Published on <a>Up Close (https://upclose.unimelb.edu.au)</a>

#275: Tick-tock tussles: Why physicists can't agree on time

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VOICEOVER
Welcome to Up Close, the research talk show from the University of Melbourne, Australia.

SHANE HUNTINGTON
I'm Dr Shane Huntington. Thanks for joining us. Each day, each month, each year, we experience the sensation that time is passing. Our culture, language and much of our technology are based around concepts of time. But what is time? Is it something that really exists in nature, or merely a social construct? Is it equivalent to other things that we can measure, like temperature, length or mass? Certainly, we can measure time with great accuracy and precision, but should we even bother? The speed at which we perceive its passing depends heavily on what we're doing. Time flies when we are having fun is not just an expression. It accurately describes the inability of our brains to consistently measure the passage of time. Today on Up Close, we'll be exploring the concept of time, how it has been used by scientists over the centuries and whether or not it really is a concept that we need at all. To help us explore these questions, we are joined by Craig Callender. Craig is a professor and Chair of Philosophy at the University of California, San Diego. Craig is joining us via a Skype connection from the UCSD studio. Welcome to Up Close, Craig.

CRAIG CALLENDER
Thanks, Shane.

SHANE HUNTINGTON
Craig, let's start with a bit of history here. Who was the first scientist to actually realistically tackle the idea of time?

CRAIG CALLENDER
I think it was Sir Isaac Newton, the great father of classical mechanics. Although
others in history talked about time, most of that discussion is really the beginning of
time, how did the world begin and that kind of thing. But when did physics really
require a theory of time? It didn't really require a theory of time until physics got
sufficiently sophisticated. And then, in Newton's mechanics, which explains
cannonballs, apples falling and whatnot, but also the solar system and a whole range
of phenomena. There, you really see that physics requires a particular conception of
time, and so I would trace it all down to Newton originally.

SHANE HUNTINGTON
Can you speak to what was different about the work that Newton did compared to
people like Ptolemy, Eudoxus, Copernicus, all the greats of astronomy that did do
quite complex predictions, presumably using time? How did Newton's work differ
from that?

CRAIG CALLENDER
I think this is more a thing where you could say it's really a spectrum rather than
clear-cut, but the way I think about it is, when did we get regularities? When did we
get things that we'd really call laws of nature? It's true a lot of the great astronomers
were able to predict when things would happen, but with Newton, you get a full,
complete physics that's supposed to be not just the celestial realm but also the
terrestrial realm. So you have these laws which are describing, in principle,
everything. They key thing here is, you don't really think of it when you first look at
the law, that it's saying something about time. But if the law says that a ball will travel
a certain distance in a certain amount of time; that's using a certain measure of time.
Otherwise, the law is false, and so if you say the ball is going to travel, say, six feet
in a couple of seconds, that's implicitly giving you a measure of how long a second is.

SHANE HUNTINGTON
I suppose, if you read the Principia and some of Newton's other work, it also makes
time an item within itself, doesn't it? I mean if you think of the old astronomers, they
would tell you that something would happen as a particular time, but in a sense,
Newton dealt with time in exactly the same way as he dealt with length. Is that a fair
statement?

CRAIG CALLENDER
Yeah, I think that's right. Time is then just another topic. What does time have to be
for my physics to work out right? The way with space, what does space have to be
for my physics to work out right?

SHANE HUNTINGTON
Most people, I guess, in the layman's worldview would consider this to be a perfectly
reasonable way to approach things. In fact, Newton's laws still cover the vast
majority of things that we measured. What aspect of this feature of time was
challenged?

CRAIG CALLENDER
Methodologically, it seems like it's a perfectly natural way to go, and I think that we
haven't changed from that. We learn about time from learning about our best physical theories. What does time need to be for our best physics? In that sense, it's been the same, but then, of course, what our best physics is has changed again and again and again. The way I think of it is, time seems to be shedding various properties through all these different historical revolutions in science. Perhaps it's best if I say what conception of time Newton's theory requires, and then we can see how it loses some of those features.

SHANE HUNTINGTON
Obviously, with Newton, when you look at the equations he put forward, they don't really have direction forward or backwards, do they?

CRAIG CALLENDER
That's right. That's one of the big ones. The theory works in either direction, so we can take a bunch of particles, or I guess Newton would have billed them as corpuscles. Take a bunch of corpuscles and take their initial state, and I could run that state forward and backward and it would be the same way. A way for the audience to visualise it is if you focused really, really closely, you took a camera and you looked at some process in the world where you could easily tell the direction of time, but if I look at the micro level and see all the atoms swarming back and forth, colliding, and I took a film of that, then I can't really tell, if I was just presented with that film, whether the film was being run forward or backward in time. It's only when I pan out that the direction becomes apparent. So that's one of the big things, but there's not a direction in the physics itself, although I think Newton thought there probably was. It wasn't so clear at the time.

SHANE HUNTINGTON
There is, obviously, for us, a very big difference between past and future, but when we look at things in the natural world, there does seem to be some indication of a difference there, as well, doesn't there? The classical one - I use that term carefully, that of entropy and the idea that we are moving towards points of greater disorder from where we are now. So there does seem to be a direction to time.

CRAIG CALLENDER
Yeah, that's certainly right. It shows up in really all macroscopic features in thermodynamic processes, but also, you know, radiation. We never have radiation converge on sources. It emerges from sources. There are just all sorts of phenomena like this. And of course, psychologically and biologically, that's all irreversible processes, too, in the loose sense of irreversible, where we age and we die and never the reverse. We have memories of the past, not of the future. So it's a huge part of what it is to be a human and to live a human life.

SHANE HUNTINGTON
Is this solely a human construct, though, or is there something physical about the universe that says there's a direction to time? Is this just our way of perceiving it?

CRAIG CALLENDER
I think it's definitely there in the universe. Trees in a forest would go to equilibrium even if no one looked.

SHANE HUNTINGTON
I'm Shane Huntington and you're listening to Up Close. Today, we're speaking with philosopher Craig Callender about the nature of time. Craig, along comes Einstein, and all of a sudden, things get whacked a bit with regards to how we consider time. One of the first things, of course, to come out was the idea of simultaneity between two events. Can you speak to how that affected our concepts of time?

CRAIG CALLENDER
Yeah. I think a huge part of our concept of time is one where we think that there's a privileged present, and we think that that privileged present is global and unique. So if you're listening to this, you would think that that's one event that picks out what's going on in the rest of the universe at that same exact time, that time that's simultaneous with you listening to this. That's fully embraced by Newton and Newton's conception of time, as well. There's a unique way of telling the story of physics. I sometimes like to put it metaphorically. If you think of the universe of a big, four-dimensional block with all the events there, past, present and future, there's a unique carving up of it in a Newtonian world. So if you think of it as a big ham or something, you can put it in the deli slicer and cut it up into various slices, only in one unique way. But if you move to Einstein's picture of the universe, then there is no unique way of doing that. Any two events that are not connectible by a light signal, their order depends on the observer. So, take two events, so I'm going to snap right now both my fingers, and so I snap. Did the one snap happen at the same time as the other snap? If I get the snaps fast enough, then we could be guaranteed that there'll be some observers for whom the right snap was first the second (left) snap was second or the other way around, or that they were both at the same time. Now, think of how that conflicts with our ordinary conception of time, where we've got this idea of this privileged present. Which of those presences is privileged? Also, think about how much it matters whether that present that we'd normally think of as privileged is distinguished. It's not just that we think it's distinguished, it's that that slices the whole universe into a past and a present, future, which we think have different properties. So you think of the past as being fixed. You think of the future as being open. But now, if there's not a unique carving, then it doesn't make sense anymore to talk about there being a uniquely cut in half universe, half-fixed, half-open. Now, it's all either fixed or all open.

SHANE HUNTINGTON
This brings in the notion, of course, also not just of different clocks sitting in different locations having different timings for different events, but when we start talking about gravity, we then have to make additional changes to that, so it's not just based on speed or location. It's also based on where in space we're actually sitting. So, Craig, maybe you could run us through an example, like if we're both relatively close to a black hole but you're half the distance I am from that black hole, how would we perceive things differently? How would time be different for the two of us?
CRAIG CALLENDER
So, Einstein first came up with special relativity in 1905, and then general relativity, where it's incorporated matter, in the 19-teens. On that theory, then gravity affects the ticking of all the clocks in the universe and, of course, mass induces gravity. Although there is no real gravity on that view, it's just curved space-time. Of course, then, a black hole will curve space-time quite a bit more, presumably, then, wherever you where, and so whoever's closer to the black hole, it'll affect their ticking rate and their clock will tick faster than the other person's clock. There'll be this difference. In fact, it's completely measurable. This is called gravitational time dilation. The most precise measurements to date have been made of this, just over the range of a metre. So, done on Earth, the Earth, of course, is very massive and it's just in the Earth's gravitational field, vertically with respect to the centre of the Earth. So, just the difference between, say, your hips and your head, there's a measurable difference in the ticking rate of clocks.

SHANE HUNTINGTON
That's incredible stuff. I suppose, when you think of that change, that's one of the reasons why our GPS network, which most people of as just sending them accurate position, but of course, more importantly, it sends accurate timing, has to compensate for general relativity, doesn't it?

CRAIG CALLENDER
That's right. There are both special and general relativistic corrections in the algorithms that the smartphones use. So, every time you upload some data and get an accurate thing, then you are indirectly testing a theory of time.

SHANE HUNTINGTON
Thank you, Einstein, for that. Now, you used the term space-time before, Craig, and as we move through history and think about how our perception of time has changed, what does this mean in terms of the way we looked at time? Obviously, it's not necessarily the separate item that Newton spoke about.

CRAIG CALLENDER
That's right, because you can't construct the universe in a unique set of three-dimensional spatial objects, the special events happening at different times. Then Minkowski, Einstein's teacher, came along and said, let's think in terms of space-time. If you think in terms of space-time, just call an event a spatial-temporal event, and then what bit of that event is space and what bit is time then depends on the observer. So it's really a profound thought, because it means then that space and time really are emergent notions and that the basic fundamental unit in a space-time theory is then a spatial-temporal event and not bits of space and moments of time. And so, already, even before you get to the more speculative theories of quantum gravity and that, even just regular old relativity is already saying that space and time are, in some sense, not fundamental.

SHANE HUNTINGTON
This would have freaked out Newton, wouldn't it? Because you would have had to
describe a scenario where his equations might have worked for you, but if I was watching from somewhere else, we would get a different answer.

CRAIG CALLENDER
Yeah. The way Newton formed his equations, they were only approximately true in certain reference frames and not others, and he would have been horrified to find that out, I think.

SHANE HUNTINGTON
Newton, of course, was looking at things that he was observing at the time, the apocryphal story of the apple, but other things, obviously, in his universe at the time that he could see, he could model, he could measure and he could try and falsify his theories as a result. With Einstein, was it the same? I mean many of the proofs of Einstein's theories have come out much later. Was he basing his work on experimental observations or was this just pure theory before the observations were made?

CRAIG CALLENDER
I think it's a bit of both. Einstein himself distinguished between what he called principle theories and constructive theories. A principle theory is, you come up with a principle based on empirical observations and then try to deduce the rest of the physics, as opposed to a constructive theory of more nuts and bolts, gears and widgets type of theory, and then you try to deal with things one at a time like that, and then come up with a general picture. He always said that his theory was a principle theory. Certainly, when he discovered special relativity, that seems like a principle theory where he just looked at existing physics, noticed some things that struck him as odd, explanatorily, and then came up with this as a better way of thinking about physics. But then, when it comes to general relativity, he did know that there were anomalies, that Newtonian gravitation theory couldn't handle the precession of Mercury. From our point of view on Earth, Mercury looks like it goes back. All the planets do. They look like they turn back a bit. There was a known discrepancy between Newtonian gravity and what we saw, and so we knew that there were certain empirical problems with Newtonian gravity when he invented general relativity, but he built in that the theory would work for those things. I think it was a surprise when his theory predicted black holes and a bunch of other things.

SHANE HUNTINGTON
Yeah, it certainly got a lot further than he probably anticipated. I suppose in his day, without things like the Hubble space telescope and the like, it would have been a lot harder to observe things like Einstein's rings, where you see gravitational bending of light and so forth, which of course, he predicted. Now, as we move from relativity, special and general relativity, into the next phase of physics, of course, quantum physics and quantum mechanics, this changed the perception of time again, didn't it? I mean Einstein had his particular, quite negative views of quantum theories, but the way in which time comes about in quantum physics is again more along the Newton's lines, isn't it?
CRAIG CALLENDER
Just as you said, Shane, the conception of time that quantum mechanics uses really is mostly classical. You can extend it to special relativity, and even there, you have some problems, but you are using this, essentially, Newtonian conception of time. Of course, that raises the big question, the million dollar question about how to unify quantum theory with relativity, since they both seem to do really well in their own domain. General relativity does really well, roughly, with the very big things, and quantum mechanics does really well with the really small things. But you know that they’ve got to come together at some point. You know, for instance, those electrons going around the nucleus, they have mass. There ought to be some relativistic corrections to make. Also, black holes, they could get so small that then, there should be quantum corrections. So you can't really think of them as two separate domains or two separate theories of physics. There should be one, but exactly what that will be - and then the big question for time is which type of time will remain standing after this is all sorted out.

SHANE HUNTINGTON
You're listening to Up Close. Today, we're speaking with philosopher Craig Callender about the nature of time. I'm Shane Huntington. Craig, obviously, as you mentioned, there are these differing views of time, the use of time in physics and so forth. How do physicists go about addressing how we'll go forward with this? Are there experiments? Are there different sorts of modelling going forward that will allow us to make a choice? Presumably, at some stage, we're going to have to pick a side.

CRAIG CALLENDER
Yes. I think what's happened now is different research groups have picked a side and are pushing the thoughts along as far as they can go in all these different directions. So it's really letting a thousand flowers bloom type of situation. Suppose you're trying to come up with a theory of quantum gravity. You know the theory's going to be different than relativity or quantum mechanics. It's not just going to be one of those theories being right and the other one being wrong. You might think to trust one more, or you might think that the techniques of one are more successful than the other. The way I roughly categorise it is, if you think quantum mechanics is right or better or a better guide to the truth or a better guide to the future, then you're going to be thinking pretty positively about old-fashioned time. And the particular research field you use will then be more quantum, something like superstring theory, which many people listening will have heard of, a more quantum type theory. On the other hand, if you want to make a theory more like relativity, then something like loop quantum gravity and many other approaches which really are more thoroughly relativistic in some sense, where time then gets really demoted even further. So you have this divide between all the different approaches and along the lines of, which theory do you trust more?

SHANE HUNTINGTON
You're a philosopher, so I'm going to ask you this question, which you may not be able to answer. But when we think about time, should we be thinking about it as an actual item, like the way we think about light or an electron, or should we be thinking
about time as a property?

CRAIG CALLENDER
What do you mean, as a property?

SHANE HUNTINGTON
So, for example, length is a property of an object, but it isn't a real thing, in a sense. It's a conceptual framework that we use that, as you rightly pointed out earlier, Einstein noted could change depending on observers.

CRAIG CALLENDER
I think of space and time as more like objects, if you put it to me like that. What's my guide to what's really out there? Well I think it's science, and if science tells me that it requires space and time, just like it requires the Higgs particle and the top quark and whatnot, then I'll believe in those things. So I do think of it as an object, although there is a big, historical controversy about the nature of space and time. Newton had this view that space and time were substances, like a container view of the universe. So, space was this container, almost like water is for a fish in a fish tank. It was a real substance. Then, other people thought, no, it's really just an abstract system of relations between the objects, the particles and whatever. So there was that debate between Newton and his contemporary Leibniz. That got very vicious a debate, and it continues today. I think general relativity, though, lends credence to the Newtonian picture. Here's a simple-minded way of thinking about it. But a gravitational wave is possible in general relativity. They're doing experiments now, trying to find evidence of them. What is a gravitational wave? A gravitational wave is a wave in space-time itself, but a gravitational wave could come by and turn on a light bulb. If it could turn on a light bulb, it's real. If it's real, then space and time have got to be real - at least, if I believe that theory.

SHANE HUNTINGTON
That's an interesting concept. The good analogy to that is that you have, say, ocean waves, which in themselves are just a summation of positions of objects. So if you take all the water molecules, you put them in a certain position and you move them to another position, we perceive a wave. Is that the sort of thing you're suggesting with regards to time, or that time is something more than that, more than just a perception of positions?

CRAIG CALLENDER
Yeah, I'm thinking that it's more than just a perception of positions. It's the ground that makes having positions make sense.

SHANE HUNTINGTON
You're talking about, essentially, the benchmark for those positions. So you can't determine where the positions sit without the ground, and so you have that benchmark. That sounds to me very much, Craig, like we're not getting rid of time any time soon.
CRAIG CALLENDER
I doubt it, actually. You may make a case that it's already been gotten rid of, because relativity makes it be space-time and not time, but I don't think you're going to get rid of space-time. There are theories where it does turn out to be emergent from something else, and that's one of the exciting things about some work in quantum gravity. But these theories are really pretty speculative.

SHANE HUNTINGTON
Emergent? Can you describe what you mean by that a bit further?

CRAIG CALLENDER
You might first of all ask, how could there even be a theory without space-time in it? What would that even mean? It's hard to even see how you could have evidence of that, if all your evidence is really of things with locations moving. At the end of the day, some physical experiment is going to give some pointer pointing in one direction rather than another. If that's change, and change is change with respect of time, then how could you ever get evidence for a theory that has no time in it if all the evidence is evidence of things changing in time? But I think you could get such a theory, as long as that theory tells you why you think that there's time. There might be some kind of funky theory where, really, all there is is quantum state, and the quantum state is some kind of wave function and some kind of real space, and then in some regime, it makes sense for certain variables to play the role of time, but not in all of them.

You wouldn't then say that time was in at the bottom. Rather, it comes out in certain approximations, so when things get classical and big, then we can treat certain things as clocks and it makes us think that there's time when, really, there's not. Here's another way to put it. It might be that the universe as a whole is timeless, but that the subsystems, when they interact with each other, then something like time pops out. It emerges. But that total system doesn't evolve in time, even if it looks like, from the point of view of the subsystems, that there is time evolution. I think that's at least possible.

SHANE HUNTINGTON
Craig, unfortunately, one of those emergent properties has caught up with us and we have to finish this interview. So I'll say thank you very much for being our guest today on Up Close and talking with us about the concept of time.

CRAIG CALLENDER
Thank you very much. It was a pleasure.

SHANE HUNTINGTON
Craig Callender is a professor and Chair of Philosophy at the University of California, San Diego. If you'd like more information on this episode, visit the Up Close website, where you will also find a full transcript. Up Close is a production of the University of Melbourne, Australia. This episode was recorded on 7 November 2013. Producers were Eric van Bemmel, Kelvin Param and Dr Dyani Lewis. Audio engineering here in Melbourne by Gavin Nebauer, and in San Diego by Michael Forsner. Up Close is