Cheap Trek Episode 5 (a cheap attempt at mimicking the legendary *Physics of Star Trek*).

**Dear Cheap Astronomy – So what the heck is a Standard Orbit?**

Various shots of various Enterprises orbiting various planets over the various series have all tended to show the same thing. A starship Enterprise progressing around a planet in an orbital velocity that is clearly faster than the planet's rotation. This may be a good way to quickly scan the whole planet, but it is problematic for any missions that involve away teams. If you are orbiting faster than the planet's rotation you are going to be spending long periods on the opposite side of the planet, leaving the away team stranded out of transporter range and out of communicator range.

There are some plausible solutions to this conundrum – such as a starship dropping off orbiting communication buoys which might relay signals to and from the surface as the starship proceeds around the planet.

But it seems more likely that a 'standard orbit' should be something like a geosynchronous orbit around Earth, where the starship orbits the planet at a velocity matching the rotation of the planet beneath it, so that the starship always stays above the location where the away team had been dispatched.

But this is problematic too – since if the planet being orbited is of a similar mass and density to Earth, such a geosynchronous orbit can only be established at an altitude of 36,000 kilometres. Now, pretty much every planet The Original Series crew ever visited had a similar mass and density to Earth, with all of them seeming to generate almost exactly 1G of gravity on their surfaces. Indeed, this has generally been the case for planets visited by every other subsequent Star Trek series crew.

So, given the propensity of starships to visit Earth-like planets with Earth-like gravities, there is a problem – since 36,000 kilometres altitude is technically out of transporter range. Well, at least it is sometimes. According to Star Trek background texts, transporter range in the 23rd century (the time of *The Original Series*) was 10,000 kilometres. In the 24th century, (the time of *The Next Generation*), it was 27,000 kilometres. Only with *Voyager*, did it extend to 40,000 kilometres – which would be sufficient to beam someone up while in a synchronous orbit about an Earth-like planet.

Of course, all that thinking goes out the window if you include the JJ Abrams reboot movies where, in a timeline-altered 22nd century, transwarp beaming meant you could pretty much do whatever the heck you liked.

But, for the most part, it doesn't seem likely that a standard orbit around a 1G-type planet could have been a genuinely-synchronous orbit. So, perhaps we should consider that a Star Trek standard orbit may not have been a free fall orbit at all. A free fall orbit is one in which you keep falling towards the planet at just the right velocity and at just the right altitude that you keep on missing it – and hence just end up going around and around it, without needing to generate thrust. But achieving a free fall orbit requires a careful balancing of velocity and altitude. To maintain a geosynchronous orbit, a satellite maintains a 36,000 kilometres altitude by virtue of moving at 3 kilometres a second – any faster and it will ascend, any slower and it will descend.

But a starship can do whatever the heck it wants. If it wants to remain at 360 kilometres altitude or even just 36 kilometres altitude above the same spot on the planet – all it needs to do is engage its thrusters or its impulse drive, or whatever, in order to maintain that position.

Arguably, it is still a kind of orbit since the ship will still follow the line of a great circle above the planet's surface as the planet rotates – it's just not a free fall orbit.

So maybe that's what every starship captain has instructed every helmsperson under their command to accomplish, every time there's been a Star Trek episode involving a planet – Helmsperson, do whatever you have to do to keep the ship above a point on the planet's surface upon which this episode's storyline will unfold – or to keep it simple, they might have just said: Standard orbit please.

**Dear Cheap Astronomy – What about tractor beams?**

No doubt you've heard that scientists have already developed a number of prototype tractor beams in the laboratory, so a bit of further development and a bit of scaling up should see these become standard issue on 23rd century star ships – if not 22nd century star ships. Right? Well… not so fast.

Tractor beams have their origin in science fiction, where they were originally called attractor beams. But the modern science reports of real tractor beams fall into three main categories. The first involves projecting a ring of laser light around an object which super-heats the air molecules around it. You can then modify the geometry of the light ring so that the mean vector of air-pressure forces moves the object towards you. Needless to say, the absence of air molecules in space makes this approach problematic for starships. Then there's the sonic tractor beam which uses sound waves to… well, OK that's not really going to work in space either.

The third option is optical tweezers, which were once called "single-beam gradient force traps", until someone unaccountably decided to change their name to optical tweezers.

Optical tweezers are capable of manipulating nanometer and micron-sized dielectric particles by exerting extremely small forces through a tightly-focused laser beam. And it's worth focusing on some key terms there – nanometer, micron-sized and extremely-small – notwithstanding the whole mechanism only works on dielectric materials. Dielectric materials are almost perfect insulators, unable to pass an electric current, but very able to contain its potential difference – that is, its energy – which is why they are important components of electronic capacitors.

But one thing that dielectric materials are not, is metallic – so the idea that one starship could project giant optical tweezers out to grab another starship is unlikely in the extreme, unless that other starship was of a uniform ceramic structure – and it would also help if the other starship was just a few nanometres in width and a few nanograms in mass. Photons just don't have the momentum required to shift large, massive objects – unless you ramp up the energy levels of those photons into gamma ray wavelengths, where they would probably ionise and disintegrate an object long before they shifted it any appreciable distance.

As is becoming a common theme in these Cheap Trek episodes, it's strange how we look to electromagnetic radiation to do a job that bog-standard matter could manage just as well. So, instead of trying to draw a distant space ship towards you with a light beam, why not just fire a grappling hook on a cable to achieve the same result - or you could send out a few shuttle craft to shepherd the thing into closer proximity first.

All that said, optical tweezers really could change the world – and in much more subtle and intriguing ways than an implausible tractor beam could. Optical tweezers can manipulate objects at the microscopic small end of town where matter tweezers just can't compete. So with optical tweezers you can build new kinds of materials that don't exist in nature. And you could take microelectronic engineering down to a whole new level.

With optical tweezers you might be able to construct something with the complexity of Data's brain that really would fit inside Data's head– as well as coming up with ways to prevent that brain from self-annihilating when it comes into contact with anything mundanely electronic (because, you know… it's a positronic brain).

You might also build fusion reactors small enough to power a shuttle craft and energy-efficient enough to keep a starship going on the scant amount of hydrogen that is available in the deep space between different star systems. Otherwise, it's not immediately clear how we are ever going to generate enough energy to keep us alive over those enormous and spacetime expanses.

So, although some Star Trek ideas might seem a bit daft when exposed to careful analysis, the thinking they inspire can still lead us to a new frontier – and yes, a new frontier, because in science there is no such thing as a *final* frontier, there's just the next frontier.

Thanks for listening.