Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *On being a black hole.*

The following is an interview with Graham Nerlich, Emeritus Professor of Philosophy, University of Adelaide and previously at the University of Sydney – and also my Dad.

Let me set the scene. We can imagine there are two frames of reference – so there's us on Earth and we've sent off an astronaut in a spaceship with a brand new rocket engine that capable of accellerating that spaceship up towards the speed of light. Now, I would imagine that under those circumstances as that ship gets close to the speed of light, it's going to start looking like its mass is increasing – potentially up towards infinity. So, under those conditions, could there be a point at which the spaceship appears to be a black hole?

Well, it might appear to be – because relative to the Earth's frame of reference the mass of the astronaut and the rocket will increase without limit. And if you consider that things contract in size, in length, in the direction of their motion – then the astronaut and everything in the rocket ship will occupy less space. So, relative to Earth's frame of reference, the density will increase.

So that sounds rather like a black hole, but it isn't quite a black hole because we are talking about things only relative to a frame of reference. It will look like a black hole, because not only is the mass increasing without limit relative to the Earth's frame and the volume that the whole thing occupies decreasing – clocks and any sort of periodical process that is happening on the rocket will slow up.

If you think of something like a vibrating atom, which is sending off a characteristic frequency of radiation – say sodium burns yellow. Then, the rotations of the atom, the number of times it pulses will decrease, because it's a kind of clock – and consequently the colour, the frequency, of light will be shifted towards the red. So, it will look a bit darker – and when you get very close to the speed of light of course the frequency drops just about to zero and that's as close as you'll get to something pretty black – so it will look black but it won't be a black hole.

And the astronaut will still be alive obviously. From his frame of reference, he's not turning into a black hole?

The astronaut won't have any trouble – or any consciousness of having done anything at all extraordinary in those periods when his ship is just coasting. When the rockets fire of course, it's a different story – because he'll be flattened on the back wall and somehow or other accelerated. And if you are going to get him up close to the speed of light, relative to the frame, it will be a very big push – and he might not survive it. But suppose he does survive it – so you accelerate him up to a big speed, relative to the Earth, then you switch off the motor and he coasts, still at that same high speed relative to the Earth. Then relative to himself, to his own frame of reference, he won't notice any different.

He'll be in free fall.

He'll be in free fall.

So can we imagine a situation where this very fast moving spacecraft – that's appearing to be a black hole – passes close to a massive object. Does the apparent black hole have any gravitational force of its own?

Well, it should do. It depends what this thing, that it passes close by, is doing relative to it. Now, if it's a sort of marker object which is just there fixed relative to the Earth – so that it's a constant distance from the Earth all the time. Then of course the ratio of the relatively moving masses will be quite large – and if they're close to each other and you don't get things (*e.g. gravitational force*) falling off with the inverse square of the distance… then there should be a very strong attraction to one another.

But if you want to bring gravity into special relativity then you have a problem. If you try to think in terms of classical Newtonian gravity, then you've got to suppose that the gravitational influence is instantaneous. So there is no travelling of gravity, say from the Sun to the Earth (*i.e. in general relativity gravity is more correctly not instantaneous, it moves at the speed of light and for example takes 8 minutes to 'move' from the Sun to Earth*). If you're talking about general relativity then it's a rather different ball game because you don't have the flat space-time to begin with. You've still got to specify your frame of reference – and the number of (*available*) frames of reference there are in general relativity is of course much more general – that's one of the reasons why it's called general relativity. So, that's a much more difficult problem.

The reason why I'm shuffling my feet and hedging around your questions is because I think if we understood what a black hole really is first – what I'm saying would become clearer.

Go ahead.

OK. Right now, you and I are in extremely rapid motion relative to some frame of reference somewhere in the cosmos. But of course, we won't notice it at all. So, for ourselves there is no gain in mass – it's only a gain in mass relative to a frame of reference.

Sure – makes sense.

So – a black hole. A black hole is really about the relationship of proper mass to proper volume. So the astronaut's proper mass might be 70kg and his size would be two metres by half a metre by half a metre – but if you think of the density, which is really the crucial thing. The proper density is the relationship between his mass and his size. Now that is something that remains always the same – it's always there even if you now refer him now to another frame of reference like the Earth. So that although by changing your frames about, you can make the mass seem to be huge and the size seem to quite small – and consequently the density quite huge. That's not a real, absolute frame-transcending thing at all.

If you look at the algebra you see that the relativistic mass is:

$$M \text{ [relativistic]} = m_0 (1 - v^2/c^2)^{-1/2}$$

So that the rest mass (m_0) is always there – you can't change that. What you can do is to change the relativistic mass by changing your frame of reference. You get a black hole just when you get the relationship between the proper mass and the proper volume – that is to say the proper density to be very, very high. Then you get all these remarkable effects – and you really get them, so that you'll get them relative to any frame of reference at all, not just to some. Making sense?

So, it really doesn't matter what your frame of reference is when you're looking at a real black hole. It's always going to be a real black hole. Good. My understanding of black holes is that you lose information when something goes into a black hole. But with the spacecraft – sure he can temporarily appear to be a black hole. But if he puts the brakes on, he stops being a black hole and you suddenly gain information about him again?

That information is always available to somebody. You might have put yourself in a position where you're not going to get the information because he's moving so fast that it's going to get to you very, very slowly. But to anybody else – and to the astronaut himself of course, the information is all there – and to his mate in the next room, it's there – and to something relative to which he's only moving at 100 mph – the information is there.

In a black hole, where you've got this crucial density... It doesn't have to be a huge mass, if it's a tiny volume. But if you've got this particular density, then nothing can get out of a black hole. In a black hole there is no escape velocity. So whatever goes in never comes out… unless you start turning to quantum theory, to rotating black holes, stuff like that – which I understand very little about, it's very complex.

I'm not a physicist after all, I'm just a philosopher – but that's what I think.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website – where if something's expensive, we say *relative to what?* No ads, no profit, just good science. Bye.