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

Some people say that we will never travel to the stars until we can break light speed because the travel time would be way too long. But really this is just an example of 3+1 thinking - where people still haven't quite got their heads around the concept of four dimensional space-time - so they still think in terms of space having three dimensions and then think of time as something different and something constant.

There are fundamental reasons why the speed of light is the absolute speed limit in our universe – and it's got nothing to do with how fast light moves, it's just that light moves as fast as it is possible for anything to move in our universe.

To explain - while it seems to us that it takes a light beam 4.3 years to go from Earth to the Alpha Centauri system, if you hop in a spacecraft going at 99.999 per cent of the speed of light you will actually get to Alpha Centauri in a matter of days, hours or even minutes - depending on just how many .999s you can add on to that proportion of light speed. This is because, while you are within your spacecraft putting the pedal to the metal of your imaginary star drive system, time dilation will become increasingly more pronounced and you will keep getting to your destination that much quicker. With enough .999s you really could cross vast stretches of the universe within your lifetime - even though someone you left behind would still only see you moving away at a tiny bit less than 300,000 kilometres a second. So, what might seem like a speed limit at first glance isn't really a limit at all.

Of course, it's all about frames of reference. As you in your spacecraft approach the speed of light someone back on Earth sees your clock slow down. As far as you are concerned your clock works just fine – but if you turned around and returned to Earth after a travel time of maybe days or hours or minutes you might find decades, centuries or even millennia had passed by back on Earth – and that's even though the clocks will have been working just fine there as well.

To try and get the four dimensional perspective on all this, consider that it's impossible to move across any kind of distance without also moving through time. For example, walking a kilometre equals a duration of thirty minutes - but if you run it might only take you fifteen minutes. And if you move at 99.99 etc per cent of the speed of light, the travel time will seem almost instantaneous - although someone timing you from the start position would correctly think that it still took you one three hundred thousandth of a second.

Speed is really just a measure of how long it takes you cross a certain distance. Relativity lets you pick any destination you like in the universe - and with the right technology you could reduce your how long it takes you to get to that destination by any extent you like - that is, until your travel time approaches zero.

That is the only limit the universe really imposes on us. Physics doesn't allow you to move in a way that involves a travel time of less than zero. This has nothing to do with the limitations of your drive system – it's a fundamental feature of reality and causality.

For example - remember the first Christopher Reeve Superman movie? Lois Lane dies so Superman starts doing loop the loops around the Earth, going faster and faster until he reaches - and surpasses, the speed of light? Now in real physics, while he is approaching light speed, his clock (which we should call his *proper* time), is drastically slowing relative to clocks on Earth.

So as Superman approaches light speed, the Earth is actually shifting into the far future beneath him. But he just breaks light speed, the Earth starts spinning backwards and he ends up arriving back just before he took off.

But in real physics you have to ask what happened to that future Earth that came about beneath Superman as he was accelerating up to light speed? Generations of people would have come and gone while Superman was orbiting the Earth above them – even though only seconds were passing from his perspective. There were probably a few wars and some bad things happened - but maybe someone found the secret to world peace and everyone had learned to live in harmony.

But according to movie physics, that whole timeline becomes null and void when Superman broke the light speed and sent the world back to the way that he liked it.

And even if we try to encompass the idea that the Earth really did shift into the far future before Superman started turning back the clock - putting a timeline into reverse breaches the second law of thermodynamics. During that backward-shifting period, eggs would have unscrambled, the dead would have recomposed and helium would have un-fused into hydrogen within the core of the Sun - in other words entropy would have gone backwards. This is utterly impossible anywhere outside movie physics.

Of course you might then appeal to some hypotheses of fringe physics that support the existence of a multiverse – that is, a multiverse of parallel timelines. So for example, the particular timeline in which Lois Lane died and Superman then absented himself from, might have persisted – because in flying back in time Superman was actually creating a whole new timeline – really a whole new universe – which could include both himself and a rescued-from-the-brink-of-death Lois.

This is really proposing that when you achieve light speed you leave your universe and somehow join another one. But you will still run into problems with the first law of thermodynamics, which says that energy can’t be created or destroyed – just transformed. Since matter is essentially energy, when Superman leaves our universe – that means energy lost (equivalent to it being destroyed) - and when he joins a new parallel universe that's energy that's being created in that universe.

So hopefully from all this you can see that when we say you can't move faster than light, we are dealing with very fundamental principles of reality and logic.

But then you might well ask - what's so special about 300,000 kilometres a second? Why is this the particular speed at which travel time across a distance reaches zero? And it seems that it *just is*. It's the default setting that makes our universe work. Someday, we may discover an underlying reason for the relationship between 1 second and 300,000 kilometres – and it may be that there are hypothetical universes with a different space-time relationship and hence a different maximum speed. But you can be confident that any such universe will still have some kind of maximum speed – representing the state of motion at which the amount of proper time you need to cross the distance from A to B reaches zero. That will always represent the maximum speed for any universe – otherwise nothing would make any sense.

So anyway, the good news from all this is that we can actually cross light years in a matter of seconds due to time dilation. So the laws of physics are not a barrier to us conquering the stars. There are just a few practicalities that we have to deal with:

1) A star drive - unfortunately we don't have one of these. Our current technology, that takes us three days to get to the Moon, just isn't going to cut it.

2) The acceleration required to get up to a speed of around 300,000 kilometres a second will generate G forces that will kill you, unless you do it very slowly and steadily - and then you will have to decelerate just as slowly and steadily at the other end. Those speeding up and the slowing down parts could easily consume your whole lifetime - even if there is a close-to-light-speed middle part that takes only seconds.

3) A grain of dust at 99.99% of light speed might be enough to kill you and destroy your spaceship - indeed radiation coming at you could also kill you, because it will be blue-shifted into high-energy gamma rays. What we will need to travel to the stars are dedicated space lanes or deflector shields - or something.

But hey, at least the real problems aren't anything to do with the laws of physics.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where science good, just profits - no, ads no. Bye.