Interstellar Travel and the Future of Physics

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Abstract

I speculate upon how interstellar travel might be achieved and discuss how this relates to the short and long term future of physics.

1 Introduction

We are approaching a Theory of Everything. The union of general relativity and quantum physics may pose substantial problems, but I can't help feeling that it won't be too much longer before it is achieved. Maybe not in the next couple of years, but I can't see it stretching out for a couple of centuries. I would say that it will probably happen within the next couple of decades. But what then? Of course, this won't be the end of physics, whatever theory we have will need testing and more testing. Most likely we'll have more than one putative theory of everything, each aesthetically acceptable and consistent with the results we have so far, but disagreeing in regions where testing is harder. In particular there is a large gap between the sort of energies achievable by particle accelerators and the Planck Energy. The trouble is that we're running out of resources here on Earth for this sort of test. If we were able to travel to other stars, though, then we would have many more options. We would be able to reach objects such as neutron stars where such energies were more typical. It would also be likely to help in probing further back towards the Big Bang, seeing the effect of ever larger energies at the start of the universe. In this essay I'll look at how the goal of interstellar, and possibly even intergalactic, travel might be achieved.

2 Subluminal speeds

The only known ways of travel at present are slower than light. We've been to the moon and sent probes to the planets in our solar system, but to get to even the nearest stars would mean travelling tens of thousands of times further than this. Obviously some new technology is needed. There have been plenty

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of ideas. [1] Nuclear fusion powered rockets seem to be the closest to a practical proposition, and may allow travel to the nearest stars within a human lifetime, achieving up to 10% light speed, but this would hardly be sufficient for any useful large scale exploration and experimentation..

2.1 Near light speed

As I've supposed that we'll soon have a theory of everything, I might also suppose that it will tell us how to generate antimatter from normal matter (or produce large amounts of energy by some other method). The vast amounts of energy available would seem to be the solution to travelling at close to the speed of light. If you can do that then time dilation means that journeys can be done within a reasonable time, and so the problems of interstellar travel seem to be solved. But it may not be that simple. Combining matter and antimatter would produce lots of energy in the form of gamma rays, which then have to be focused into a beam to propel the rocket, giving huge specific impulse, but low thrust. The alternative is to use the reaction to heat an exhaust fluid (such as water), which then propels the rocket. This has the catch that large amounts of the exhaust fluid must be carried, reducing the overall efficiency of the rocket. I would expect that such problems could be overcome, possibly by utilising a ramjet, which collects the material needed for the rocket as it goes. Such a rocket could be used for long distance travel within our galaxy, and possibly beyond. I'm still doubtful though about whether such a rocket would be usable for the sort of interstellar toing and froing I'm hoping for.

3 Faster than light devices

As any science fiction devotee knows, to get anywhere useful you need faster than light travel. Although the speed of light does seem to be one of the ultimate limits in physics, several schemes for breaking this limit have been proposed. One is the traversable wormhole[2]. General relativity seems to allow distant regions of space time to be joined up, giving us a short cut for our journeys. Note that this requires the other end of the wormhole to be transported to the destination, so it isn't very useful for the first, exploratory trip, (although we might hope to find pre-existing wormholes to use). An alternative method of FTL travel is the Warp drive, [3] , where a spacecraft travels at sub-light speeds locally, but manipulates the space surrounding it so that it covers a much greater distance globally.

There is no guarantee that any of this is allowed by physics, even in principle. These devices require some form of 'exotic' matter, violating of various energy conditions, [4] Although there may be the possibility of some such violation, for instance in the Casimir effect, a greater violation is needed for FTL devices. Indeed the possibility of FTL travel is the best argument against such violations. The trouble is that it gives you too much. Wormholes can be manipulated to form time machines. Other FTL travel, if combined with special relativity, seems to imply that you can travel backwards in time. And travelling backwards in time is the one thing that is likely to remain a total impossibility. One might be able to get round this by assuming that such methods worked relative to a preferred reference frame, and that trying to convert a wormhole into a time machine would destroy it, but such assumptions seem rather artificial to me.

4 Travelling at the speed of light

If travelling slower than light isn't enough and travelling faster is impossible, that leaves travelling at the speed of light, that is using some sort of 'transporter beam'. One way for this to work is to scan the object to be transported in minute detail, and transmit the information to the destination, where it can be recreated. Now quantum uncertainty poses a problem here. 'Star Trek' has a 'Heisenberg compensator' to deal with this - when asked how it works the reply is 'very well thank you'. Actually, this problem has been solved, at least in principle, using quantum teleportation. The problem of dealing with the vast numbers of atoms in our bodies still remains though. Note that this can be thought of as a thermodynamic problem - how can we deal with large numbers of objects and manipulate them accurately - rather than a quantum problem. I'm not sure that this helps with the solution though.

4.1 Zero rest mass

An alternative idea is to note that massless particles always travel at the speed of light. If we could set the rest mass of the object we want to transport to zero (or extremely close to it) then its energy would be transformed into motion. When we have a theory of everything then we might find out how to do this. You might think that it is very unlikely that we could change the rest mass of a particle in this way, but I think that there is a good reason to believe that it might be possible. This is the analogy between superconductivity and the Higgs mechanism by which particles get a non-zero rest mass[5]. In a superconducting system, photons may behave as massive particles. Not only does this motivate the above idea, it also suggests how an analogue of the transporter beam might be built. Have such massive photons reach a non-superconducting region where they travel at light speed, and then reenter a superconducting region where they gain mass again. Various questions could be tested. Would it be possible to arrange for a group of photons to travel coherently? Could we create a non-superconducting 'bubble' in which the photons travelled at light speed, but which decayed when they reached their destination? If we could answer such questions then we would be able to apply this knowledge to creating a true transporter beam when the technology became available.

5 How far can we go?

If we could travel faster than light then presumably we could reach anywhere in our universe, and possibly in several other universes as well. But what if we're restricted to light speed or below? In a universe with zero cosmological constant it would be also be possible to get to anywhere in the universe. Note that there is some confusion about this, as it is sometimes assumed that galaxies which are said to be travelling away from us faster than light would be unreachable if we are restricted to light speed, but this is not the case[6].

In the actual universe though the cosmological constant is not zero, instead there is acceleration of the expansion. This means that there is a Cosmological Event Horizon which does give a limit to where we can travel. There are galaxies which we can see which we will never be able to reach. Personally I find this limit a bit claustrophobic. I would hope that even FTL travel is forbidden in general, there might be a way to overcome this limit. Certainly issues such as the information paradox have called into question whether black hole event horizons are quite what they seem. The cosmological horizon has received less attention, since for a while it was assumed not to apply to our universe. Maybe as we get understand it better - in particular its thermodynamic properties - it won't seem like so much of a limit..

5.1 Our attitude towards time.

One problem which you may have thought of is what is happening to the rest of the world while you are traveling round the universe. You take a trip via a transporter beam to the centre of the galaxy and back - the journey only takes an instant of your subjective time. When you get back, you find that thousand of years have passed and everyone you knew is dead. Except that, presumably, many of them would be doing the same thing, so that it is more a case of keeping your personal clocks in some sort of sync. If we had transporter beam technology then I would guess that we would also have the technology to slow down or stop how fast our personal time goes with respect to that of the Earth, and so even those who chose to stay put could join in. The lure of absolute time is very strong,even in science fiction, and the only time I've seen this idea considered is with the 'Slowdown' in *Schild's ladder* [7]. But relativity tells you that in the end your personal time is the only time there is. Maybe we should start getting used to the idea.

6 The Future

These ideas may seem like a pipe dream, but the same could be said of the idea of atomic power a century ago. The crucial experiments were being done which turned it into a reality within a few decades. Likewise the experiments being done now will be vital in devising the technologies of the future. In particular the study of the Higgs boson may provide the information we need to escape the bounds of our solar system.

Do we want to do this? Well, any new technology can be dangerous, but in the end we get used to it, and think of it as natural part of our lives, rather than something to be treated with suspicion. Our ancestors might have decided that it was best never to sail out of sight of land, but it's hard to imagine what the world would have been like if they had. There is a point of view that the theory of everything means an end to physics, and the new technologies we will be gaining will mean that we no longer have the motivation to do anything of interest. I would argue that, on the contrary, if we take the opportunities which become available to us then we will instead be entering a new era of exploration and discovery.

References

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