**Prof. Russell Stannard: The questions on everyone's minds**
*The Nature of Time*

**Russell:** The subject of time has always fascinated people. We all start off thinking there's just the one time, the same for everyone. But Einstein's theory of relativity shows that this is not the case. Two people moving relative to each other they have their own times - and they're not the same. At normal speeds, me moving relative to you like this, at these sorts of speeds the difference between your time and mine is not obvious. It's too tiny to notice. But at high speeds, really high speeds, the effects become enormous. Suppose, for example, we have a space craft and it's flying to a distant planet. And, just suppose, it is going at a speed equivalent to well let's say 9/10ths the speed of light, around 270,000 kilometres per second. Not realistic but just suppose. At that speed the astronaut's time will be going at half the rate of that of the mission controllers back at Houston.
At that speed everything happening in the space craft is slowed down by a factor of about 2. Not just the rate of the clocks and watches, but also the astronaut's breathing rate, pulse rate, even his ageing processes. It's Time itself that is slowed down. It's called time dilation. Now you might think that the astronaut would find this all very strange - living in a world of s-l-o-w m-o-t-i-o-n. But no. With everything slowed down, his thinking processes will be slowed down - in the same ratio. And if you look at a s-l-o-w w-a-t-c-h with a s-l-o-w b-r-a-i-n it appears normal. So for the astronaut, everything happening in the craft appears perfectly normal. It only appears slowed down to the mission controllers. 'But', you might think, 'Well surely, you know the astronaut will know his time has been going slow when he arrives at the distant planet in only half the expected time?'
No. There's a second effect of relativity theory. This is the situation as seen by the mission controller – here we have the earth and this is the planet to which the astronaut is journeying. But according to the astronaut, this is what it's like. Relative speed affects not only time, but also distances. According to the astronaut, travelling at 270,000 kilometres per second, the distance from the earth to the planet is only half of what the mission controller says it is. It's squashed up. The earth and the planet themselves, they're squashed up. In fact any length seen to be moving relative to the spacecraft, according to the astronaut, will be squashed up. It's what we call length contraction. So, we have time dilation and also length contraction. The mission controller says, "Your time is running slow," the astronaut says, "There's nothing wrong with my time, it's your distances that are squashed up. My journey took half the time because I've gone only half the distance, it all makes perfect sense." Except it doesn't agree with what the mission controller says is going on. OK, if this is the first time you've come across this sort of thing, then it all seems quite bizarre. But it's all been tested out and found to be true. Not with spacecrafts flying about at speeds close to that of light, but here high energy physics laboratories like CERN just outside Geneva. Here we can check out Einstein's theory using subatomic particles hurtling around the particle accelerator at speeds that are indeed very close to that of light. This is the Large Hadron Collider. If you yourself were to travel at the speeds achieved here, you'd live to be half a million years old. That's time dilation. As I say, all of this sounds very confusing: different people having different ideas about lengths and times. But fortunately there is something the astronaut and the controllers over there, in fact all observers can agree on. It comes about like this: We're used to thinking in terms of a three dimensional space: up-down; sideways; backwards, forwards. So, three axes at right angles - like this. That, coupled with a one dimensional time; past-future. A separate one dimensional time Things changing in three dimensional space as it moves up the time axis.
But what if we're wrong? What if they're not separate and they are joined together, welded together to form a four dimensional spacetime? That's what we call it: space time. What would we expect to find in this four dimensional spacetime? Well whatever it is, it will have to be characterised by a particular point in space (as measured along the three spatial axes) together with a particular point in time (as measured along the time axis). In short, we are talking about events.

One event might be the launch of the space craft at the earth (that’s its point in space), the launch also taking place at a particular point in time. Three, two, one, blast off. A second event could be the arrival of the space craft at the distant planet at a later point in time. Now what one finds is that, although the two sets of observers, the astronaut and the mission controllers, they don't agree about either the spatial distance or the time the journey took, they do agree about the interval between those launch and arrival events in four dimensional space time. And it's because everyone agrees about what the situation is in four dimension space time, that gives rise to the idea that what is real - what actually exists - is four dimensional spacetime.

Our familiar time and space, they’re nothing more than appearances, appearances of this reality, subjective appearances as seen from some specific point of view. Okay now, what does that mean? You know, different appearances. Well, take this pen. It has many different appearances depending on the angle one is looking at it. Sometimes it appears short. But sometimes, from another angle, from another point of view, it appears long.

This is because all we see with our eyes, or photograph with a camera is a flat two dimensional projection, a projection of something that is actually solid, something that exists in three spatial dimensions, not just two. So, what we are saying now is that space by itself is but a 3 dimensional projection - a projection of something that is actually 4-dimensional. And the time interval is nothing more than a 1-dimensional projection of this 4-dimensional reality. As Einstein once said 'Henceforth we deal in a 4-dimensional reality, not a 3-dimensional reality evolving in time.' So that neatly solves the problem of those differing perceptions of times and distances. But does it? This 4-dimensional spacetime is sometimes called the block universe. It encompasses all of space and also all of time. The whole time axis - past, present, and future. This point here, that represents the present instant and then on this side that point there is when we started the program and I say “The subject of time has always fascinated people.” And here on the other side, that’s when I say “Will we ever fathom the riddle of time?” And the programme comes to an end (and you can take a headache pill).

It's all here. Past, present, and future – all on an equal footing. According to the block-universe idea, the future already exists. It's out there waiting for us to come across it and experience it consciously. The block universe is static. Nothing changes in the block universe. Changes occur in time. But time isn’t out here, time is in it. But if nothing changes how come we experience a flow of time? Time rolling on. How come we have this impression that whatever exists is what is happening now - at this present instant. The past?

That has ceased to exist, it used to exist but not now. The future? Well we might try and guess what it’ll be like but we can’t be sure because it doesn’t yet exist. What we're talking about now is the mental experience of time - an experience that seems not to be reflected in the physics. In fact the physics community is deeply divided over the concept of the block universe. While all physicists accept that observers agree over distances measured in this 4-dimensional spacetime, they don't agree over whether that necessarily means that spacetime is real - that it’s THE reality and not just some, well mathematical thing. So, does all of time exist, including the future, in some sense? And if so, in what sense exactly? Will we ever fathom the riddle of time? Or is this another encounter with the Boundaries of the Knowable?

*After piece*

**Tony :** Okay, Russell I thought you said you needed less than 10 minutes for that section.

**Russell:** How long did it take?

**Tony:** Well actually it was about 12.

**Russell:** Well it depends on how fast you're going. Yeah, why don’t we get the viewer to get up and rush around the room whilst they’re watching it, that’ll slow everything down and that should do the trick. No, hold on, no that would slow. No that’s alright that would make it seem even longer wouldn’t it? No forget I said that.

**Tony:** Cut.