Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *The shape of space: The mathematics of De Sitter space-time.*

This is the second of two podcasts on some interesting aspects of Einstein's general relativity field equations featuring my Dad, who is also Professor Graham Nerlich.

What interests me about De Sitter space-time is that he gets it out of pure mathematics.

Do you have a story you can talk us through - so we can see how that comes together?

Yeah I have. Minkowski said - and this is back in 1908. You don't really need to approach the Lorentz transformations and special relativity in the way that Einstein did. You can really get it out of pure mathematics. And other people said why was that ten years before Einstein people didn't just look at the maths and say this looks funny. Why shouldn't it be that we've got all four dimensions tied together by this constant c - which is just there in order to make a unity - that's all it's doing in the first instance. It's got nothing to do with light, nothing to do with electromagnetism or anything in the world other than space and time themselves.

OK? That's what Minkowski said. And then in 1977 you get Freeman Dyson writing a paper called *Missed Opportunities* and he says Minkowski saw that an opportunity had been missed. Then he goes on to say Minkowski should have pushed this further because the Lorentz transformation tells you what happens at a point. But there is something else about transformations, what if you shifted the whole position of this and translated it to another spatial region – or another later event – then you get another strange looking thing purely mathematically –and Dyson says if Minkowski had only applied the same reasoning to this group of transformations, which is called the Poincare group, he would have seen that its bizarre in just the same way and if tried to fix it up in a very similar way to the way he fixed up the Lorentz transformations by adding a new constant – then you would get the cosmological constant.

And so you think to yourself , OK what's the geometry that this is telling you about – and the answer is De Sitter space-time.

De Sitter space-time just goes a bit further. It's what you get by making the Lorentz transformations - together with movements in space-time - homogenous. That uses a more elegant transformation group and out of it pops this hyperboloid De Sitter space-time

So all that according to Dyson and these guys of whom Cacciatori is the main name. Well, look you can get accelerated expansion just out of pure mathematics - you don't need dark energy. That's just there because people think that what happens to space-time must be a matter of what happens to the matter in it - and Dyson and Cacciatori are saying no, it could be the geometry - just the natural geometry.

So… It sounds like Einstein had all the right maths, but he decided for reasons that aren't aren't clear to me that the universe was static.

He said this was the greatest mistake of his life, to think you had to have a stationary universe. The cosmological constant was lurking around the place anyway as one of the constant's of integration - and he said I want Minkowski space-time to be the result you get if there is no matter. You've got to do something special with the cosmological constant to stop the universe from changing, either expanding or contracting - and he did. And people then said 'But if you didn't do anything special and just let it rip, what you get is De Sitter space-time and that'd be the simplest solution'. So Einstein was sort of timid really - rather than thoughtful and he said so himself - it was the worst mistake of his life.

But did he ever talk about De Sitter space?

He was well and truly familiar with it

Would he have ever derived the fact that the universe is expanding at an accelerating rate.

Well, it was one possibility. When he looked at what the equations told him, he just saw that they weren't going to allow a steady state - unless he tinkered with the cosmological constant, which he forthwith did, because he thought it was just unreasonable that you have an expanding or contracting universe. I don't know that the accelerated expansion idea occurred to him, though it was certainly there with De Sitter.

But people thought that the De Sitter space-time was not interesting really because it was an empty matter solution to the Einstein equations - so you set the matter tensor to be zero and then you get De Sitter space-time. But if you now consider well what if we put some matter in (and naturally put it in) in such a way that it just disturbs the overall structure of De Sitter space-time fairly locally - just where there is matter. So the overall picture - the big cosmological picture - just remains the De Sitter space-time.

That is very consistent with the observational data where dark energy seems to arise in the emptiest parts of space - and seems to appear more quickly now, compared to billions of years ago - because the universe is bigger and emptier.

So is it fair to summarise with this idea that dark energy isn't really a force- the same way gravity isn't really a force either.

Yeah, it's very difficult to find people who will talk consistent sense about this, because they start talking about dynamical terms like force energy and so on - when what the theory is really telling them is something geometrically. Now this is one of the reasons why I wanted to write a book about the shape of space, because this seems to me to be outrageous because if you look at this in the natural way all this is just about geometry.

But people think if you've got to have space and space-time, you've got to have an eerie something or other and we don't quite understand what it is, so we'll write it as if it was all dynamics - and to do with matter, when it isn't. So I think there are fundamental ways in which general relativity is frequently misunderstood (not always, frequently) by people who are just intimidated by the idea of admitting that space-time is something real.

So *The Shape of Space* says that's what you want to be thinking of - the shape of space, the geometry never mind all this stuff about dark energy. So the fact that Dyson and Cacciatori have said all this stuff and Cacciatori says, you don't really need dark energy it's not about energy, it's about geometry. That's something that pleases me a lot - it fits with what I like to think is the truth.

I get the impression that people don't like 'dark energy deniers' because it sounds like you are saying there's something wrong with physics - which I don't think you're saying at all. In fact all the physics we have now works fine - it's just that the geometry of the universe has a influence on these things.

You're taking the fundamental equation of the brilliant long-standing theory which has worked wonders- and your saying look you don't need to tinker with things on the right hand side of the equation which is all about matter, when it's already all there in the left hand side - the geometry.

So, rather than think we've got to fake up something called dark energy - and who knows what it could possibly be… but it would cheer us up if we think that energy is got to be what expands the universe.

Can I ask you then, do you have any views about dark matter.

No - I don't. It's one of those things that astronomers, observers and physicists worry about - but if you're a philosopher it's not really terribly interesting.

It seems the more plausible of the two the two dark things that we're struggling with at the moment.

Yes, I gather it's not so bad as dark energy.

OK. Thanks for this. See you.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where dark energy spelt backwards is *ygrene krad*. No ads, no profit, just good science. Bye.

References

H. A. Lorentz, Albert Einstein, Hermann Minkowski, and Hermann Weyl (1952). *The Principle of Relativity: A Collection of Original Memoirs.* Dover. *(See section 1)*.

Freeman J Dyson. (1972) *Missed Opportunities.* Bulletin of the American Mathematical Society Volume 78, Number 5.

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