Cheap Trek Episode 3 (a cheap attempt at mimicking the legendary *Physics of Star Trek*).

Dear Cheap Astronomy - How do Heisenberg compensators work – and please don't say very well.

Lawrence Krauss in *The Physics of Star Trek* did a fine job of explaining the sheer impossibility of Star Trek transporters – just on the basis of the volume of information required to represent the full human form down to a sub-atomic level, not to mention the bandwidth required to then move that information from one location to another. Here at Cheap Astronomy, we also raised the conservation of momentum problem involved with transporting someone from a rapidly-orbiting starship to a relatively-stationary point on a planet's surface.

But putting all that to one side, just how do Heisenberg compensators work? The transporter concept requires a system that can measure the position and the state of each and every subatomic particle in your body.

But, Heisenberg uncertainty means you simply **cannot** measure those two things, position and state, simultaneously. This is a fundamental problem for a transporter, since if it can't measure both things simultaneously then it can't capture the complete set of information needed for transportation. This is where the Heisenberg compensators come in.

But that is only part of the story. For Heisenberg uncertainty to be a problem in the first place, we might assume that from the moment the transporter is activated, every aspect of information about a person's physical form is captured in one go. However, this is clearly at odds with the visual representation of transportation, where the operator uses a sliding control, as though working through some sort of staged process. Indeed, the standard visual representation of a person being transported is that they slowly fade from view, rather than vanishing in an instant.

If a person's complete form is scanned before transportation, their innards need to be scanned just as much as their out-ards. This surely requires some kind of energetic, penetrating radiation – which suggests a scanning process that actually disintegrates people in the process of scanning them.

After all, everyone who gets transported is physically moved from one location to another. When various Star Trek personnel have been duplicated during transportation, it's always been their post-scanning information that is duplicated, no-one ever gets left behind on the pad and then copied elsewhere.

The best explanation offered to deal with all the conundrums of the transporter process is that old favourite of science fiction plot devices – tachyons. Tachyons get you out of all sorts of trouble since they can not only carry information, but also move backwards in time.

So, here is how a Star Trek transporter *might* work. As the transporter is activated, a person's sub-atomic particles are measured and that information is transmitted to the Heisenberg compensators. Of course, only the state **or** the position of all their sub-atomic particles can be measured, not both. So, moments later a second measurement is made – of either the state or the position, but not both. In a Schrödinger live cat / dead cat sort of way, you don't actually know if it was the first or the second measurement that captured either position or state. And so, a required level of uncertainty is retained.

Anyway, the results of the second measurement are transmitted by tachyons back in time to the Heisenberg compensators so that the second measurement arrives at exactly the same time as the first measurement arrives, meaning that the Heisenberg compensators receive two simultaneous measures of both the position and the state of all the subatomic particles in a person's body.

The tachyons also work around the problem of the scanning process. If you ever decide to try transporting, you will die horribly as you are bathed in tissue-destroying radiation, while the transporter scans all your body's information from the outside in. However, that moment of appalled awareness gets shifted into an alternate universe, as tachyons arrive from the past to provide your complete measurements to the Heisenberg compensators.

The Heisenberg compensators act by integrating the two sets of parallel information about you into one and then deleting one 'dead cat' version of events from history. So from your revised time-line perspective, the transporter switched on and then you found yourself rematerialised in another location – no fuss and no mess.

And so, hooray for Heisenberg compensators.

Dear Cheap Astronomy – How does impulse drive work?

As we all know from watching Star Trek, a standard star ship has warp drive for long hauls, impulse engines for scooting around subliminally and thrusters to manoeuvre in and out of space dock.

Impulse engines, as they described in Star Trek background texts, are quite plausible in concept, even though they are not something we could build today. Firstly they rely on fusion reactors, so they require some technology that we are yet to fully harness. But harnessing fusion is certainly feasible. We have already managed a few small-scale demonstration projects here on Earth.

The fusion reactions that we have managed here on Earth use deuterium, which is a hydrogen isotope made of one proton and one neutron. Tritium has also been used on occasions, which is one proton with two neutrons. To make fusion work, particles of either deuterium or tritium are forcefully driven together. Forcefully driving them together can be achieved by electromagnets or by lasers – and it generally has to happen under very high local temperatures. We have managed to achieve particle fusion under these conditions, but we are yet to generate more energy from the fusion than was first put in to power the electromagnets… or the lasers… or whatever. Nonetheless, most people think that gaining power from a fusion reactor is just an engineering problem – and it is a nut that we will crack before long.

Of course, in the Star Trek universe, that nut has long been cracked and fusion reactors work magnificently. Star Trek impulse engines have fusion reactors that work a bit like a mini-Sun. So, not only do you get fusion energy, but the reactors also produce charged plasma as a by-product. The plasma can then be used as a propellant – after accelerating it through a series of magnetic coils that are themselves powered by energy produced from the fusion reactions.

This is the most plausible application of fusion reactors to physically move a spacecraft. The heat and light produced by fusion aren't very effective as propellants since they don't have mass. If you want to move quickly through a vacuum, you're best bet is to propel mass in the opposite direction, in accordance with Newton's third law – the one about actions and reactions.

The good thing about Newton's third law is that it's flexible on the point of how you gain a reaction – you can either propel a large amount of mass slowly, or propel a small amount of mass quickly. A fusion reactor can turn neutral sub-atomic particles into charged sub-atomic particles and it can also provide the energy to accelerate those charged particles up to near the speed of light before hurling them out the back of the ship.

It might not be warp drive – but such a propulsion system would be nothing to sneeze at. To make it actually work you would need big-bloated deuterium (or tritium) fuel tanks bulging out around the sleek lines of your star ship – and its nacelles would be long, straight particle accelerators capable of projecting charged plasma particles out the back of the ship. But, since the nacelles would be generating a lot of heat you would certainly want to put them on long stalks to keep them well away from the rest of the ship. And it would also make sense to have two of them in the event that one breaks down. So, like we've said before on this podcast, the basic design of the Enterprise is actually quite sensible – even if it won't quite manage to do everything that it does on the show.

Of course, if we are going to accept that Newtonian physics still has a role to play in Star Trek space travel, then we also need to deal with the issue of *inertial dampers*. Inertial dampers are a Star Trek plot device to explain why the crew are not all flung against the back wall every time the Enterprise accelerates to high speed.

Trouble is, if we accept that these inertial dampers are real, it becomes difficult to see how the action/reaction mechanism of the impulse engines could work. You won't gain much speed by pushing propellant out the back of the starship if either the propellant or the ship have their inertia dampened. That's the thing with Newton's laws of motion, you can't just have one, you have to have them all.

But hey, that's just a minor story line problem. As for impulse drives – heck, yeah! They might still be science fiction today, but they sound quite plausible for the reality of tomorrow.