Cheap Trek Episode 2 (a cheap attempt at mimicking the legendary *Physics of Star Trek*).

Dear Cheap Astronomy - How do phasers work?

There is much debate about whether phasers rely on electromagnetic radiation, since on the telly and in the movies, phaser beams are always visible. This might be plausible behaviour for a hand phaser in atmosphere, but not for ship-to-ship phaser battles in the vacuum of space. A beam of light in a vacuum should just move in a straight line with no sideways diffraction – so unless you are directly in the line of the beam, it should be invisible to you. Also, the beam should move at the speed of light, so you should not be able to track its motion across the screen from gun muzzle to target.

But we could just blame all that on a bit of cinematic licence, because it does seem very clear from Star Trek lore that phasers really do fire light beams. Lasers and laser pistols are mentioned in a few early episodes of *the original series*, before evolving into phasers in later episodes – and phasers became standard issue throughout the next generation and later series.

According to early script notes, the word phaser is short-hand for *photon maser*. Masers (just like lasers) are real technology, in common use today, where maser is just an acronym for *microwave amplified by stimulated emission of radiation*. In other words, a maser is just a particular type of laser, which operates in *microwave* light frequencies, unlike standard lasers, which operate in *optical* light frequencies.

Thus, in all important respects, a maser functions via the manipulation of photons. So, specifying that a Star Trek weapon is a *photon* maser seems a rather unnecessary elaboration.

But it's best not to dwell on such details when exploring fictional technologies. If we accept that a phaser is basically a powerful, focused light beam, we can go onto explore the physical basis of its destructive properties. Two factors define the potentially-destructive power of light beams – wavelength and intensity.

Wavelength is what determines light energy – that is, the energy carried by each photon. Again, it must be said it's a bit puzzling that Star Trek tells us photon masers are more advanced weaponry than optical-light lasers. After all, optical light has more energetic photons than microwave light and hence you'd think optical light would provide the basis for a more destructive weapon.

But you've also got to consider intensity. Intensity is a measure of how bright visible light is; or how hot infra-red light is; or how ionising gamma ray light is. If we think of light as waves, intensity is the amplitude (or the height) of those waves – or, if we think about light as photons, intensity is photon *density* – that is, how many photons are squeezed into one narrow beam. Either way you look at it, if you want to increase the intensity of your light beam, you use amplification and concentration.

But, once again, we are back with the problem of why the heck you would want a photon *maser*. If you concentrate and amplify microwaves, what you will get is a microwave oven. If you are in the middle of a fire fight with a Klingon warbird, you really don't want your life depending on a microwave oven. If you amplify and concentrate optical light, at least you will get a laser, with which you might manage to annoy the Klingons, by shining it in their eyes.

But if you want to take the Klingons out, what you want to do is to concentrate and amplify *gamma rays*. And, fortunately, there really is such a technology – sometimes called a gaser, or a graser, that is – a gamma ray laser.

While an optical laser, or a maser, result from excited *electrons* dropping back to their ground state and releasing a photon in a very precise and predictable way, a graser results from excited *nucleons* dropping back to their ground state.

A nucleon is a proton or a neutron, the things that make up an atomic nucleus – and for a nucleon to shift from its excited state back to its ground state, it has to release one mother of a photon – that is, a *gamma ray* photon.

In 21st century science, we have managed to produce small-scale graser emissions from heavy elements like hafnium and tantalum, names which are already sounding a bit cool and Star Trekky. If we ever manage to weaponise this kind of stimulated emission, then a graser-enabled Star Fleet vessel is definitely not something you would want to get on the wrong side of.

Perhaps Gene Roddenberry just got his P Hs and his G Rs mixed up.

Dear Cheap Astronomy – How do shields work?

Here's what we know about Star Trek shields. They are generally called deflector shields – implying that they deflect rather than absorb the energy of a weapon fired upon them. Nonetheless, such shields are progressively weakened under a continued assault, unless you divert power away from other ships' systems to replenish them. Shields also operate with a particular *frequency* –suggesting that they have some kind of electromagnetic nature.

Although it's never actually stated (perhaps because it sounds a bit too pedestrian) the power that drives a starship's systems – and hence also drives its shields – is probably electricity. After all, the standard response to a starship taking a hit, is that all the lights dim. So, even though the power *source* may be dilithium crystals or whatever, the power *medium* that is generated by that source is still just plain-old electricity. In deference to anticipated technological advances in the 23rd century, we might assume starship power will be DC rather than AC, assuming that we are not still running steam-driven turbines by then.

Beyond that, how shields might work is not clear. Some off-screen commentators claim their protective effect is due to the manipulation of gravitons, which for anyone in the 21st century equates to pseudo-scientific hand-waving. There is no evidence to indicate that gravitons exist, let alone a plausible rationale as to why a theoretical particle that mediates the force of gravity would be useful in deflecting a phaser blast.

A more plausible line of thinking comes from the Enterprise series – a prequel to all the other Star Trek series, including the Original Series. In the Enterprise series, the NX-01 Enterprise did not yet have shield technology, but it could polarise its hull plating. Apparently, this polarisation realigned the molecular structure of the hull plates to make them stronger. It was never explained why that

stronger configuration was not just locked in permanently during the hull material's manufacture, but it's generally best not to dwell on such details.

The point of the Enterprise NX-01 example is that a ship's hull deserves a lot more prominence when considering a starship's overall defence capabilities. A number of Star Trek plots suggest that once your shields are gone, you are pretty much finished. But it is not good battle tactics to make the integrity of your star ship and the survival of your crew entirely reliant upon something that you may only think to switch on now and again.

Back in the real world of 21st century technology, there are various forms of magnetic shielding we can create in a laboratory setting, which are powered by electricity and which might be one day be usefully deployed to deflect harmful cosmic rays from penetrating a spacecraft's hull. However, most weapons that we can currently manufacture today, let alone those we might imagine for the 23rd century, could easily plough straight through such a magnetic shield.

That same weaponry, though, would struggle to penetrate a one inch thick hull made of a dense metal, let alone two, three or six inches of such a hull. Matter-based shielding can very effectively protect you from most ballistic projectiles, as well as a range of speculative electromagnetic-based weapons – and probably a range of wildly-imaginary quantum weapons that employ mesons, bosons, tachyons or whatever-ons.

So, even though we should acknowledge we await two centuries of unimaginable technological advancement, it still strains belief to accept that some intangible quasi- electric shield thingy, that doesn't even block visible light, could ever hope to match the defensive capabilities of a few inches of good-old solid matter. You can keep all your magnets and your plasmas and your sub-atomic wibbly-wobblies. Matter will take a bullet for you in the 23rd century just as well as it does in the 21st.

Fortunately, there is another off-screen suggestion for how shields might work. Shields might actually be based upon replicator technology. So, as the Klingon fleet approaches, you tell your replicator to create a six-inch-thick layer of transparent aluminum around your ship. Now *that* is a shield, in anyone's language.