Events and the Nature of Time: Carlo Rovelli

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Transcript - Long

Robert Lawrence Kuhn:

Carlo, we're at the FQXi Conference dealing with observers and events, particularly in quantum physics and in cosmology, the smallest and the biggest, and in understanding events which are things that happen through time, we naturally are getting to the concept of time and what is time? And this is a major controversy and interest in physics and general relativity and quantum mechanics. Time seems to be at opposite views in terms of the fundamentals here. So if we're saying that the universe is more fundamentally events than objects, okay, I'll give you that for a moment, what does that imply about the nature of time?

Carlo Rovelli:

When we say time, we mean a lot of different things, very articulated, complicated things, time. We think of time as one line which goes from minus infinity to plus infinity, which is oriented that the past is different from the future. We have a very complicated notion of time, which is, in our intuition, in our education, how we were told time is. It's pretty clear that time is not like that. Time is different from that. It's pretty clear because we can make experiments. If we have a clock, a watch like this one and another like this one, and we make one higher and one lower and then we bring them back, and if these were better clocks than what they are, we would see a difference. So, what is it? Is it this that goes faster in the real time, which is this one? Or this goes slower in the real time than this one?

Robert Lawrence Kuhn:

And the reason is that one's closer to the center of gravity?

Carlo Rovelli:

One's closer to the earth, so the mass sort of slows down time. So there isn't one time. There's one time per each movement, per each position, per each...there are many times.

Robert Lawrence Kuhn:

That's a fundamental point of general relativity.

Carlo Rovelli:

That's one of the key discoveries of Einstein. And at the time – it was 100 years ago – it was a remarkable intuition by Einstein. Now, it's something which is checked in the laboratory. In fact, everybody can do that. One can buy, for a few thousand dollars, clocks precise enough to see the difference at different altitudes.

Robert Lawrence Kuhn:

Well, our GPS wouldn't work without it. We'd be...

Carlo Rovelli:

The GPS wouldn't work without it, so this idea of a single time is just wrong. It's factually wrong and, in fact, I think it goes far more far than that. If we want to write a quantum theory of gravity, I believe we better forget about a time variable or some time variables and we'd better say this is the universe. It has [unintelligible] variables, and what the theory describes is the relation of these without having any need to say this is the true time, this is the true time, or this is the time variable. So I think at the fundamental level, the world doesn't need time. It needs to...we need to be able to describe how quantities vary with respect to one another. This does not mean that there is no change. Change is ubiquitous. Change is...nature is change...is to change. But change is not sort of nicely happening all together in a single, like there's a big clock out of the universe to keep time.

Robert Lawrence Kuhn:

So it's critical that we really distinguish the difference between change and time because that's really fundamental. Is this a measurement issue or a fundamental issue?

Carlo Rovelli:

It's a fundamental issue. I think that, at the fundamental level, everything indicates, everything meaning what we have understood so far about the world, general relativity, quantum mechanics, that we should forget about the idea of a fundamental time variable in terms of which things change.

Robert Lawrence Kuhn:

But time is critical in at least classical, classical quantum mechanics. The Schrodinger equation is over time.

Carlo Rovelli:

Right. I think the Schrodinger equation is an approximation. It's like up and down, right? Up and down are really real. That's up and that's down. I cannot walk on the ceiling and so on and so forth, but they're not fundamental. If you just go with an astronaut on a little capsule, there's no up and down. They're all actually the same. So we do understand up and down, but not as fundamental things of reality. It's something that appears in some approximation, some regime. The same is for the Schrodinger equation or for Newtonian time. Newtonian time is good when things don't move too fast with respect to one another, when there's not enough gravity and we're far away from the Planck scale.

Robert Lawrence Kuhn:

Yeah, because Newton is an approximation of relativity at normal speeds and activities and they're almost imperceptibly different. It's only when you go close to the speed of light in some way that you get the perceptional—

Carlo Rovelli:

They become very different. At that point, they become very different. You see...

Robert Lawrence Kuhn:

But how does that affect the quantum mechanics, the time in quantum mechanics, which seems to be more fundamental?

Carlo Rovelli:

I don't think so. I think that quantum mechanics can be formulated in a slightly more general formulation than the Schrodinger equation one as a theory that keeps us transition amplitudes between variables without saying which one is a time variable. So quantum mechanics admits to be formulating a way which is consistent with general relativity, with what we've learned. I think...put it this way. It's Newton that has convinced everybody that there should be a time, independent from change. When Newton wrote the Principia, he insisted on that. Nobody believed him. [Unintelligible] protested. Every protested, complained. Why? Because the ancient way of thinking about time, which goes back to Aristotle, which is the same until Descartes, is that there's no time. There's just things changing and time is just a way we use to label some change.

Robert Lawrence Kuhn:

Sequence of events.

Carlo Rovelli:

Right. So that's Aristotle's definition of time. Time is the measure of change. So what do we mean by time? There's a sun that goes up, goes down, goes up, goes down, so time is counting of the days. It's counting of change. Newton said, oh no, wait a minute. It's easier to write physics if we imagine that there's a time even when nothing happens, so the real question is when nothing happens, does time pass us or not? Newton would say yes. I mean, nothing happens, but nevertheless, time goes. Aristotle and I think modern physics is saying no, there's nothing that happens when nothing happens. There's no time when nothing happens. Time is just a way of counting how things change.

Robert Lawrence Kuhn:

Why is that not semantics, because if nothing's changed, you can't measure anything because if you measure it, that's something that goes through the process. So I'm trying to understand, why is that not just a kind of tautology, a semantic, if there's no change, there's no time?

Carlo Rovelli:

It becomes relevant when you want to write the fundamental theory of the world.

Robert Lawrence Kuhn:

Okay, sure, sure.

Carlo Rovelli:

Do you write it by saying this is my T variable, which is the flowing of time, and then I write how things change in T, or...

Robert Lawrence Kuhn:

Which is the classic quantum mechanics.

Carlo Rovelli:

Which is classical quantum mechanics. Or do you write by saying these are the possible observables of the world and that's an equation that tells me how they're related to one another without any specific things called time. So it becomes crucial, this difference, when you want to write a physical theory.

Robert Lawrence Kuhn:

So if we have events being the most fundamental property of, of the universe, how do then the events create the sense of time?

Carlo Rovelli:

The sense of time, it's something related to our own feeling of time passing.

Robert Lawrence Kuhn:

That's the wrong time. It's our, our...let's just leave it to be in the physical realm. Take the psychology out of it for a minute. We'll add that later.

Carlo Rovelli:

Okay. So I think that what physics tells us is that there are processes. So, given something, something else comes out of it, and so there's change. If we have a number of these changes, we can arbitrarily choose some of the variables and use it to track the change, so we can use the sun going up and down and say that's what I call time.

Robert Lawrence Kuhn:

Or the pulsing of an atom.

Carlo Rovelli:

Or the pulsing of an atom. Quantum gravity is telling us that, in this way we read a clock, right, that's a clock. Quantum gravity is telling us that no good clock, no perfect clock exists, so you always will have clocks go wrong with respect to one another. You always have clocks that don't last forever because they come down, they break. You choose a variable, but then even the sun at some point will stop burning and so, in a sense, quantum gravity is the discovery that this change is not nicely ordered. Or really special relativity is the discovery that events are not completely ordered. Some are neither past nor future, so just time is much more comp...the temporal relations, the structure of change is much more complicated, articulated, than the simple, linear, long line from the past to the future that is in our intuition.