

## Starships assembly

Just before Christmas, it was announced that both Voyager 1 and 2 have left the solar system. They are the first man-made objects to enter interstellar space, the vast dark between the stars. They have travelled the farthest of anything made by humans. In addition, they are travelling faster than any man-made object. Every second, Voyager 1 travels 11 miles - that's about 40,000 miles an hour. Are you impressed by that speed? Don't be. In the context of the interstellar deeps that Voyager has entered, it is hopelessly slow. 40,000 miles an hour is 0.00006 of the speed of light, and it would take Voyager 17,000 years to go just one light year. The nearest star to our own is Alpha Centauri, which is 4.3 light years away. Even if Voyager were aimed directly at our nearest neighbour in space (which it isn't), it would take over 73,000 years to arrive. So although the two Voyager spacecraft have entered interstellar space, they certainly cannot be classed as starships. They are nowhere near good enough.

The idea of travelling to worlds orbiting other suns is deep in our popular culture. We are all familiar with these iconic images of fictional starships. The Millennium Falcon, the Death Star from Star Wars, Star Trek's USS Enterprise and the endearingly homely Tardis are just a few examples of the starships that inhabit our imagination. We are a restless species, and as soon as it became apparent that new worlds exist, our minds travelled ahead in our stories, imagining a new age of exploration and discovery.

So could it be true? Could we really build a starship and travel to strange new worlds, lit by distant suns? It sounds impossible, given the vastness of the space between the stars. Nothing we have currently would allow us to do it. However, I want to suggest this morning that we may be nearer than you think. Indeed, we may become a star faring species within the lifetime of people in this Hall. That sounds absurd, but let's explore the idea. Assuming current progress in medical science, I imagine that many pupils in this room could hope to live to see the 22<sup>nd</sup> century. That is 81 years away. Could we get to the stars in the next 81 years? Well, some scientists at NASA are seriously exploring something called the Alcubierre Drive. It currently exists only in theory, but it has the capacity to put any one of us in orbit around Alpha Centauri in under two weeks. I'll say more about Alcubierre Drive later, but let's explore some slightly less fanciful ideas first.

Before we develop manned exploration, we generally like to send an unmanned mission. So is it possible to send a machine to another star, to explore an alien world? The answer is yes. Could it be done in the lifetime of people in this room? Absolutely – it's already happening.

The project is called Breakthrough Starshot. It plans to send a fleet of light sail spacecraft to the Alpha Centauri star system 4.37 light-years away, where we know there is an Earth-sized planet in the habitable zone, where water and life can exist. About a thousand tiny spacecraft (on the scale of centimeters) will be placed in orbit and then ground-based lasers will focus a light beam on the crafts' sails to accelerate them one by one to a speed between 15% and 20% of the speed of light. At that speed, it will take between twenty and thirty years to complete the journey, and approximately four years for the starships to send pictures (which would be sharp enough to show surface features) and data on the alien planet back to Earth.

A fantasy? No. The project was announced in 2016 by physicist Stephen Hawking, who was joined on the board by Facebook CEO Mark Zuckerberg. The project has already received funding of \$100 million and the first craft could launch by around 2036. That's well within your lifetimes.

But let's go one further. Forget about robot exploration. Could someone in this room travel to another star and perhaps walk upon an alien planet? The nearest is around our neighbour star, Alpha Centauri. But can we get there? With a reasonable expectation of scientific progress, yes. In order to get anywhere in the galaxy, all you really need is the capacity to deliver a continuous acceleration of 1g, which is what you are experiencing right now as a consequence of Earth's gravity. There is a brilliant web page called the Relativistic Star Ship Calculator. It does the maths for you. Assume a starship, perhaps attached to an asteroid which is mined for energy and materials as we go, that continuously accelerates at 1g until it reaches half way to its target, at which point it turns around and decelerates at 1g to come to a stop at its destination star. 1g sounds pretty achievable and would make life on ship feel like normal life on Earth. A ship travelling at 1g to Alpha Centauri would reach a peak speed of more than 95% light speed. For those onboard ship, it would take only 3½ years to get there. However, because time slows down when you get close to light speed, on Earth 6 years would have passed. That sounds manageable. What is harder to manage is the increase in mass you experience as you get faster – to maintain 1g is going to take an awful lot of energy.

Let's think bigger. At this moment, we know of 15 planets within 20 light years of Earth, which are in their star's habitable zone. That's 15 planets where you could live. But there's more to discover. We think that as many as 15% of stars have Earth-sized planets in the habitable zones. There could be scores of viable new worlds for us in our cosmic backyard. At 1g acceleration, it takes just over 6 years to travel 20 light years. But be aware of time dilation – over 21 years would have passed on Earth. If you don't care about going home again, anything is possible. Do you want to go to another galaxy? The nearest is Andromeda, a mere 2.5m light years away. At 1g acceleration, you could get there in just 28 years of ship time. Of course, over 2.5m years would have passed by back on Earth, and humans would probably have died out.

Can we go one better? Could we really go to the stars and return, in our own lifetimes? Well, maybe. May I remind you of the Alcubierre Drive. This is an entirely new concept – totally different to the classical physics of chucking out matter behind you in order to go forwards. With the Alcubierre Drive, you don't move at all. You are held in a small piece of spacetime, that is contained inside a bubble. That bubble can then be accelerated to speeds many times the speed of light. No material object can go faster than light speed, but there doesn't seem to be any restriction on the ability of whatever makes up spacetime to expand and contract – just think about the Big Bang and the incredibly fast inflation of the size of the universe in its early seconds. The Drive uses gravitational effects, focussed by a disc, to compress spacetime in front of the warp bubble, and expand spacetime behind it. The starship sits motionless on top of a wave of spacetime, rather like a surfer. No acceleration is experienced by the ship – and because the bit of spacetime you sit on isn't moving, the ship has no relativistic problems with time. The maths behind it all seems to fit with Einstein's theories. The only problem is the vast amount of energy needed. However, recent work has greatly reduced the problem, and it may come down further. The Alcubierre Drive exists only on paper at the moment, but it is not inconceivable that it could get off the drawing board in the next 81 years, which would allow travel between the stars to be like modern-day long haul flying. You may have seen the Alcubierre Drive disc on smaller spaceships in the Star Wars Trilogy, episodes 1-3. This is another idea of what it might look like:  
<https://www.youtube.com/watch?v=t8LD0iUYv80>

Of course, we may not have to build the technology needed to get us to the stars. They may come to us, in the form of starships from elsewhere. We have made no effort to hide ourselves. There is a shell of transmissions around Earth extending 83 light years into space. Ever since 1936 we have been firing organised electromagnetic signals into the universe, in the form of TV transmissions. Any alien craft clipping through that sphere would know where we were and may or may not decide to come and visit. That would be fine with me, but a little bit of species pride makes me want us to be the proactive ones. So how about it? Who in this room wants to go to the stars? Make it so, gentlemen.