, at the end of 19th century, came up with the set of units asking, well, meters and centimeters and grams and seconds, they're all arbitrary. They're defined by some international body, and nature doesn't know anything about meters and seconds.

And so how can you make units of time-- in length and mass and so on-- that are really natural units? And one thing suggests itself is to use various physical constants, such a speed of light, Planck constant, gravitational constant, and combine them in a way that yield length of time, or mass, or whatever. And so here they are. And useful thing to remember is that, well, roughly speaking Planck length is 10 to the minus 35 meters. So it's 33 centimeters. Planck time is roughly 10 to the minus 43, 44 seconds. And Planck mass is roughly 10 to minus 5 grams.

So when the universe reaches densities that would correspond to say, 1 Planck mass per cubic Planck length, which is around Planck time, for sure something interesting must be happening back then. We don't really know that this is the case. But it's a pretty good hint, because those constants are there for some reason.

And we think that roughly then, gravity was unified with the other forces, just because when else could it do it? And how that happened? Well, we do not have a believable theory of gravity yet. There are attempts to do this-- the statistical M theory, which is a generalization of the string theory. There are other cosmologies called ekpyrotic cosmology. There's string landscape of multiverse and so on. All of that is extremely speculative and not tested, and maybe a priori not testable by experiments.

But eager minds can try. And so, conceivably, this is what will seem like the next level of understanding in fundamental physics, in the same sense that quantum mechanics and the theory of relatively changed our fundamental understanding of physics.