Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Equivalence*.

This is another interview with Graham Nerlich, Emeritus Professor of Philosophy at the University of Adelaide and also my Dad.

SN: Now, Einstein talked about the equivalence of acceleration and gravity and he used a story of a person in a box that was like an elevator – and if there was a hook on the top of the box and it was pulled in a particular direction that person would feel a force pushing them towards one side of the box that they would then perceive as the floor – and indeed if you accelerated that box they were in at 9.8 metres per second per second, I guess they would feel exactly like they were standing on the surface of the Earth at sea level.
GN: That's pretty well right.
SN: So that makes sense to me, but I know you and I have talked about people in spaceships before as a nice way of thinking about relativity and general relativity. So you can think of someone who's out in fairly empty space. If they are moving at a constant velocity they're essentially weightless, Yeah?
GN: Yep.
SN: And they can continue at that constant velocity without firing their rockets kind of indefinitely.
GN: Quite indefinitely, yes.
SN: But of course if you put a planet in their way, they are going to hit the planet – but on the way down towards the planet's surface they are entering the planet's gravitational field... they won't notice a thing presumably if their windows were blanked out they wouldn't realise what was going on?
GN: No. So, going back to the Einstein box, there are really two stories to be told there. One is – you've got someone in a box who is being pulled steadily by a constant force and that feels to him like gravity, he's got to find the floor and stand up and exert pressure on his legs. That's one part of what Einstein called the principle of equivalence. The other part is that if you are in a gravitational field and somebody cut the cable on you and you just fell, it would be for you exactly as if you were at rest in gravity-free space.
SN; But an external observer might assume you were experiencing something quite different because they see you accelerate – so they might assume you're being thrown towards the top of the box, because it's accelerating in that downwards direction. And you sometimes see that in bad movies that don't understand physics well. But why aren't you thrown towards the roof in that scenario?
GN: Because the roof and the sides of the box – and you – are all being pulled in exactly the same way by the gravitational field of the Earth. So as Galileo found out a long time ago – as you drop a heavy object and a light object from the leaning tower of Pisa they will hit the ground together. So all of these things, your body, the box and so on in the gravitational field react to it in exactly the same way. So you are falling just as fast as the box is falling and you don't move relative to it at all.
SN: So I guess that then brings me to try and understand how the person standing on the surface of the planet should interpret what they're seeing. So that they're seeing this box accelerate down towards the surface, I guess they might just say "oh well, it's gravity, but..."
GN: That's what we've being saying for centuries.
SN: But I've heard you say previously - gravity is really a pseudo force. It's more a consequence of geometry than a force per se.

GN: If you look at it from the perspective of four dimensional space-time that's true. Once you start talking the 3+1 language the space + time language – where we think our ourselves as three dimensional things and the box falling is a three dimensional thing through time and so on –you then really have to talk about gravitational force. But if you unify them and talk the space-time language, the story is different, there's no gravitational force.
SN: Can you tell us that story then? Is there a way to quickly talk through the physics of what's happening as you are falling?
GN: Well, take a simple example of curvature – we're both at the equator and we're fifty miles apart and we both head due north. We don't have to turn any corners, we don't have to put forces on a steering wheel, we just go straight. When we get sufficiently far up, we will meet at the north pole. That's because of the curvature of the Earth – we both went straight, but I accelerated towards you and you accelerated towards me because of that curvature, because the further we go the quicker we start to come together. That's just a simple three dimensional example – and what you have to learn to do – and it's not easy by any means – is to envisage all this in four dimensions.
SN: Another perspective is the rate at which clocks appear to run relative to the person on the surface. Does that give us some insight into why there's an acceleration?
GN: Well, space-time both in the spatial dimensions and in the temporal dimension has a curvature. Maybe if you thought of a mountain range and you imagined going across it – and imagine carrying one of those distance measures – a little wheel on a stick, so it's a bit like a clock face that the number of revolutions of the wheel tells you how far you've gone. Then it might be that one person has a certain distance to go and maybe has to go down a dip and come up – whereas somebody 50 metres along doesn't have nearly so much of a dip to go down and come up. Then as they both pass the first fence, let's say, the top of their wheel touches 12 – then they both go on until they reach the next fence – and the one wheel has measured say 20 metres the other's measured say 18 – and that's just the curvature of the mountain at different places.
SN: I'm thinking of a contour map. You might have the same distance as the crow flies between two mountain peaks, but obviously if there's a very deep valley between one set of peaks and a shallow valley between another set of peaks – with a deep valley..
GN: There will be more revolutions of your wheel, more revolutions of the clock.
SN: There's more duration.
GN: More duration. So the revolutions of the wheel as it runs along the track are the analogy with the clock face.
SN: Alright. Then the last thing I think is I'm trying to imagine the person on the surface and the person in the box both have stop watches. They're both going to experience a normal passage of time, their own proper time. I'm trying to imagine the relative duration of the fall from a particular altitude – would it be the same for both observers?
GN: No, the falling observer should measure it as taking less time on the falling watch than one the one at rest in the gravitational field.
SN: Makes sense because it would have started in a high altitude location where time runs faster.
GN: With less distorting curvature and so on – yeah.
SN: And does that somehow explain the apparent acceleration that the person on the surface sees?
GN: It would be part of it, but the distances would be also measured differently.
SN: So, the distances would actually contract I guess, as you get towards the surface.

GN: There is a curvature of space and a curvature of time – so in all dimensions there is a curvature. And in a way the curvature of time and the curvature of space are very alike. In fact, in the equations they look exactly alike, but then you've got the problem that the temporal measures we use and the spatial measures we use are so different from each other. So there is three hundred thousand metres for every second. So there's that big factor – that makes them seems to us so very different. Make sense?

SN: Yep, so it's both the clocks slowing down and the distances getting relatively more contracted towards the surface that accounts for that acceleration that you see – that the person in the box doesn't notice happening.

GN: Yes.

SN: Alright... well, I think we're done Dad.

GN: (Laughs) Yeah I reckon so.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where we didn't quite get around to explaining what would happen if you fall towards a black hole. It's true that in a box falling towards the Earth you really wouldn't notice any difference from floating out in fairly empty space – but if you were falling in your box towards a black hole, the extremely distorted nature of the curvature of space-time around a black hole would require you and the box to conform to that extreme distorted curvature – which would see you simultaneously stretched and squashed and killed. So you'd certainly notice that. No ads, no profit, just good science. Bye.